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A New Dimension

Wallops Island Flight Test Range: The First Fifteen Years

Joseph Adams Shortal

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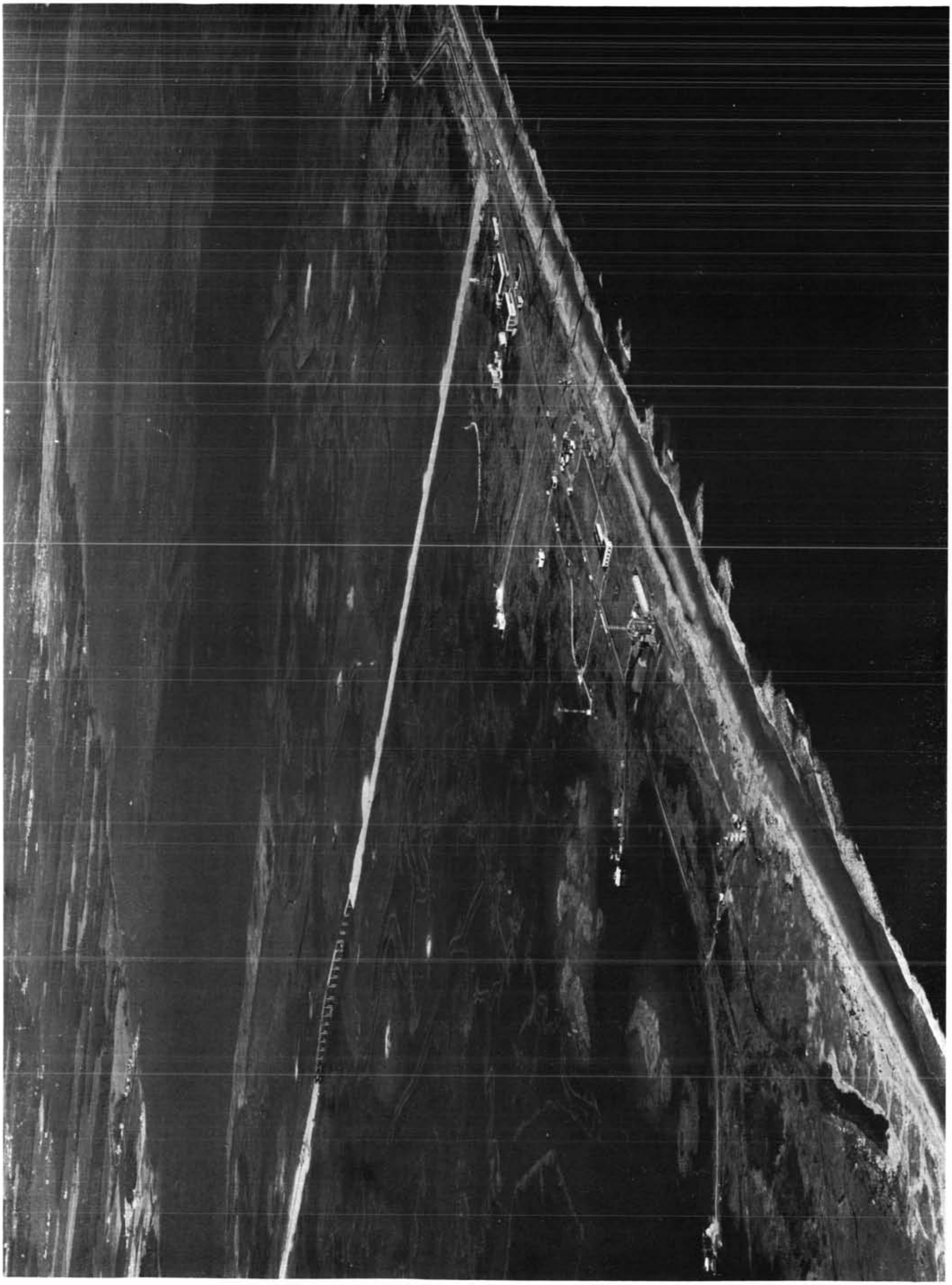

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A New Dimension

Wallops Island Flight Test Range: The First Fifteen Years

Joseph Adams Shortal
Wallops Flight Center
Wallops Island, Virginia

National Aeronautics
and Space Administration

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FOREWORD

In 1945, the National Advisory Committee for Aeronautics (NACA) added a new dimension to its capability for aerodynamic research at high speeds when it authorized the Langley Research Center to proceed with development of Wallops Island as a site for research with rocket-propelled models. This step was prompted in large part by the need for extending capabilities for aerodynamic research through the speed of sound and into the supersonic range of speeds, with continuous coverage of flow phenomena at all speeds involved. Transonic wind tunnels had not yet been developed, and supersonic wind tunnels were far from adequate for exploration of the many aerodynamic problems that required immediate consideration.

The availability of small solid-fuel rockets and advances in instrumentation made it possible to proceed rapidly with a wide variety of experiments that served as a most useful supplement to other research capabilities. The great demand for aerodynamic information of all kinds obtained at continually increasing speeds was met by constant improvement in the techniques for applying rocketry and flight instrumentation to acquisition of a broad spectrum of scientific and engineering aerodynamic data. Rocketry and instrumentation were considered only as a means to an end, continually being improved and varied so as to provide a thoroughly coordinated supplement to the constantly advancing capability of ground-based research facilities.

Starting with initial operations in 1945 and continuing throughout the years, Wallops Flight Center, as a launching site used for research purposes, has retained a flexibility and responsiveness to the continually varying requirements of experimental research to achieve important advances in aeronautics and space science. Nearly all requirements for propulsion have been met with relatively small solid rockets staged in various ways to meet the needs of any given research task. The largest and most sophisticated of the launch vehicles has been the versatile Scout four-stage solid-fuel vehicle capable of launching small satellites or of being adapted to other uses.

A very important result of the program carried out at Wallops was effective preparation of the NACA to take on responsibilities as the nucleus of the National Aeronautics and Space Administration (NASA). The know-how and knowledge stimulated and developed by this program, coupled with NACA research activities with man-carrying aircraft at the Dryden Flight Research Center, Edwards, California, were prime factors that prepared the NACA for its subsequent responsibility.

Floyd L. Thompson, Director (1960 - 1968)
NASA Langley Research Center
Hampton, Virginia 23665

PREFACE

I have written this history of the first 15 years of Wallops Flight Center (1945–1959) because it represents an exciting episode of my life and because I agree with Robert L. Krieger, Director of Wallops, that unless the early years are documented, the many contributions made by Wallops to the development of this nation's guided missiles and supersonic airplanes might be forgotten.

A story of Wallops Island and its flight test range is at the same time a story of the Pilotless Aircraft Research Division (PARD) of the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics (NACA), Langley Field, Virginia, because Wallops was the experimental laboratory or test base for this division. The test models, constructed for the most part at Langley, were shipped to Wallops where they were assembled with their rocket motors and then launched out to sea. These rocket-propelled models provided the research data, obtained in flight at transonic and supersonic speeds, that made possible the design of effective supersonic airplanes and missiles at a time when comparable ground facilities were nonexistent. In later years, the flight speeds of the rocket models were extended first to the hypersonic speed range, then to intercontinental ballistic missile speeds, and then into the satellite range and even higher as the NACA became the nucleus of the National Aeronautics and Space Administration (NASA) in 1958.

In the spring of 1965, Krieger and Joseph E. Robbins, Administrative Officer, asked me to prepare a history of the early years of Wallops. They were aware of my personal knowledge of the activities in the early years, as well as my interest in Wallops. When I retired from Langley in 1963, I had been engaged in research there for nearly 35 years. I was appointed Assistant Chief of PARD in 1948, and in 1951 succeeded Robert R. Gilruth as Division Chief, a position Gilruth had held since the beginning of the station in 1945. I held this position until my retirement and supervised all Langley projects involving rocket launchings during this period.

Although this history has been prepared with the benefit of my personal knowledge of the activities, I have tried to verify all of my recollections with official letters, memoranda, reports, photographs, and other historical documents. In addition, I have held many discussions with other NASA employees who were also directly involved with Wallops. I wish to express my appreciation to all of these people for their assistance; and, in particular, I want to acknowledge the aid of Mrs. Neva B. Brooks, Head of Central Files at the Langley Research Center, who was most helpful in locating pertinent historical documents.

Joseph Adams Shortal
Hampton, Virginia 23665
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CONTENTS

CHAPTER 1

EVENTS LEADING TO THE ESTABLISHMENT OF WALLOPS FLIGHT CENTER

Wallops Flight Center is the only flight test facility wholly owned and operated by the National Aeronautics and Space Administration (NASA). It is located in the northeast corner of Virginia's Eastern Shore and contains two installations: a large airport on its mainland base, for use in aircraft-related research, and a launchsite for satellites, sounding rockets, and other rocket-propelled vehicles on nearby Wallops Island, a sandy, barrier island just offshore in the Atlantic Ocean. The mission of Wallops is to operate these flight-test facilities, with their extensive tracking and data-acquisition instrumentation, in support of aeronautical and space research programs. The facilities are used by the scientists and engineers from the laboratories and research centers of NASA, and by other U.S. governmental agencies, colleges and universities, and the worldwide scientific community. International cooperation in space has become a major objective, and nowhere in NASA is this international cooperation demonstrated more actively than at Wallops.

This was not always so. Wallops Flight Center was established by the National Advisory Committee for Aeronautics (NACA) during World War II (in the spring of 1945) as an auxiliary base of the NACA Langley Laboratory at Langley Field, Virginia, to provide a test range for guided missile flight research, initially at subsonic speeds, but with plans for extending the research into the transonic and supersonic speed ranges. It was anticipated that the findings of such missile research would be applicable to airplanes as well. Operation under the NACA continued until 1958 when NASA was created out of the NACA, and Wallops was made a separate station reporting directly to NASA Headquarters.

In the early years, the mere existence of this new test range was cloaked in secrecy; for many years practically all the research information was made available only to those agencies having a need to know. In this period, the only users of Wallops data were the military services and their contractors. As a result of the secrecy surrounding the early operations at Wallops, little information about it found its way into the open literature.

In this first chapter of the history of Wallops Flight Center, the events which led to its establishment are reviewed, with special emphasis on the status of aeronautical technology at that time. Considerable attention is given to the extent of NACA activity in the field of guided missiles and to plans for extending aeronautical research beyond the speed of sound. But, first, it is important to understand what the NACA was and how it operated with respect to the military services.

THE NACA AND ITS WARTIME ROLE

The NACA was established during World War I in a belated attempt to overcome the lead in aeronautical technology which European countries had gained over the United States in the 12-year period following the Wright brothers' flight in 1903. The committee was formed too late to have much influence on the course of World War I, but its activities after this war had a profound effect on the ability of the Allies to wage effective air operations in World War II.

After several unsuccessful attempts by the Smithsonian Institution—the supporter of Samuel Pierpont Langley's work in aeronautics—to obtain congressional support for an aeronautical laboratory, the NACA was authorized by Congress on March 3, 1915, in a rider to a Navy appropriations bill (ref. 1). The bill directed the NACA "to supervise and direct the scientific study of the problems of flight, with a view to their practical solution, and to determine the problems which should be experimentally attacked and to discuss their solution and their application to practical questions. In the event of a laboratory or laboratories, either in whole or in part, being placed under the direction of the committee, the committee may direct and conduct research and experiment in aeronautics in such laboratory or laboratories."

The NACA consisted of 12 members appointed by the President. (The number was increased to 15 in 1929 and to 17 in 1948.) The law provided that the members "shall be acquainted with the needs of aeronautical science, either civil or military, or shall be skilled in aeronautical engineering or its allied sciences." The Government agencies represented on the committee were the Army Air Forces (AAF),[1] Navy Bureau of Aeronautics (BuAer), Weather Bureau, Bureau of Standards, and Smithsonian Institution. Later, members from the Department of Commerce and Civil Aeronautics Authority were added. The remaining positions on the committee were filled with outstanding men from the universities (such as William F. Durand, Joseph S. Ames, and Jerome C. Hunsaker) and from private life (such as Orville Wright and Charles A. Lindbergh). The committee served without compensation, elected its own chairman, and appointed the Director of Aeronautical Research.

This organization was quite different from the typical government agency, and allowed the committee, free from external political pressures and internal administrative duties, to apply its talents and to exercise its collective judgment in development of an aeronautical program that enabled America to regain its leadership position. Responsibility and authority for this program rested with the committee, while authority for carrying out the program rested with the executive officer, the Director of Aeronautical Research. According to Ira H. Abbott, "The NACA enjoyed great prestige and authority in all scientific and engineering matters concerning aeronautics. This prestige resulted from the character of its members and the excellence of its staff. It is unfortunate that this successful experiment in government organization of scientific research came to an end in 1958 with the National Space Act, and that it has been all but forgotten."[2]

Headquarters for the committee were established in Washington, D.C., and a full-time staff was engaged. John F. Victory was hired as a clerk to be the first employee, and he consecutively served as assistant secretary, secretary, and finally Executive Secretary, until the end of the NACA. In 1919, Dr. George W. Lewis was appointed head of this staff and later was given the title of Director of Aeronautical Research.

The members of the main NACA committee were the top aeronautical men in their particular organizations. For assistance in carrying out their duties in the coordination of all aeronautical research activities in the nation, the NACA established special committees and subordinate subcommittees to cover each field of research. For example, there was an Aerodynamics Committee with such subcommittees as Stability and Control, High-Speed Aerodynamics, Propellers, etc. By this means, specialists in each field from all over the United States were brought together to discuss problems and recommend research programs to aid in their solution. At each meeting, the members were brought up to date on the latest research at the NACA laboratories, and in turn each member reported on any research his organization had conducted. This was a very effective method of keeping everyone informed and of focusing attention on the most urgent problems.

Soon after it was organized, the NACA recognized the need for an experimental field station and in 1916 persuaded the War Department to purchase land about 4 miles north of Hampton, Virginia, for joint use by the Army, Navy, and NACA as an aircraft proving ground. This area was later named

1. At this time, the Air Force was a branch of the Army.
2. Letter from Ira H. Abbott to the Editor, *Science*, June 23, 1967, vol. 156, p. 1549.

Langley Field and in 1917 became the home of the NACA's first laboratory. The Army and the Navy did not accept the joint use idea, but established separate airplane test bases elsewhere—the Army at Wright Field, Ohio, and the Navy at Norfolk, Virginia.

On June 11, 1920, the Langley Memorial Aeronautical Laboratory was dedicated at Langley Field. At this time, a 5-foot wind tunnel was placed in operation to supplement flight research already in progress there. Although the Army did not use Langley as an aircraft proving ground, it retained administrative control over the base and made extensive use of it for training, education, and housing of many elements of the Air Force. The NACA was essentially a tenant on the base.

During the next 18 years, many unique wind tunnels and other facilities were developed by the NACA at Langley, and the results of the research were accorded worldwide acclaim. Through a close working relationship between the military services, the aeronautical industry, and the NACA, the United States regained recognition as the leader in aeronautics. By 1938, however, it was apparent to Dr. Lewis that a great expansion of research facilities was needed if the United States was to maintain this leadership. He had learned that Germany had greatly expanded her research facilities, including supersonic wind tunnels. With the backing of several special committees, one of which was headed by Charles A. Lindbergh, the NACA obtained congressional approval to expand its facilities at Langley and to build two new field centers—one at Moffett Field, California, authorized August 9, 1939, and the other at Cleveland, Ohio, authorized June 26, 1940. This expansion of facilities was just in time to be put to use in meeting the wartime demands of the Army and the Navy. In fact, the centers continued to expand their facilities and personnel throughout the war.

With the Japanese bombing of Pearl Harbor on December 7, 1941, the United States was in World War II, and the NACA's role was changed. The NACA now became "a consulting and research agency for the armed services" (ref. 2). It began to operate under the Mobilization Plan of the Aeronautical Board, which had been approved by the President on June 29, 1939. This plan provided in Section III, paragraph 5, that "The National Advisory Committee for Aeronautics will operate during a national emergency declared by the President as a consulting and research agency for the Aeronautical Board. The entire facilities of the Committee's research laboratories shall be placed at the service of the Aeronautical Board and the Director of Aeronautical Research shall execute every project referred to the Committee by the Aeronautical Board."

This conversion to a solely military support mission was not at all difficult to implement. The situation was aptly described by John F. Victory of the NACA: "Because the NACA was originally set up to serve the military as well as civil needs of the country with respect to aeronautics, there was no occasion for reorganization in anticipation of the war. Throughout the peacetime years of its operation the Committee felt obliged to ever anticipate wartime needs and acted accordingly" (ref. 3).

The research investigations carried out at the NACA laboratories were officially authorized by NACA-approved Research Authorizations (RA's). These RA's were the official documents against which the research efforts of the laboratories were charged. Before the war, most RA's were aimed at general problems affecting all types of aircraft, although a small percentage were directed toward specific airplanes under development by the military services. During the war, however, practically all facilities were engaged in specific military projects, and almost all new experimental work had to be related to specific requests of the military. Such "specific" projects differed from "general" research in that the test model was usually a scaled model of a specific military airplane or missile under development, and such models were usually supplied by the military services or their contractors.

For the initiation of a new specific research project, representatives of a given branch of the military service requiring assistance would visit the laboratory, discuss their problems with officials at the test facility, and agree upon a specific program. It was only after this agreement was reached that a formal letter of request to NACA Headquarters would be sent by the cognizant military office. The NACA would then consider the request and, after approval, issue the necessary RA. Beginning in late 1946, such requests were also submitted for clearance to an Aeronautical Board, by which all the military services were kept informed of the initiation of new projects and were given the opportunity to express their opinion on the need for the requested research.

All of the American airplanes used in the war bore the mark of NACA research not only in their original design but in regard to improvements made during their development. In addition, all new proposed designs were extensively investigated in NACA facilities on a continuing round-the-clock basis. Over a hundred different specific military airplane designs and a dozen missiles were tested in one or more of the many NACA facilities during the war period.

The Air Technical Service Command (ATSC) of the Army Air Forces maintained a liaison office at Langley Field to coordinate and report progress on Army projects at the Langley Laboratory. The liaison office was very effective in keeping the Army's Wright Field Development Center informed of activities at Langley, and in addition, was equally effective in helping Langley obtain military supplies and equipment required to support the research at Langley. Men from this office were usually present at any discussion between Army project representatives and Langley personnel, and provided assistance in the preparation of letters of request. In particular, the civilian representative in the office, Jean A. Roché, was most helpful and provided needed continuity.

Although the Navy Department made some use of the Army's liaison offices at the NACA laboratories, the fact that the Navy's Bureau of Aeronautics was located in Washington, D.C., made it easier for some Navy personnel to work directly with NACA Headquarters. In this connection, a close working relationship developed between Charles H. Helms, NACA Assistant Director for Aeronautical Research, who served as the chief military contact, and Captain Walter S. Diehl of the Navy Bureau of Aeronautics. The Bureau had always relied heavily upon the NACA laboratories and, in turn, supported and encouraged all the activities at the NACA centers.

STATUS OF HIGH-SPEED AIRPLANE RESEARCH

Although the United States was far behind Germany in guided missiles at the beginning of the war, the status with respect to airplanes was a different story. The military services, with direct NACA support on each design, had developed high-speed fighters and bombers to such an extent that by the end of 1944 the German air force had been eliminated as a threat. Although Germany was beaten in the air war, her research and development teams were ahead of those in the United States in advanced high-speed designs. When Germany, in August 1944, brought out her Messerschmitt Me-163B rocket-propelled Komet tailless airplane with sweptback wings and a top speed of 596 miles per hour, and her Me-262 jet-propelled interceptor airplane with a top speed of 540 miles per hour, she demonstrated a speed margin over the United States of more than 100 miles per hour (ref. 4).

American designers knew that their existing airplane types could not go much faster with safety even if their powerplants would allow it. The fighter airplanes were able to reach sufficient speed in dives to encounter compressibility problems, the most serious of which, to the pilot, was the high stick forces required to recover from a dive. A partial solution to this problem had been found at Langley in the form of dive-recovery flaps (Reference 5 contains a good treatise on the subject of compressibility effects on World War II airplanes and the development of dive-recovery flaps.). While these flaps served as a "fix" to allow pilots to recover safely from dives, they did not solve the compressibility problems, which continued to get worse as speed was increased. Separation of airflow behind strong shock waves induced extreme vibrations or buffeting, changes in trim of the airplane, and loss of control. In addition, with the new P-80 airplane the phenomenon of "aileron buzz" was encountered.

The NACA was aware of the problems and went to work on them. In December 1943, Dr. Lewis appointed a special panel to coordinate the activities of the NACA in the study of high-speed phenomena (ref. 6).[3] This panel met with W. S. Farren, Director of the Royal Aircraft Establishment of England, and agreed upon a joint attack on the high-speed aerodynamic problem, using a new technique of free-falling bodies dropped from high altitudes. On March 16, 1944, the NACA issued RA 1224 to cover this research. The bombs, upon release, were tracked by ground-based radar to define the trajectory from which the altitude at each instant was known and from which the velocity could be derived. Acceleration could also be determined, but a more accurate method involved the use of onboard accelerometers with radio transmission of readings by telemetry.

The free-fall body technique provided valuable large-scale data in a period when no other method existed. Dr. Lewis referred to this program at the March 16, 1944, meeting of the NACA as "the beginning of an investigation leading to supersonic flight." The dropping of "practice bombs" to

3. This panel consisted of R. G. Robinson, chairman, H. J. Allen, J. Stack, E. N. Jacobs, and R. E. Littell, recorder.

develop the technique began on May 31, 1944. Near the end of 1944, successful instrumented bombs were dropped. The first report on the results of this program was based on drops made in January 1945. Initial drops in the program were made on targets near Langley Field, but the program was moved to Wallops Island in July 1945 when the missile station was opened there. This technique became a regular part of Wallops operations and will be discussed in later chapters (ref. 7).

The next proposal of the high-speed panel was a continuation of the airplane flight program, but this time with specially built airplanes. A P-80 airplane was fitted with a special wing designed for 18-g lift loads. Designated the YP-80A, it was assigned to the NACA Ames Laboratory for test. The "beefed-up" wing was considered necessary because of the hazards involved in pulling out of high-speed dives at low altitude. To achieve higher speeds with this airplane and to allow high-altitude testing, attempts were made to supplement the thrust of the jet engine by the addition of small rocket motors. Littell and Helms of the NACA Washington Office visited the Naval Engineering Experiment Station at Annapolis, Maryland, on April 20, 1944, to get information on small jato units which might fit into the YP-80A fuselage.[4] They were interested in small solid rockets or in the liquid oxygen-gasoline jato motor being developed there by Dr. Robert H. Goddard. None of these rockets were suitable, so this attempt at higher speeds for the YP-80A was abandoned.

Early in the deliberations of the high-speed panel, John Stack proposed that an entirely new research airplane be built for high-speed research at high altitude. Stack, Chief of the Compressibility Research Division at Langley, had been working in high-speed aerodynamics almost from the day he reported for work at Langley in 1928. The wind tunnels in his division could approach the speed of sound or they could operate at supersonic speeds, but through a rather wide transonic speed range they would "choke" and no reliable data could be obtained. Stack proposed that special airplanes be built with rocket or jet propulsion to allow transonic flight at high altitude, so that the high-speed phenomena could be studied. This would be a much safer plan than to continue with piloted conventional airplanes which must dive to achieve transonic speeds (ref. 8). At a meeting at Langley, March 16, 1944, attended by Army Air Forces and Navy personnel, the NACA proposed that such an airplane be built (ref. 9).

Langley made many design studies for such an airplane, which showed that for supersonic flight a wing of 5-percent thickness[5] would be desirable (refs. 10 and 11). This was a radical change from the conventional thicknesses of 12 to 15 percent, and imposed a severe load on the structural designers. A compromise was reached in writing the specifications for the new high-speed research airplane by specifying that two wings be built: one, of 10-percent thickness and the other, of 8-percent thickness. As it turned out later, these were both too thick to avoid compressibility troubles.

The specifications for the research airplane were completed at Langley in January 1945, and shortly thereafter a contract was let by the Army Air Forces with Bell Aircraft Company for the XS-1 rocket airplane. A similar contract was placed by the Navy Bureau of Aeronautics with Douglas Aircraft Company for the D-558-I turbojet airplane. This was the beginning of a high-speed flight program that extended over many years (refs. 12 and 13).

The X-1 made its first powered flight December 9, 1946, with Chalmers H. Goodlin, Bell Aircraft Company test pilot, in the cockpit. Then, on October 14, 1947, Captain Charles E. Yeager flew the X-1 through the sonic barrier. It was fitting that the team of Stack, Yeager, and Lawrence D. Bell received the Collier Trophy in 1947 for this historic breakthrough.

A third method for obtaining aerodynamic data in the transonic speed range was suggested in July 1944 by Robert R. Gilruth, Assistant Chief of the Flight Research Division at Langley. Gilruth proposed that the transonic flow field generated on the upper surface of an airplane in a high-speed dive be utilized in much the same manner as a wind tunnel is used for model testing, but without the choking effects related to tunnel wall constrictions. In practice, small half-span wings at right angles to the upper surface of a P-51 airplane wing were connected to internal balances to measure forces and moments (ref. 14.). The first results from this test technique were released in May 1945 (ref. 15).

The decision to develop a fourth technique for obtaining experimental data in high-speed flight

4. From personal notes in the files of R. E. Littell, NASA.
5. The thickness of a wing is expressed as a percentage of its chord length.

was made in 1945. This was the decision to establish a missile test range. Although the initial requirements for the range stemmed from an expanding guided missile program, it was felt that such tests could provide design data for high-speed airplanes as well. The success of such a technique, which will be described in more detail later in this history, depended upon the availability of radar and telemetry instrumentation and suitable rocket propulsion systems.

RADAR AND TELEMETRY

Prior to 1945, the NACA Langley Laboratory had had considerable experience with the SCR-584 radar. This radar, which had been developed for the Army Signal Corps as a tracking aid and director for antiaircraft guns, operated in the S-band of frequencies (2200 mc) and had a range of approximately 10 miles. According to R. L. Krieger, who was a research engineer in the Langley Instrument Research Division, the first radar received at Langley late in 1943 was the prototype for the SCR-584, designated XT-1. It was on loan from the Navy, complete with operating crew and armed guards.

The first use of this radar at Langley was in determining airplane speeds in terminal velocity dives at speeds beyond the airplane's air-speed calibration range. This use posed no problem; such radars were used for air-speed calibration purposes for many years.

In the spring of 1944, a production version of the SCR-584 was assigned to Langley, and the XT-1 was returned to the Navy. This 584 was assigned to the free-fall body or bomb-drop program. By December 1944, a technique had been developed which allowed accurate tracking of the bodies which were dropped from high altitudes. The main problem was that the radio signal reflected from the carrier airplane completely masked the signal from the dropped body. The addition of an M-2 optical sight solved this problem. The optical sight, which was slaved to the radar set and could direct it automatically, was manually operated and positioned on the falling body until the radar could obtain a signal from the body unaffected by the launch airplane. This was the breakthrough that made the free-fall body technique a success. The same technique was applied later to the ground-launched rocket program, wherein the optical sight was used to direct the radar until the rocket had cleared ground effects. Early in 1945, an M-9 computer and plot board were added to the radar to allow ground observers to follow the flight path in "real time."

Some modifications or additions were made to the SCR-584 radar to improve its accuracy for research purposes. These consisted of adding large elevation and azimuth scales to the tracking head and photographing them with synchronized motion picture cameras which also recorded time. In addition, another motion picture camera equipped with a 40-inch focal length lens was mounted on the tracking head with its optical axis parallel to the radar beam. This camera photographed the test body and enabled a correction for any error by which the radar failed to point directly at the body. The modified radar was sometimes referred to as a "radar theodolite."

The question of whether rockets with their high acceleration and high velocity could be tracked by the SCR-584 radar was answered in the spring of 1945 when Krieger and a radar crew took a 584 radar to the Navy proving ground at Dahlgren, Virginia. Fortunately, the answer was an unqualified "Yes." The SCR-584 was the "backbone" of the NACA free-fall body and rocket model programs for many years to come.

In obtaining research data from airplanes in flight, the NACA had had many years of experience with special instruments designed to withstand the flight environment. Prior to the high-speed research airplanes, however, flight data generally were recorded on board the airplane and returned with it. Some preliminary use had been made of a radio telemeter in special tests of an XC-35 airplane at Langley in 1941, but its size precluded its use in the free-fall body program of the Flight Research Division, and a special development was required. The use of telemetry was essential to this program because the most interesting high-speed range was not reached in the dive until the altitude was too low for parachute recovery. The experiment would be compromised if recovery methods were adopted.

In early 1944, when the Langley Instrument Research Division (IRD), directed by E. C. Buckley, was assigned the job of providing a telemeter for the body-drop program, there were none available commercially of the required size, weight, and accuracy, although several groups in the United States were working in this field. The job of developing a special telemeter to meet the research needs of Langley was assigned to M. J. Stoller, Head of the Radio Control and Telemetering Section of IRD. His team members C. A. Taylor, A. Ruvin, and H. H. Youngblood worked full time on the development. This Langley group chose to use existing components for expediency. The telemeter developed was a system unique to Langley and was jealously guarded by its Langley "inventors." It was a system of research quality that made possible the use of nonrecoverable instrumented models in free-flight research. Through close monitoring and supervision of its use and through calibration and environmental testing, the overall inaccuracies with the system were kept to less than 2 percent of full-scale readings.

In the NACA telemeter, the basic measurements were registered as a linear movement of an iron core in an inductance coil which modulated the frequency of a subcarrier oscillator. The IRD had oscillators in the 160-kilocycle (kc) range and adapted them to this use. The first four-channel telemeter used frequencies of approximately 140, 150, 160, and 170 kc. When six channels were needed, 130- and 180-kc oscillators were added. The output of these frequency-modulated oscillators was, in turn, used to modulate the amplitude of the main carrier. An amplitude of 118 megacycles for the main carrier was selected because of availability from television components. The system became known as an FM/AM system.[6]

A four-channel telemeter system of this type was developed in the fall of 1944 at Langley and had its first flight test in a falling body on December 1, 1944. Through a misunderstanding, the body was dropped prematurely and the ground observers were not notified of the impending drop in time to turn on their telemeter recorders. Through the alertness of Ruvin of IRD, who was monitoring the telemeter receiver, data were recorded during the final 10 seconds of the drop after he correctly concluded from the readings he was getting on his monitor that the body had been dropped early. He turned on the recorder despite repeated statements by the airplane pilot that the bomb had not been dropped.

Although the data from this first instrumented drop could not be completely evaluated, the success of the telemeter gave Langley the confidence to proceed with an extensive flight program based upon its use.

STATUS OF JET PROPULSION

Because of the low efficiency of even the special high-speed propellers at speeds beyond 500 miles per hour, any hope for attaining transonic or supersonic speeds with either missiles or airplanes rested with the availability of suitable jet propulsion systems. Early analyses had shown that at low speeds jet propulsion was so inferior in efficiency to propeller systems that little consideration had been given to it in the United States prior to 1939.

A Special Committee on Jet Propulsion was established by the NACA in March 1941, with Dr. William F. Durand as chairman, to guide jet propulsion research (ref. 16). As a beginning, this committee recommended and guided three turbojet-engine development contracts with compressor or turbine manufacturers. After the flight on May 14, 1941, of the British Gloster jet airplane equipped with the Whittle I engine, the Army Air Forces decided to put the Whittle engine into production in the United States with General Electric Company as the contractor. The first airplane in the United States to be equipped with this engine was the Bell P-59. From this time on, the turbojet "was here to stay," with continual improvements fed in from research and development programs. These engines, which were designed to power airplanes, were too large, however, for all but the large types of guided missiles. The less efficient but adaptable ramjets and rockets were of greater interest for the smaller "self-propelled" guided missiles.

The NACA Special Committee on Jet Propulsion also took under its wing the research that had been under way at Langley since 1939 under the direction of Eastman N. Jacobs. Jacobs had been head of the Variable Density Tunnel at Langley and had pioneered the improvement of airplane performance, including development of the NACA low-drag airfoils. He was aware that a new form of propulsion would be required if airplane performance were to be very greatly increased. He began a jet propulsion program at Langley, first with models and then with a full-size engine. This program concerned itself mainly with jet-burning characteristics, utilizing a piston engine driving a compressor

6. From the author's discussions with H. H. Youngblood, Langley IRD Branch Head, April 27, 1966.

as a source of air. The work would have application to ramjets with the piston engine replaced by air that would be compressed dynamically by the forward motion of the aircraft at high speeds. The secret of efficient combustion in such an engine was found to be in the burner or "flame holder" design. The "Sherman thin-plate burner" was developed in this program by Albert Sherman, a member of Jacobs' team.

In 1944, the Committee on Jet Propulsion organized by the Office of Scientific Research and Development (OSRD) recommended that a special panel be appointed to investigate the subject of ramjets. Dr. Vannevar Bush, OSRD Chairman, considered ramjets basically an aerodynamic problem and recommended instead that the NACA be asked to undertake the coordination and guidance of the experimental ramjet program (ref. 17). On June 30, 1944, the Navy Bureau of Aeronautics requested the NACA to provide assistance in the development of ramjet and aero-pulse jet propulsion systems, including design, construction, and testing of experimental units. These units were of primary interest for use in the Gorgon series of air-to-air guided missiles that had been under development at the Naval Aircraft Factory since July 19, 1943 (ref. 18). As a result of these requests (OSRD and Navy) the NACA Cleveland Laboratory organized a ramjet working unit and began research and development on ramjets.

Interest in ramjet research at both Langley and Cleveland increased rapidly from this time on. Both laboratories made analyses of supersonic missiles with ramjet propulsion. At Langley, Macon C. Ellis and Clinton E. Brown calculated that a supersonic interceptor missile 3 feet by 15 feet could carry a 200-pound warhead and in 30 seconds intercept an airplane flying at an altitude of 60,000 feet.[7] The Cleveland Laboratory was having good success with burner development and, like Langley, also calculated that a ramjet would be a good propulsion unit for a supersonic interceptor missile and for a larger ground-to-ground guided missile as well. The Army Air Forces became interested in this proposed ground-to-ground ramjet missile and on December 18, 1944, held a briefing for prospective contractors who were asked to submit proposals for the construction of 25 such experimental missiles. This Army project was designated JB-7. Although this was a Cleveland project, R. T. Jones of Langley was involved in automatic control calculations (ref. 19).

By the end of 1944, when Langley began to give consideration to establishment of a guided missile flight test base, ramjets were not available for propulsion, but their development was in such a state that a flight ramjet research program was considered the next step, and all plans for a test base included the flight tests of ramjets. The control and instrumentation requirements for such a flight test missile were decided upon at a special meeting at Langley, February 22, 1945. In March 1945, discussions held at Langley led to resumption of ground tests of ramjet engines there, this time in the new Induction Aerodynamics Laboratory under Dr. Kennedy F. Rubert and John R. Henry.

The development of rocket propulsion systems was much farther along in 1944 than was the development of ramjet systems. Although rockets were inherently the least efficient of the jet propulsion systems, they were attractive because of their simplicity. During the war, the NDRC was the Government agency which had cognizance over most of the solid-rocket motor development in the United States.

Although solid rocketry dates back to the early Chinese, and rockets were used in the War of 1812, they did not attain full military stature until World War II. Russia, Germany, England, and the United States all had various forms of unguided, solid rockets in their arsenals and used them against all types of targets. They were both air- and ground-launched. The Germans were the first to capitalize on the use of guided rocket-propelled missiles, not only the V-2 with its liquid propellant, but also various guided missiles having solid propellants.

Dr. Robert H. Goddard is credited with launching the first liquid rocket (the propellants were liquid oxygen and gasoline), but attempts to capitalize on this invention in the United States during World War II were unsuccessful.

One liquid rocket development that eventually resulted in a number of applications was the acid-aniline rocket developed at the Jet Propulsion Laboratory (JPL) of the California Institute of Technology (Cal Tech), Pasadena, California, and first used in flight as a jato unit April 15, 1942. Earlier jato units developed at JPL were of the solid type. Although the solid rockets had a lower specific impulse

7. Unpublished report by Macon C. Ellis and Clinton E. Brown in Langley historical files.

than liquid rockets, they were used more generally because of their greater simplicity and safety.

The rocket development team at JPL, headed by F. J. Malina under the direction of T. von Kármán, did not have the facilities to produce the rocket motors in the quantity needed by the military, and Cal Tech did not wish to get into industrial production. Consequently, this team organized a special company to handle the production. This company, originally called Aerojet Engineering Corporation, produced both the liquid- and the solid-rocket motors. The solid motors were used chiefly as a thrust adjunct to airplanes, while the liquid engines became the propulsion unit for the Aerobee sounding rocket. This type of motor was also used later in the Gorgon and Nike missiles.

The solid-rocket motors available in 1944 were of two general types: (1) the jato units which were characterized by large diameter, long burning time, and low thrust; and (2) the military unguided rockets which had small diameter, short burning time, and high thrust. The jato units were typically 10 inches in diameter, burned for 12 seconds, and developed 1,000 pounds of thrust. The other rockets were 3 to 5 inches in diameter, burned for 1 to 5 seconds, and developed from 1,000 to 5,000 pounds of thrust.

A solid propellant used in this period was generaly one of three types: (1) the Aerojet composition, developed by JPL-GALCIT (Guggenheim Aeronautical Laboratory, California Institute of Technology), consisting of 75 percent potassium or ammonium perchlorate and 25 percent asphalt and oil; (2) the NDRC or Monsanto composition, consisting of 45 percent each ammonium picrate and potassium nitrate, plus a resin binder; and (3) the more common double-base propellant consisting of nitroglycerin and nitrocellulose plus various additives. British Cordite was of this third type and contained 9 percent carbamite. Ballistite and JPN were two other similar propellants (refs. 20 and 21).

All of these solid propellants had specific impulses of approximately 180, appreciably better than gunpowder with its impulse of only 65.

LANGLEY SUPPORT OF GUIDED MISSILES

The activity of the Langley Laboratory in support of military guided missiles[8] during World War II started with wind-tunnel tests. Later on, after the military services had experienced difficulties with automatic control and guidance, Langley was requested to assist in this area also.

Prior to World War II, there were practically no guided missile activities in the United States. The extensive research and development of rockets and missiles by Germany in the thirties went unnoticed and unchallenged. As the war approached, however, it was realized by the military services that guided missiles would be needed, and a modest development program was undertaken.

To obtain a better understanding of guided missile development in the United States, it is necessary to understand the nature of the development organizations in the military services. For years, the respective roles of the ordnance and airplane groups were clear. The Navy Bureau of Ordnance (BuOrd) and the Army Ordnance Corps developed and supplied the guns, bombs, and rockets used by all the forces—land, sea, and air. The Navy Bureau of Aeronautics (BuAer) and the Army Air Forces developed and supplied the airplanes for their respective services. With the coming of guided missiles, however, the roles of the various services were no longer clear. Was a guided missile merely a modified bomb, or was it a pilotless bomber? The question was not settled until much later. In the meantime, both the ordnance and airplane groups developed missiles.

The Army Air Forces and the Navy BuAer turned to the NACA for help with their guided missile development just as they had been doing with their airplanes. The military airplane departments had relied heavily upon private contractors to develop their airplanes and followed the same procedure with guided missiles. The ordnance people, on the other hand, had had little contact with the NACA in their regular ordnance development, and in general such development had been carried out in their

8. The term "guided missiles" is used here as a general term covering all types of unmanned aircraft. Some of these aircraft were called, at various times, "special flying weapons," "pilotless aircraft," "guided bombs," "glide bombs," "robot bombs," and "secret weapons."

own facilities. When they entered into guided missile development, they tended to follow this same policy or to organize special development laboratories.[9]

The NACA itself was slow to recognize that the ordnance people were involved in aeronautics. Although they were represented on some of the NACA subcommittees, the NACA main committee never had members from military ordnance groups. Nevertheless, the NACA supported both Army Ordnance and Navy BuOrd in any request they made.

A fifth organization which was involved with guided missiles was the National Defense Research Committee (NDRC), which was organized in 1940 to coordinate defense research activities throughout the nation.

In one way or another, the Langley Laboratory was involved in practically every guided missile project established during the war. The extent of this support is shown in table I, which is a good chronology of missile development during the war. The report references given by number in the table describe the type of investigation undertaken with each missile at Langley and give the names of the individuals directly responsible for the particular investigation.

The guided missiles developed by the Army Air Forces were given one of three general designations. Bombs fitted with glider wings for added range were designated GB for glide bomb; controlled bombs without wings, VB for vertical bomb; and jet-powered missiles, JB for jet bomb.

Although most of the missiles listed were unpowered, the first project undertaken at Langley with a complete missile had a conventional engine and propeller. This was the General Motors Flying Bomb and, except for the powerplant, bore a resemblance to the German V-1 buzz-bomb. It had a conventional wing of 21-foot span and a conventional tail which could be attached, along with the engine and propeller, to either a bomb or a torpedo. It was a ground-to-ground missile designed for catapult launching. The Army Air Forces requested tests on a full-scale missile in the Langley Full-Scale Wind Tunnel. The development of this missile was never completed because of automatic-control difficulties, but even if it had been developed, its slow speed would have made it too vulnerable for effective use as a ground-to-ground missile.

Up to 1944, almost all of the missiles under development were air-to-ground subsonic controlled-bomb types, and most of these were tested in Langley wind tunnels to provide stability information and control settings for trim. Missiles included the Navy BuOrd Gliding Torpedo; the Navy BuAer Air Stabilizer Mark 13 and Gargoyle bombs; the Army Air Forces GB-5 Glide Bomb and AZON bomb; and the NDRC-sponsored Bat, Pelican, Roc, and Tarzon bombs. Three of these missiles were used against the enemy during the war. The AZON, which was simply a controlled bomb, was used extensively in the bombing of bridges, particularly in Italy. GB-5 Glide Bombs were air-launched against German targets in 1944; and the Bat, developed by the Bureau of Standards under Dr. Hugh L. Dryden, was used in the Pacific Theater. Of these three missiles, two—the AZON and the GB-5—experienced automatic-control-system difficulties during their development, and the Army Air Forces asked for assistance from Langley with the problems.

At Langley, the division responsible for stability and control research was the Stability Research Division directed by Hartley A. Soulé. When the Army Air Forces came to Langley with their control and guidance problems, Soulé turned the problems over to his Stability Analysis Section, which was headed by Robert T. Jones. This section handled the theoretical aspects of the problem while the Instrument Research Division, headed by Edmond C. Buckley, participated in the solution of difficulties with particular pieces of equipment. Participation of Jones and Buckley in development of the GB-5 and AZON missiles was extensive and contributed greatly to their eventual success. For example, on the GB-5, Jones suggested that directional control be changed from rudder only to ailerons only. This change greatly reduced the large oscillations in flight path previously experienced (ref. 51).

There were two ground-to-ground missiles under development in this period, both subsonic. The first, an Army Air Forces development, designated JB-1, was a Northrop "flying wing" robot, powered

9. In January 1945, BuOrd established the Applied Physics Laboratory of Johns Hopkins University to develop surface-to-air interceptor missiles; and in 1944, Army Ordnance turned to the Jet Propulsion Laboratory of California Institute of Technology for surface-to-surface missile development. The JPL had previously developed jato units for aircraft.

TABLE I. LANGLEY WARTIME GUIDED MISSILE PROJECTS[1]

RA Number	Project	Facility(2)	Request: Agency(3)	Request: Date	Reference Number
856	General Motors Flying Bomb	FST	AAF	6-21-41	22
939	Navy Gliding Torpedo	PRT	BuOrd	12-1-41	23
959	Pelican Glide Bomb	FFT	NDRC	2-6-42	24
1065	ROC Shrouded Bomb	8-ft. HST	NDRC	12-28-42	25
1158	Bat Glide Bomb	PRT	NDRC	8-21-43	26
1189	GB-5 Glide Bomb	FFT-SA	AAF	11-22-43	27-30
1213	AZON 1000-Pound Bomb	16-ft HST	AAF	2-18-44	31
1232	Gorgon II Airframe	PRT	BuAer	3-7-44	32, 33
1246	Modified AZON Bomb (Dove)	8-ft HST	BuOrd	4-21-44	34
1251	Air Stabilizer Mark 13	PRT	BuAer	6-9-44	35
1276	MX-544 JB-2	SA	AAF	8-15-44	36
1287	Gargoyle	FFT	BuAer	9-29-44	37
1287	Gargoyle	PRT	BuAer	9-29-44	38
1287	Gargoyle	SA	BuAer	9-29-44	39, 40
1316	MX-570 JB-3 Tiamat	SA	AAF	12-7-44	36
1316	MX-570 JB-3 Tiamat	AFRS	AAF	12-7-44	(4)
1317	Lark	8-ft. HST	BuAer	1-7-45	41
1318	MX-595 JB-5	SA	AAF	1-19-45	42, 43
1328	Lark and Tiamat	FFT	BuAer	1-16-45	44-46
1328	Griswold Tiamat	FFT	BuAer	1-16-45	47
1345	Tarzon	SA	NDRC	4-10-45	36
1351	Lark	SA	BuAer	5-11-45	48-50

Notes: (1) This table was prepared, in part, from material contained in a letter dated August 22, 1944, from Dr. H.J.E. Reid to the NACA. The material was prepared for use by Dr. Hunsaker, NACA Chairman, in deliberations regarding expansion of missile facilities within the NACA.

Not listed in the table are approximately a dozen tests of bomb components, such as the wind-tunnel measurement of the characteristics of bomb fuses for the Army and Navy ordnance groups.

(2) Abbreviations used for facilities:

FST Full-Scale Tunnel
FFT Free-Flight Tunnel
HST High-Speed Tunnel
SA Stability Analysis Section
PRT Propeller Research Tunnel
AFRS Auxiliary Flight Research Station

(3) Abbreviations used for military service organizations:

AAF Army Air Forces
BuOrd Bureau of Ordnance (Navy)
NDRC National Defense Research Committee
BuAer Bureau of Aeronautics (Navy)

(4) The results of flight tests of the MX-570 Tiamat missile at the Auxiliary Flight Research Station (Wallops) are discussed in a later chapter.

with turbojet engines. The second was a direct copy of the German V-1 "buzz-bomb" and was designated "JB-2" in the Army version and "Loon" by the Navy. Jones and his Stability Analysis staff participated in both of these projects. One suggestion made by H. S. Ribner of the group in connection with launching techniques for the JB-2 greatly simplified handling and was to have a profound effect on all future ground launchings. The suggestion concerned the method of accelerating the missile to its flying speed. In the German version, flying speed was obtained by mounting the missile on a dolly which was then propelled along a low-angle rail or ramp by either a steam catapult or a rocket system. Ribner asked Army representatives, "Why don't you attach the rocket to the tail of the missile as a booster, launch it at a steeper angle, and eliminate the long launching ramp?"[10] After a few engineering calculations and a satisfactory trial, the proposal was adopted and used successfully. In fact, all ground-launched missiles of this general type have followed the boost principle.

By the middle of 1944, both the Army and the Navy realized their need for interceptor missiles for use against high-flying airplanes, and began consideration of both ground-launched and air-launched types. The Army began development of the air-to-air Tiamat, while the Navy began the surface-to-surface Lark. Both of these missiles were subsonic. It was quickly recognized that ground-launched interceptor missiles would need to be supersonic, and that their development would require extensive research, including flight testing. The story of these interceptor missiles is so closely related to the establishment of Wallops Flight Center that further discussion of them will be postponed until later in this chapter.

Langley's R. T. Jones provided extensive assistance to the Army Air Forces with actual flight problems of guided missiles under test at Eglin Field, Florida, and in the desert near Tonepah, Nevada. This substantial requirement for assistance, plus the ever-expanding missile program, convinced Langley that a test range of its own was needed to fly research missiles in anticipation of military needs.

INITIATION OF THE TIAMAT PROGRAM

The Tiamat was the first missile launched from Langley's missile test station on Wallops Island. In fact, requirements for the station were based, in large measure, on the requirements of this missile. It is appropriate, therefore, to discuss initiation of the program in some detail.

The Army Air Forces, early in 1944, invited Hughes Aircraft Company to submit a proposal for a subsonic air-to-air guided missile to be launched from a pursuit airplane or bomber. The main target in mind was the Japanese "Kamikaze" aircraft. Hughes made a design proposal; and on August 8, 1944, the company's representative, Carl Babberger, a former employee of Langley, visited Langley to solicit the assistance of Robert T. Jones in the control system design. Hughes had planned a wind-tunnel test program at the NACA Ames Laboratory because of its more convenient location with respect to the Hughes plant. Babberger discussed the design with Hartley A. Soulé, Chief of the Stability Research Division at Langley, and with Jones.

The proposed Hughes design included a cylindrical fuselage with faired nose and tail, a rectangular wing, and conventional tail surfaces. The body was 14 inches in diameter and 8 feet in length, while the wing had a span of 5.5 feet. The overall weight was estimated to be 600 pounds, and the missile was to be accelerated from its airplane launching speed of 300 miles per hour to a final speed of 600 miles per hour, by use of a Monsanto WF-1 solid-rocket motor (ref. 52).

Following this visit, Jones made an independent study for an interceptor missile to meet the requirements as given by Babberger. On November 8, 1944, he proposed to the Army Air Forces a radical design consisting of three large tail surfaces mounted symmetrically at the rear of an ellipsoid of revolution (ref. 53). The proposed original design as drawn by Jones is shown in figure 1. The proposal was for an interceptor missile that could be launched either directly from an airplane in flight, or from the ground by addition of a booster rocket.

The missile in either proposal (that of Hughes or Langley) was, according to Jones, "to be directed to a hostile aircraft by an automatic steering device." The configuration proposed by Jones "was arrived at after considering the target-seeking and steering equipment likely to be used and the aerodynamic requirements for flight speeds in the neighborhood of Mach 0.8." Jones also made two suggestions

10. Based on the author's discussions with Hartley A. Soulé, February 21, 1966.

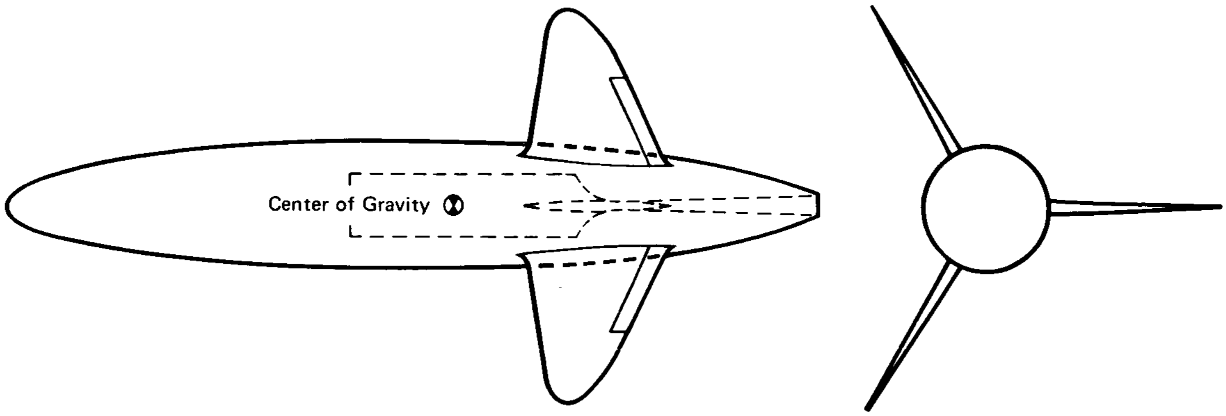


FIGURE 1. Original design by R. T. Jones for MX–570 Tiamat "Interceptor Aircraft" as proposed to Army Air Forces, November 8, 1944.

connected with the internal design. The first was to place the rocket motor at the center of gravity of the missile and to provide a blast tube from the nozzle back to the tail of the fuselage. This was to eliminate any center-of-gravity change as the rocket fuel was consumed. The second suggestion was "to dispense with electrical or compressed air followup systems and to manipulate the controls directly from the precessional torque exerted by the gyroscope. This torque could be restored to the system by an erection motor, as in the Hammond gyroscope."

The Air Technical Service Command of the Army Air Forces accepted Jones' proposal and arranged for Hughes to develop this design instead of the company's own. This was the Army's first air-to-air guided missile. The Army also accepted Jones' proposal to call this missile the Tiamat.[11] The AAF then requested NACA support in development of the Tiamat.[12] The missile was officially AAF project MX-570 and was also designated JB-3. It is interesting to note than in the letter from the AAF, the MX-570 was referred to as "a short-range interceptor pilotless aircraft."

The AAF requested that a research program be established at Langley for Project MX-570 "to include free flight tests of small models powered by rocket motors." The models were to be furnished by the NACA. The last paragraph of the request letter contained some rather unusual statements for this type of official correspondence but reflected the close working relationship that existed between Langley and Wright Field during this period. The request was made that Jones be authorized to make trips in connection with development of the MX-570, and the writer then went on to comment: "Mr. Jones has been doing considerable work on the Air Technical Service Command guided missile devices and his work has been an important factor in the development of these items. His untiring efforts and the inconveniences to which he has been subjected during tests of the JB-2 Buzz-Bomb are greatly appreciated."

Langley's reply to the ATSC letter stated that the proposed flight tests were considered desirable, but that the models would have to be large, at least 5 feet long, and their construction would constitute a major drain on Langley shop resources. In addition, "Flight work on this proposal will require the acquisition of a suitable launching site." Analytical work would also be required.[13]

On January 29, 1945, the NACA issued RA 1316 to cover the MX-570 program. This RA stated that the purpose of the investigation was "to develop MX-570 for combat use." The scope of the work was to include (1) analysis of the control system and (2) flight tests. The flight work was to "include the development of the launching apparatus and the instrumentation for recording or transmitting data." With this RA, Langley was authorized to proceed actively with its own missile flight test program.

In the beginning, the Stability Analysis Section was given overall responsibility for the MX-570 program. The Instrument Research Division was assigned responsibility for the automatic control and

11. Tiamat, according to Babylonian mythology, was a sea monster.
12. ATSC letter to Dr. G. W. Lewis, prepared by Captain D. W. Pearsall and signed by Colonel H. Z. Bogert, Dec. 7, 1944.
13. Letter of Jan. 24, 1945, to the NACA regarding Project MX-570. Letter was prepared by H. A. Soulé and signed by John W. Crowley.

telemeter systems. The Engineering Division performed the necessary design work and prepared construction drawings, and the Langley shops began construction of the missiles. The Stability Analysis Section made arrangements for the solid-rocket motors through the local ATSC liaison office, designed the booster-rocket system, and performed the necessary stability and automatic-control calculations. By the time a test station was available, the Tiamat test missiles were ready for launching.

ARMY AND NAVY REQUESTS TO ACCELERATE HIGH-SPEED RESEARCH

The request by the Army Air Forces for Langley to conduct flight tests of the Tiamat missile was only one of several requests that brought to a head the need for an NACA flight test range for missiles. A second letter from the AAF, coincidentally bearing the same date as the Tiamat request (December 7, 1944), was directed to NACA Headquarters, asking for assistance in the design of a ground-to-air interceptor missile.[14] The Army Air Forces and Army Ordnance had jointly initiated development of a ground-to-air, high-altitude, supersonic guided missile in February 1944. The requirements for this missile stemmed from antiaircraft forces, but in this wartime period it was not clear which element of the Army had the responsibility for development of the missile. Because of past relationships, the Army Air Forces turned to the NACA for assistance. Contractors' representatives who visited Langley discussed the requests they had received from the Army Ordnance people as well.

The Army Air Forces' letter stated that "the development of guided missiles for antiaircraft use is being undertaken" and specifically asked that Langley initiate a program to develop the vehicle and the propulsion system. The requirements were for a speed of up to 1,500 miles per hour to intercept targets at altitudes up to 60,000 feet. The missile was "to be ground-launched, self-propelled, and ground-controlled to interception of the target."

On December 22, 1944, representatives of Bell Telephone Laboratories visited Langley in connection with a ground-to-air missile for which the Army had requested Bell Laboratories to act as prime contractor. The requirements were to intercept a 600-mile-per-hour bomber at a 60,000-foot altitude. This would require a missile with a speed of 2,000 feet per second, carrying a 200-pound explosive charge. Langley recommended the use of a ramjet in the missile itself. A liquid-rocket system similar to the V-2 rocket was also discussed.

On January 10, 1945, Dr. W. B. Klemperer of Douglas Aircraft Company visited Langley; he stated that Douglas had been asked by both the Army Special Weapons Unit and Bell Telephone Laboratories to assist in the design and construction of special weapons, in particular, a ground-to-air interceptor. This interceptor was now called "Supercondor" and "JB-8." Klemperer stated that Ordnance people were interested in this or a similar independent project. On January 31, 1945, Army Ordnance finalized their plans by awarding a contract to Bell Telephone Laboratories for development of a ground-to-air interceptor missile that became the Nike I.

Before a reply to the AAF letter of December 7, 1944, was agreed upon, a letter dated December 19, 1944, was received by NACA Headquarters from the Navy Bureau of Aeronautics, expressing concern about the slow progress being made in the whole field of high-speed research.[15] In this letter, the Bureau Chief, Admiral D. C. Ramsey, stated, "The Bureau considers that the progress being made on high-speed research is not as rapid as military necessity now demands. Current combat requirements dictate that jet-propelled aircraft and missiles be developed with highest practicable priority. It is essential that all phases of the research be expedited in every way."

The Bureau had some specific suggestions for the NACA to expedite this high-speed research. They recommended that construction of supersonic tunnels be expedited. They offered to supply the NACA with free-fall models of the F8F-1 airplane and with existing rocket-propelled missiles. Finally, they stated, "A more promising line of attack may be the use of small rocket-propelled airplane models. The Bureau is prepared to underwrite the design and procurement of any special models of airplanes or rocket units that may be required in this program." In his communication forwarding this letter to Langley on December 29, 1944, Dr. G. W. Lewis asked "for the recommendations of the laboratory as to additional equipment and personnel desirable for carrying out the mandate of the Bureau."

14. Letter from Colonel H. Z. Bogert, ATSC, to Dr. G. W. Lewis, prepared by Major J. M. Pomykata, December 7, 1944.
15. Letter from Chief, BuAer, to the NACA, Dec. 19, 1944. Letter was signed by Admiral D. C. Ramsey.

From this came the final decision to establish what eventually became Wallops Flight Center.

The December 19 letter from BuAer was prepared jointly by Commander E. W. Conlon of the Structures Division and Captain W. S. Diehl of the Aerodynamics and Hydrodynamics Division of BuAer, upon recommendations of Captain W. H. Miller. According to Diehl, it was "perhaps the only such joint letter in BuAer files." It was prepared following a directive from the Chief of Naval Operations for "an all-out effort to provide new weapons." Prior to the preparation of the letter, there had been many discussions between Diehl and Helms of NACA Headquarters and other members of the NACA and Langley staff. Diehl knew, therefore, of Langley's interest in establishing a test range for missiles. Diehl said he "threw everything he could think of into it" with the idea of stirring the NACA into a large expansion of research in the supersonic range, with extensive BuAer support. Helms referred to it as the "$64,000,000 letter."[16]

LANGLEY SPECIAL FLYING WEAPONS TEAM

The numerous requests from the military services for increased support of high-speed missile research prompted John W. Crowley, Acting Engineer-in-Charge of Langley[17] to organize a "Special Flying Weapons Team" with himself as chairman.[18] The overall assignment to this team was to take an active part in the direction of all work at Langley on flying weapons. At the first meeting on December 9, 1944, the overall program at Langley was discussed, and Crowley concluded "it appears that some flight operation work is necessary in connection with the development of flying weapons."

At the second meeting of the team on January 2, 1945, K. F. Rubert summarized rocket motor availability and specifically gave the characteristics of two Monsanto solid rockets which were to be used later in the Tiamat flight program. These were the WF-1, to be used as the sustainer rocket, and the ACL-1, to be used as a booster. The main activity at this second meeting, however, concerned the establishing of a new flight test range. By this time, Langley was ready to recommend that such a base be established. Crowley stated that he had learned that BuAer was considering making Cherry Point, North Carolina, its main station for studying guided missiles. If this were so, it might also be a convenient location for the NACA station. The idea would be for the Bureau to supply much of the overhead equipment and personnel, while allowing the NACA to conduct research and development in all phases of high-speed flight research. Crowley recommended that the Bureau's offer to provide rockets and other items of support be accepted.

A possible program for the new test range was discussed at this same meeting. It was agreed that both rocket and ramjet subsonic and supersonic missiles should be considered. The requirements for the base were discussed, and the need for a large supersonic wind tunnel at Langley was brought out. At this stage, much could be learned by simply determining if the missiles could be flown and controlled at supersonic speeds; but at the same time every effort should be made to obtain scientific data from tracking, telemetering, and photography. Crowley stated that the work should definitely point to supersonic testing, although the initial project would be subsonic, to develop techniques. The Army MX-570 and the Navy Gorgon subsonic missiles were to be the first to be tested. It was also brought out that this flight work should be carried on simultaneously with the Langley bomb-drop program and the NACA research-airplane program.

Soulé pointed out that the proposed missile operation would require a large organization, and that the need for considerable work on guidance and control systems should be recognized.

In order to put Langley's plans into a formal document, Crowley assigned Thompson, Stack, and Soulé the job of preparing the proposal for NACA Headquarters. In addition, Crowley was to find out more about Cherry Point. He assigned Rubert to investigate the rocket motors in use by the Navy, and Robert A. Gardiner to survey the field of target seekers, including the radar seeker used by Dryden in the Bat missile (ref. 54).

16. Based on discussion with Captain Walter S. Diehl, USN (Ret.) May 24, 1966.
17. Dr. H. J. E. Reid was in Europe with the Alsos Mission, a group sent by the War Department to the World War II European Theater of Operations in late 1944, to identify and collect valuable scientific research information abandoned by the enemy in retreat.
18. The members of the Special Flying Weapons Team were J. W. Crowley, Chairman, F. L. Thompson, R. R. Gilruth, R. T. Jones, F. J. Bailey, E. C. Buckley, M. C. Ellis, J. Stack, H. A. Soulé, J. A. Shortal, and K. F. Rubert.

COMMITTEES ON GUIDED MISSILES

In Washington, D.C., the increased activity in the field of guided missiles was recognized by establishment of two high-level committees to coordinate such activities. The first was the Guided Missiles Committee of the Joint Committee on New Weapons and Equipment of the Joint Chiefs of Staff. It was organized to formulate broad programs and to recommend means for the coordination of research and development in the field of guided missiles. Dr. Hunsaker, NACA Chairman, was made a member of this committee, with Dr. Lewis serving as his deputy (ref. 55). The committee later became the Guided Missiles Committee of the Research and Development Board (RDB), and the NACA was represented on its various working-level panels for several years.

The second committee to be organized was the NACA Special Committee on Self-Propelled Guided Missiles, which was authorized by the NACA Executive Committee on January 25, 1945. The members of this committee were Dr. Hugh L. Dryden, Bureau of Standards, Chairman; Brigadier General James F. Phillips and Major Ezra Kotcher, Army Air Forces; Captain Robert S. Hatcher and Captain H. B. Temple, Navy Bureau of Aeronautics; Dr. Joseph C. Boyce, Office of Scientific Research and Development; John W. Crowley, Jr., NACA Langley; and Abe Silverstein, NACA Cleveland.[19]

In proposing the formation of this NACA committee, Dr. Hunsaker presented a memorandum he had prepared on "Guided Missiles, NACA Program and Facilities." He said the policy of the NACA was to undertake scientific and engineering studies of such guided missiles as came within the cognizance of the Army Air Forces and the Navy Bureau of Aeronautics. He stated further that the relationship of the NACA with respect to them was the same as it had been with respect to airplanes. The Executive Committee did not think Hunsaker went far enough in recognizing only the missile interests of Army Air Forces and Bureau of Aeronautics. They proposed that the needs of the Army Ordnance Corps and Navy Bureau of Ordnance also be recognized and that full support be given them in connection with any "airborne devices" on which they were working. The scope of this new committee's activities was considered to be broad, and it was expected to include sponsorship of research in such new fields as "radio, radar, television, photoelectric, infrared, and special application of physics to homing and guiding devices."

NACA DECISION TO ESTABLISH A MISSILE TEST STATION

In response to the Navy letter of December 19, 1944, regarding acceleration of the high-speed aerodynamic research program, Langley Laboratory made recommendations that were contained in a letter addressed to the NACA and prepared by Floyd L. Thompson and John W. Crowley, Jr.[20] It was an extensive letter and one that suggested certain definite plans of action.

It was recommended that high-speed research could best be accelerated "by flight tests of bodies or missiles launched from the ground and from airplanes in flight and propelled by various means, including rockets, jet engines, and ramjets. Such tests will require . . . the acquisition of an auxiliary station with a range of about 50 miles free from habitations or shipping. . . . it appears desirable to attach it to some existing base such as, for example, the Navy's Cherry Point base." Crowley also recommended expansion of Langley's high-speed wind-tunnel facilities. In particular, a new supersonic tunnel, an increase in power for the 16-foot tunnel, and modifications to the new high-speed 7-foot by 10-foot tunnel were recommended.

With regard to personnel needs to handle the increased workload, Crowley stated that no increase in the complement of Langley would be required because Langley already had authorization for 700 additional personnel. Crowley recommended accepting all the offers made by the Navy. In particular, he suggested that BuAer be asked to allocate 6 free-fall models of the F8F-1 airplane and 12 special Gorgon missiles.

NACA headquarters was ready to move with the plan for high-speed research expansion and had received suggestions from the Ames and Cleveland Laboratories as well as from Langley. During his

19. Despite awareness that the Navy Bureau of Ordnance and the Army Ordnance were involved in missile development, neither was represented on this committee until the committee itself, at its meeting on January 17, 1946, recommended that they be included.
20. Langley letter to the NACA, dated January 16, 1945, and signed by John W. Crowley, Jr.

visit on January 11, 1945, Dr. W. B. Klemperer of Douglas Aircraft Company was asked for his recommendations on new facilities for guided missile work. Dr. Klemperer suggested a Mach 2 supersonic tunnel with at least a 2-foot throat; he thought the first extensive exploration of the transonic region would be by pilotless guided missiles.

At their regular meeting on January 25, 1945, the NACA Executive Committee considered recommendations from all the laboratories. Dr. Hunsaker summarized the letters from the Army and Navy asking the NACA to serve as a central scientific agency to provide basic research data to aid the military in development of supersonic guided missiles and aircraft. Dr. Lewis had prepared a list of facilities needed to perform this research. One facility, a 6-foot supersonic wind tunnel for Ames Laboratory to cost $4,500,000, was considered by the Navy to be so urgently needed that they transferred funds to cover its cost. The remaining facilities were proposed for a supplemental appropriation. These came to a total of $12,981,722, of which $4,536,200 was for an auxiliary flight research station on or near the Marine base at Cherry Point, North Carolina, to be operated by the Langley Laboratory. Also included in the plan was a supersonic tunnel for Langley at a cost of $700,000, and a larger supersonic tunnel for Cleveland at $5,000,000. Additional funds for salaries and expenses in the amount of $2,199,422 were also included. The Executive Committee authorized the Chairman to submit the estimates to the Bureau of the Budget (ref. 56).[21]

Earlier in the month, Dr. Hunsaker and Dr. Lewis had appeared before the House Appropriations Subcommittee in connection with hearings held January 9, 1945, on the regular appropriations. After discussing the work that the NACA had been doing in connection with guided missiles, Dr. Hunsaker made this prediction: "We will have to come in with a supplemental estimate for 1945 to take care of some of the new things that have come up." He was able to explain these in more detail when the hearings were held in March on the supplemental bill.

21. Before submitting these estimates to the Bureau of the Budget, NACA Headquarters reduced the salaries and expenses item to $667,500, making a new total of $11,449,800.

References

1. *United States Code,* Title 49, Section 241. Public Law 63–271.
2. Hunsaker, Jerome C., testimony before House Select Committee on Post-War Military Policy, NACA, Jan. 26, 1945.
3. Statement for Special Congressional Committee Investigating the National Defense Program, James M. Mead, Chairman, NACA, 1946.
4. Sunderman, James F.: *World War II in the Air—Europe.* Franklin Watts, Inc., 1963.
5. Gray, George W.: *Frontiers of Flight.* Alfred A. Knopf, 1948.
6. Minutes of the Meeting, NACA Executive Committee, Mar. 16, 1944.
7. Thompson, F. L.: "Flight Research at Transonic and Supersonic Speeds With Free-Falling and Rocket-Propelled Models." *Proceedings of Second International Aeronautical Conference,* New York, May 1949.
8. Stack, John: "Experimental Methods for Transonic Research." *Proceedings of Third Anglo-American Aeronautical Conference,* Brighton, Sept. 1951.
9. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Science and Technology in the Exploration of Space, 1915–1960.* NASA, 1961, p. 47.
10. Physical Research Division: *Preliminary Dimensional Analysis of Transonic Airplane Using Turbojet Propulsion With Rocket Boosters.* NACA Preliminary Analysis for Army. Dec. 23, 1944.
11. Ellis, Macon C., Jr.; and Brown, Clinton E.: *Analysis of Supersonic Ram-Jet Performance and Wind-Tunnel Tests of a Possible Supersonic Ram-Jet Airplane Model.* NACA ACR L5L12, 1945.
12. Soulé, Hartley A.: *Review and Status Report of High-Speed Research Airplane Program.* NACA, June 30, 1950.
13. *The Rocket Research Aircraft Program, 1946–1962.* Air Force Flight Test Center.
14. Gilruth, Robert R.: "Resume and Analysis of NACA Wing-Flow Tests." *Proceedings of Aeronautical Conference,* London, 1947.
15. Gilruth, R. R.; and Wetmore, J. W.: *Preliminary Tests of Several Airfoil Models in the Transonic Speed Range.* NACA ACR L5E08, May 1945.
16. Gray, op. cit.
17. Minutes, Special Meeting of NACA Executive Committee, June 8, 1944.
18. Emme, op. cit., p. 45.
19. Silverstein, A., Chief, Engine Installation Research Division, NACA Cleveland, Memorandum to Executive Engineer, Jan. 3, 1945, regarding visit of Silverstein and R. T. Jones of Langley to Wright Field on Dec. 18, 1944.
20. Burgess, Eric: *Guided Weapons.* Macmillan, 1957.
21. "Historical Development of Jet Propulsion." *High Speed Aerodynamics and Jet Propulsion. Vol. XII, Jet Propulsion Engines,* Princeton University Press, 1959.

22. Reeder, John P.; and Preston, G. M.: *Full-Scale Wind-Tunnel Tests of the General Motors Aerial Torpedo.* NACA MR for Army, Oct. 29, 1941.
23. Valentine, E. F.; and Conway, R. N.: *Wind Tunnel Tests of an Aerial Torpedo.* NACA MR for Navy, Apr. 25, 1942.
24. Campbell, J. P.: *Free-Flight Tunnel Tests of a 1/4-Scale Model of a Controlled Glide Bomb.* NACA MR for NDRC, Mar. 24, 1942.
25. Baals, D. D.; and Smith, N. F.: *Aerodynamic Tests of the NDRC Shrouded Bomb in the 8-Foot High-Speed Wind Tunnel.* NACA MR for NDRC, Apr. 13, 1943.
26. Conway, R. N.: *Wind-Tunnel Tests of a Target Glider.* NACA MR for NDRC, Oct. 15, 1943.
27. Pitkin, Marvin: *Force Tests of a 1/5-Scale Model of the Type GB−5 Controllable Glide Bomb.* NACA MR for Army, Mar. 27, 1944.
28. Schade, R. O.; and Polston, L. E.: *Force Tests of a 1/5-Scale Model of the Type GB−7B Controllable Glide Bomb.* NACA MR for Army, July 26, 1944.
29. Stability Analysis Section: *Theoretical Analysis of Stability of Aeronca Glide Bomb.* NACA Preliminary Data for Army in 11 parts. 1944.
30. Jones, Robert T.: *A Method for Studying the Hunting Oscillations of an Airplane With a Simple Type of Automatic Control* NACA MR for Army, May 5, 1944. Later released as TR−801, 1947.
31. Pearson, E. O., Jr.: *Aerodynamic Tests of an AN−M−65 AZON 1000-Pound Radio-Controlled Bomb in the Langley 16-Foot High-Speed Tunnel.* NACA MR for Army, June 16, 1944.
32. DeKoster, Lucas J.: *Wind-Tunnel Tests of Gorgon IIA and IIB Airframes. Part I, Surface Pressure Distribution and Duct Tests.* NACA MR for Navy Oct. 6, 1944.
33. Mastrocola, N.: *Wind-Tunnel Tests of Gorgon IIA and IIB Airframes. Part II, Power-Off Longitudinal and Lateral Stability and Control.* NACA MR for Navy, Jan. 2, 1945.
34. Wright, John B.: *High-Speed Wind-Tunnel Tests of a Controllable Modified AN−M65 Bomb.* NACA MR for Navy, Aug. 31, 1944.
35. Marino, A. A.; and Vollo, S. D.: *Longitudinal Stability and Control Investigation of Navy Air Stabilizer MK−13 Conducted in the Langley Propeller Research Tunnel.* NACA MR for Navy, Jan. 25, 1945.
36. Stability Analysis Section: Various Preliminary Data Reports for Army 1944−1945.
37. Paulson, John W.; Schade, Robert O.; and Johnson, Joseph L.: *Stability and Control Tests of a 1/3-Scale Model of the Navy Design No. 13ADR (Gargoyle) in the Langley Free-Flight Tunnel.* NACA MR L5G26 for Navy, Aug. 2, 1945.
38. Marino, Alfred A.: *Stability and Control Tests of Full-Scale Navy Model LBD−1 Aerial Bomb (Gargoyle).* NACA MR L5I18 for Navy, Sept. 26, 1945.
39. Stability Analysis Section: *Interim Results of Theoretical Analysis of the Stability of the Model LBD−1 Aerial Bomb (Gargoyle) I (A), Effect of Control Gearing Ratio and Servo Motor Rate on Longitudinal Stability.* NACA MR L5B02 for Navy, Feb. 2, 1945.
40. Sternfield, Leonard: *Effect of Gyro Tilt Angle, Control Gearing Ratio, Rate of Control Surface Deflection, and Time Lag on Lateral Stability of the Model LBD−1 Aerial Bomb (Gargoyle).* NACA MR for Navy, July 9, 1945.
41. Smith, N. F.: *High-Speed Tests of 1/4-Scale Model of Navy Special Missile "Lark."* NACA MR for Navy, Aug. 7, 1945.
42. Ribner, H. S.: *Attainment of a Straight-Line Trajectory for a Preset Guided Missile With Special Reference to Effect of Wind or Target Motion.* NACA MR for Army, Aug. 28, 1945.
43. Ribner, H. S.: *Study of a Bomb Configuration With Torque-Exerting Gyros for the Attainment of a Straight-Line Flight.* NACA MR for Army, July 7, 1945.
44. Paulson, John W.; Schade, R. O.; and Johnson, J. L.: *Investigation of Stability and Control Characteristics of a 1/2-Scale Model of an NACA Configuration of Guided Missiles (MX−570) in the Langley Free-Flight Tunnel, Part I Three-Fin Arrangement.* NACA MR for Army, Sept. 19, 1945.
45. Johnson, Joseph L.; and Varney, Elizabeth P.: *Investigation of Stability and Control Characteristics of a 1/2-Scale Model of an NACA Configuration for Guided Missiles (MX−570) in the Langley Free-Flight Tunnel. Part II, Four-Fin Arrangement.* NACA MR L5J01 for Army, Oct. 16, 1945.
46. Johnson, Joseph L.; and Varney, Elizabeth P.: *Investigation of Stability and Control Characteristics of a 1/2-Scale Model of an NACA Configuration for Guided Missiles (MX−570) in the Langley Free-Flight Tunnel. Part III, Damping in Yaw and Pitch.* NACA MR L5L28 for Army, Jan. 17, 1946.
47. Paulson, J. W.; Johnson, J. L.; and Varney, Elizabeth P.: *Stability and Control Force Tests of Four and Six Unit Low Aspect Ratio Wings of 20° Triangular Planform.* NACA MR for Army, Jan. 8, 1946.
48. Harmon, Sidney M.: *Aerodynamic Frequency-Response Curves and Automatic Dynamic Stability Boundaries for Navy "Lark" Missile.* NACA MR L5J05a for Navy, Oct. 29, 1945.
49. Watkins, C. E.: *Calculated Flight Paths of the Lark Pursuing a Moving Target.* NACA MR for Navy, June 1945.
50. Watkins, C. E.: *Calculated Paths of the Lark Pursuing an Evading Target.* NACA MR L5H07a for Navy Aug. 17, 1945.
51. Jones, R. T., Memorandum for Engineer-in-Charge, Feb. 1, 1944, regarding visit to Eglin Field on Jan. 13, 1944, to witness target-seeking glide-bomb tests.
52. Jones, Robert T., NACA Langley, Memorandum to Chief of Research, Aug. 15, 1944.
53. *Preliminary Design Study; Part I, Short Range Interceptor Aircraft.* Langley Stability Research Division, Nov. 8, 1944.
54. Minutes, Meeting of Langley Special Flying Weapons Team, Jan. 2, 1945, Joseph A. Shortal, Secretary.
55. Minutes, Meeting of NACA Executive Committee, Jan. 25, 1945.
56. Minutes, Meeting of NACA Executive Committee, Jan. 25, 1945.

CHAPTER 2

PRELIMINARY PLANS AND PROGRAM

Once the NACA Executive Committee had approved the establishment of an auxiliary flight research station for guided missile research under the direction of Langley Laboratory, it was time to prepare detail plans and cost estimates and secure their approval by the Bureau of the Budget, the President, and the Congress.

FORMAL PROPOSAL FOR A MISSILE TEST STATION

On February 1, 1945, Langley submitted a formal proposal to NACA Headquarters for construction of an auxiliary flight research station. Preparation of this document had been assigned to Thompson, Soulé, and Stack at the January 2, 1945, meeting of the Langley Special Flying Weapons Team. The Request for Approval (RFA) gave the justification, description, and estimated costs associated with the new flight test program. The RFA was so complete that it also served as an operational plan and a budget document.

The justification given in the RFA for an auxiliary flight research station was solely that of providing a range for guided missile flight testing. The RFA referred to the Army and Navy requests which "suggested an expansion of the laboratory facilities so that the Committee can make flight trials of flying missiles." The request further stated: "It is evident . . . that work on Special Flying Weapons will constitute a major project for the Committee."

The listing of problems to be studied in the development of flying weapons constituted a "research program" for the new station:

1. Subsonic missile configurations
    a. Aerodynamic efficiency
    b. Stability, including automatic devices
    c. Maneuverability against evasive targets
    d. Control by remote pilots
2. Supersonic missile configurations
3. Transonic aerodynamics of supersonic missiles
4. Use of minimum equipment in development of launching techniques for ground-launched missiles

The RFA suggested that the test range be located in North Carolina, to operate out of the Marine base at Cherry Point, which is about 150 air miles from Langley. The missile flights would be parallel to the barrier islands off the coast between Cape Lookout and Cape Hatteras. A line of observation

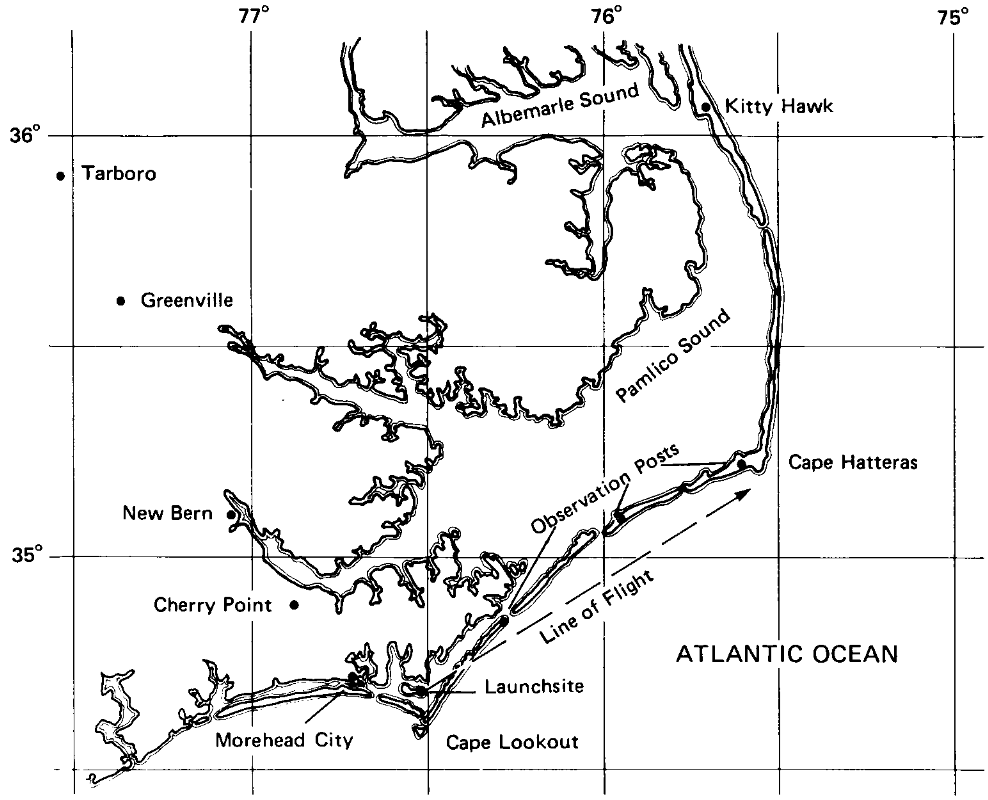


FIGURE 2. Proposed Auxiliary Flight Test Station at Cherry Point, North Carolina.

stations was to be placed on the barrier islands. The overall plan at Cherry Point is shown in figure 2. It was stated in the RFA, however, that the same plan would apply "to any location, that, for reasons not apparent at present, may be chosen later." Wallops Island was selected after Congress approved the project.

The overall facilities required for this new flight test range were related to the plan of operation. The proposed plan, which was followed throughout the period of operation of the station under Langley management, was to have minimum facilities at the missile station for final assembly, launching, and data recording. Principal research and development was to be centered at Langley, where all missiles would be designed, constructed, proof-tested, and instrumented. The plan envisioned air transportation between Langley and Cherry Point, and land and water transportation between Cherry Point and the launchsite.

The funding request to carry out the plan was as follows:

A. Langley Field Station	$1,208,200
B. Cherry Point Station	650,000
C. Launching Site	458,000
D. Observation Stations	10,000
E. Airplanes	850,000
F. Ground Transportation	10,500
G. Water Transportation	50,000
H. Models	668,000
I. Instrumentation	631,500
Total	$4,536,200

The facilities and equipment planned for procurement under each of the above categories are given in the following list.

A. Langley Field: Enlargement of existing model shop, building of new missile construction shop, and purchase of new equipment.

B. Cherry Point Station: Construction and equipping of final assembly station at Cherry Point, North Carolina.

C. Launching Site: Construction of receiving station, liquid-fuel storage, solid-fuel storage, final loading building, bombproof observation post, launching track, and launching platform; provision of utilities such as powerplant, water tank, and well; and construction of roads and fence.

D. Observation Stations: Construction of radar storage shelter and concrete ramp at each location.

E. Airplanes: A DC-3 airplane to carry freight and a B-29 airplane for launching "hi-angle devices" and "man-carrying supersonic airplane."

F. Ground Transportation: One 10-ton truck, a pickup truck and two station wagons.

G. Water Transportation: One Navy LCT boat and a motorboat for patrol and retrieval operations.

H. Models: Six F8F-1 drop models and twelve Gorgon missiles to be supplied by the Navy; construction of 36 MX-570 models and ten supersonic models with booster rockets and attachments.

I. Instrumentation: Modified SCR-584 radar, ballistic camera, 60 telemeters, telemeter receivers, radios and telephones, CW radar for direct velocity measurement, and other miscellaneous instruments.

The above plan, essentially unchanged, was submitted to the Bureau of the Budget along with corresponding material prepared for the supersonic tunnels required at Langley and at Cleveland. The Bureau removed funds for the airplanes, boats, and radars because these would be obtained on loan from the Army and Navy.

The appropriations request as finally prepared by the Bureau of the Budget was as follows:

Construction and Equipment at Langley Field, Virginia, including not to exceed $2,195,000 for auxiliary flight research stations on sites elsewhere	$ 4,100,000
Construction and Equipment, Cleveland, Ohio	5,540,000
Additional Salaries and Expenses	667,500
Total	$10,307,500

This request was sent to Congress by President Roosevelt on March 7, 1945.

CONGRESSIONAL ACTION

When the request for supplemental appropriations to expand NACA facilities for high-speed research reached the Congress, hearings were held on March 16, 1945, before the Senate Appropriations Subcommittee, because the House Appropriations Committee was not in session.

At the hearings, Dr. Hunsaker explained to the Senate Committee, chaired by Senator McKellar, that the NACA needed facilities to conduct research into the supersonic range for missiles and airplanes. This research had the backing of both the Army and the Navy. Dr. Lewis stated, "The Committee is the recognized research agency of the Army and Navy." He also explained that the new facilities requested were the minimum necessary to meet the urgent requirements of the Army and Navy in the new field of guided missiles (ref.1).

The request for funds was approved by Congress and signed into law on April 25, 1945. The appropriations became officially the First Deficiency Appropriations Bill, 1945. The only change made by Congress was the addition of a 100-acre limitation on the purchase of additional land. The bill provided $4,100,000 for Langley, $5,540,000 for Cleveland, and $667,500 for salaries and expenses—a total of $10,307,500 (ref. 2).

BREAKDOWN OF FUNDS

NACA Headquarters informed Langley of the approval of the appropriations for the new facilities and assigned Project Number 371 for the auxiliary Flight Research Station and Project Number 363 for the Langley supersonic tunnel. The funds were allocated to Langley by NACA Headquarters as follows:

Project 363	Supersonic Tunnel	$ 700,000
Project 371	Auxiliary Flight Research Station	3,400,000
	Total	$4,100,000

On May 11, 1945, a breakdown of these funds was proposed by Langley. It was approved by NACA Headquarters on May 24, as follows:

Project No.	*Item*	*Research*	*Expenditure*
371	Auxiliary Flight Research Station		
	A. Langley Field Station		
	1. Model Shop Extension	$151,000	
	2. Missile Construction Shop	485,000	
	3. Equipment	451,300	$1,087,300
	B. Receiving Station (airport)		105,000
	C. Launching Site		
	1. Launching ramp	15,000	
	2. Launching platform	10,000	
	3. Final Assembly building	232,500	
	4. Office and Radio Building	28,000	
	5. Living Quarters	44,000	
	6. Oil Tanks	20,000	
	7. Powder and Chemical Storage	25,000	
	8. Loading Room	7,500	
	9. Bombproof Shelter	9,000	
	10. Site Purchase or Lease	20,000	
	11. Utilities	338,800	
	a. Causeway, roads		
	b. Water well, tank, main		
	c. Heat and powerplant		
	12. Preflight Blower	142,400	892,200
	D. Observation Stations		9,000
	E. Airplanes		0
	F. Ground Transportation		6,750
	G. Water Transportation		0
	H. Missiles		
	1. 6 F8F-1 models	0	
	2. 12 Gorgon missiles	0	
	3. 36 MX-570 missiles	129,600	
	4. 10 supersonic missiles	450,000	
	5. Booster rockets	21,600	601,200

	I. Instrumentation		
	1. Tracking	275,670	
	2. Missile	45,900	
	3. Ground	36,900	358,470
363	6000-HP Supersonic Tunnel		630,000
414	Contingency Fund		410,000

In allocating the funds to Langley, NACA Headquarters set aside 10 percent of the total amount as a contingency fund and assigned to it Project Number 414.

By this time the decision, as noted later, had been made by the NACA to locate the auxiliary station at Wallops Island, and provision was made in the breakdown of funds for a causeway and bridge between Wallops Island and the mainland, as shown by item 371.C.11a, above. In addition, funds for a preflight blower setup for ramjet testing were also provided, as shown by item 371.C.12.

Langley did not wait for final approval and allotment of funds before starting design activities. The project was considered so urgent that early in February design work began for the facilities associated with the new missile test station as well as for the MX-570 missile. Harold I. Maxwell was asked to organize a Special Projects Group in the Langley West Engineering Section to design the MX-570 missile and its launching equipment. Maxwell had never heard of the MX-570 because of its security classification, but he was told that he could take any men he wanted with him to form the group. The first men he selected were Caldwell C. Johnson, James W. Mayo, and John W. Wilkey, all of whom were to remain involved with missile or space vehicle design for many years under NASA as well as under the NACA.[1] Under the overall direction of Hartley A. Soulé, representing the Research Department, and Ray W. Hooker from the Technical Service Department, practically all design work on missiles and facilities was completed by the time Congress had appropriated the funds.

SELECTION OF SITE

The requirements for location of the Auxiliary Flight Research Station were that it be reasonably close to Langley, that it offer a 50-mile launch range unobstructed by people or shipping, and that it be close to an existing military base for logistic support. The initial proposal of February 1, 1945, was prepared with Cherry Point, North Carolina, in mind because it was understood that the Navy Bureau of Aeronautics contemplated locating a missile range there.

By the end of February, the Bureau of the Budget had given informal approval to the plan for expanded missile testing facilities, and the time had come to recommend a specific location. Detailed studies of possible sites were begun.

Location of the new range at either Cape Lookout, North Carolina, near the Marine Base at Cherry Point, or in the Chincoteague, Virginia, area, near the Naval Auxiliary Air Station (NAAS) appeared equally promising in that both were near existing Navy facilities, both offered a 60-mile flight range along barren coastal islands on which tracking stations could be located, and both were convenient to Langley Field by air. (See figure 3.)

On March 2, 1945, Soulé, Hooker, and Melvin N. Gough, Chief of the Flight Research Division at Langley, flew over Cherry Point and then up the Atlantic cost to the Chincoteague Naval Auxiliary Air Station in a general survey of possible launchsites. The team concluded that the Chincoteague area looked better than Cherry Point from the standpoint of possible interference.

On March 27, Crowley, Soulé, and Hooker of Langley visited Cherry Point with Charles H. Helms of NACA Headquarters, Commander Conlon and Lieutenant Carl From BuAer, and Lt. Commander Herbst from the Naval Aircraft Experimental Station (NAES), Philadelphia, Pennsylvania. Reception of this group by the Marines at Cherry Point was very cool. In fact, the Operations Officer said that he would file an official protest if the NACA planned to locate there. In addition, the barrier islands were rather inaccessible, and the combination of factors practically eliminated Cherry Point as a possible site.

1. Based on the author's discussions with Harold I. Maxwell at Langley on April 29, 1966.

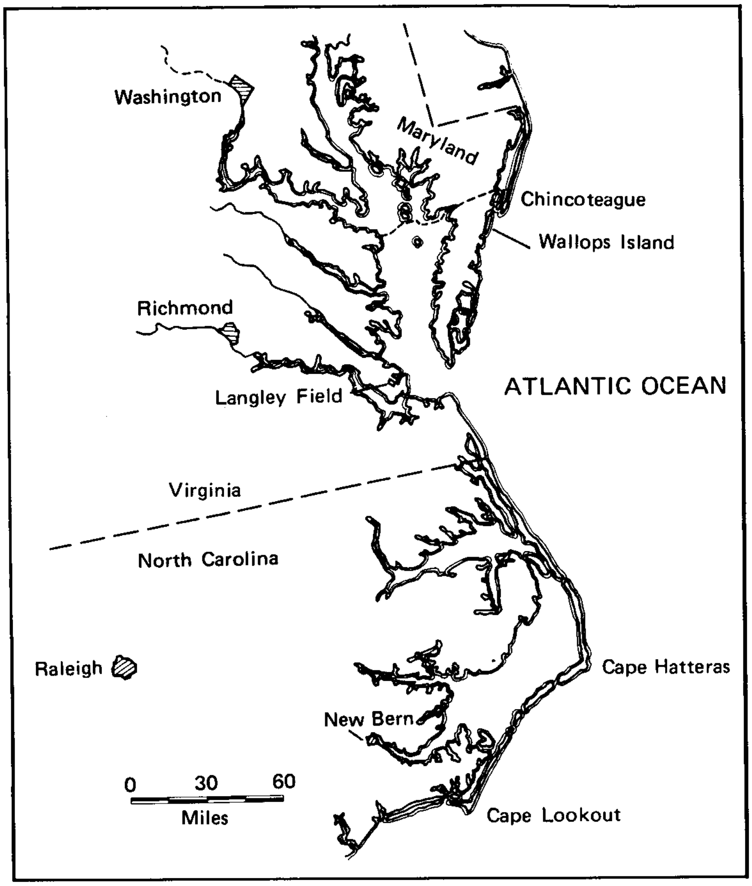


FIGURE 3. Map showing location of Langley Field and Wallops Island, Virginia, and Cape Lookout, North Carolina.

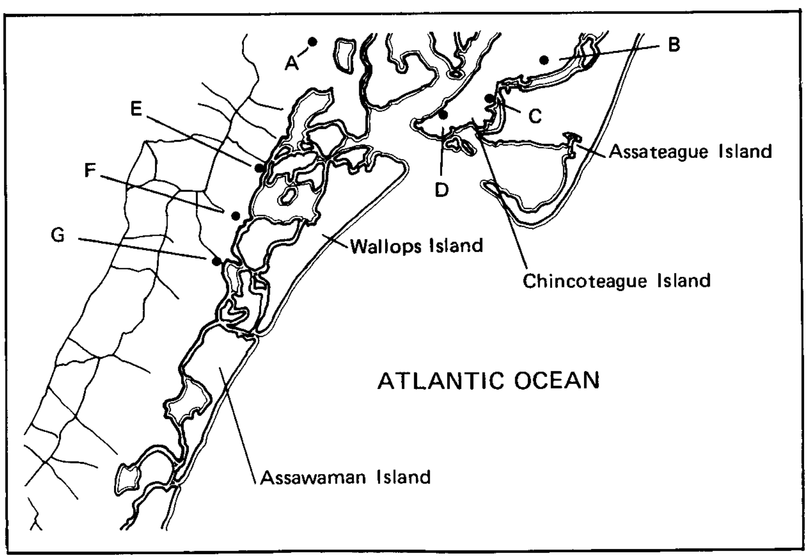


FIGURE 4. Locations considered for proposed launch site in Chincoteague area.

Most of this same group (Crowley, Soulé, Hooker, Helms, Conlon, and Carl) visited Chincoteague on April 4, 1945, to investigate the possibilities for locating a range there. They learned that the Navy BuOrd was establishing a test unit at Chincoteague to handle all naval airplane ordnance problems. The region investigated is shown in figure 4. Four areas were considered for a launchsite: (1) Assateague Island, (2) Chincoteague Island, (3) Wallops Island, and (4) the mainland behind Wallops Island.

Assateague Island was believed to be a good location for a launchsite although it was not visited on this trip. A causeway would be required from Chincoteague to Assateague (at location "C" on figure 4).

The southern tip of Chincoteague Island was considered suitable for a launchsite (location "D"), but had one disadvantage—the flight path of missiles would be near a "resort hotel" close to the Wallops Beach Coast Guard Station. Missiles launched from Assateague, on the other hand, could fly parallel to the coast without passing near the "Wallops Beach Hotel." One objection to both Assateague and Chincoteague was that all missiles would pass over Chincoteague Inlet and cause some interference with local shipping. The "Hotel" referred to in the memorandum was actually the clubhouse of the Wallops Island Association.

Wallops Island was ruled out at this time because of its inaccessibility. A 2-mile causeway would need to be constructed.

A location on the mainland on the Clyde Lange farm was considered a "very likely spot" for a launching site. (location "G" on fig. 4). Power was available and the point was accessible by road. The site overlooked marshland and Wallops Island toward the Atlantic Ocean.

The survey group concluded that "the Chincoteague Area offers very good possibilities for the location of the Auxiliary Flight Test Station." Additional survey activity was recommended.

An official engineering survey party was sent to Chincoteague on April 11, 1945, to make a more detailed study. This party consisted of Hooker, W. C. Roberts, G. S. Brown, and C. R. Dahl of Langley. After a 4-day study, they concluded that a location on Wallops Island would be the best for a launchsite. Selection of either Assateague or Chincoteague Island would mean firings over Chincoteague Inlet and interference with the local fishing fleet operations. Locating the site on the Clyde Lange farm would require condemnation of too much land out to the Atlantic Ocean.

Wallops Island looked the best. It could be reached by boat using existing Coast Guard docks, or by construction of new docks or a causeway. It was recommended, therefore, that the station be located on Wallops Island (ref. 3).

Hooker also prepared a summary of the characteristics of all the sites investigated in both the Cherry Point and Chincoteague areas. In this comparison, Wallops showed up the best on nearly all counts. The recommendation that the launching site be located on Wallops Island was approved by NACA Headquarters.

The overall launching site plan as envisioned on April 19, 1945, is shown in figure 5. The NACA launching site is shown on the southern end of Wallops Island, with observation stations spaced every few miles all along the mainland coast at the edge of the marsh. Flights of up to 60 miles could be made along this network of stations. An unlimited range existed out to sea. The proposed Navy Ordnance range covered the northern end of Wallops Island, but at this time the only occupants of Wallops were the Coast Guard and the Wallops Island Association, a Pennsylvania hunting club that owned the island and maintained a lodge there for the use of its members.

CONTACTS WITH NAVY AT CHINCOTEAGUE

One of the reasons for selecting Wallops Island as the launching site for the Auxiliary Flight Research Station was its proximity to the Chincoteague Naval Auxiliary Air Station. Experience at the Langley Laboratory, which shared Langley Field with the Army Air Forces, had shown that, from a logistic standpoint, being on a military base offered a considerable number of advantages.

Early contacts with the Navy at Chincoteague indicated that operations at the NAAS were to be expanded from those of a simple training base to include activities of a naval aviation ordnance test facility. Plans for the facility were not complete, but they involved construction of additional facilities at the southern edge of the Naval Station, from which guns would be fired and perhaps missiles would be launched out to sea across the northern end of Wallops Island.

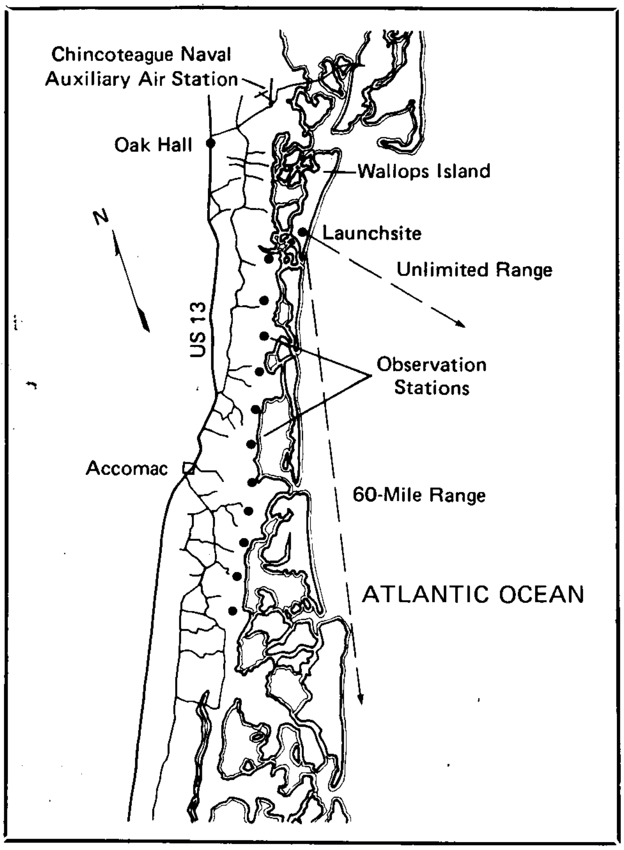


FIGURE 5. Proposed launchsite at Wallops Island, Virginia.

In these early contacts, the NACA representatives were informed that the Navy planned to condemn and purchase Wallops Island in its entirety and would not object to the NACA's establishing operations on the southern end of the island. The Navy had no buildings at Chincoteague which the NACA could occupy, but they had no objection to the NACA's constructing whatever was needed. Utilities were available on the base, airplane flight operations could be arranged for, and the use of certain Navy equipment and material could be arranged.

ROCKET MOTOR PROCUREMENT

The procurement of rocket motors for the initial operations at Wallops generally followed the recommendations of Dr. K. F. Rubert, which were based on his survey in December 1944. He concluded that the Aerojet acid-aniline liquid-rocket motor was hazardous and difficult to operate; the Aerojet solid rockets presented storage problems and, in addition, were not available in the desired sizes. The British Cordite rocket motor was recommended, although availability was uncertain. The most favored rocket motor was the Monsanto solid-propellant series because of "ease and safety of handling, and simplicity of design for special needs" (refs. 4 and 5). All rocket motors were military material and were supplied to the NACA from military supplies, at no cost.

The initial missile program for Wallops included 12 Gorgons, 36 Tiamats, 10 supersonic missiles, and a ramjet test vehicle. The Gorgon missiles were to be supplied by the Navy with their liquid-fuel rocket propulsion system. The Gorgon was an air-to-air missile, and all tests by the Navy had been with air launchings. The NACA planned to launch the Gorgon from the ground, however, so a boost system would be required. Early planning envisioned use of a dolly and the planned 400-foot launching ramp. Consequently, no rockets were procured for the missile at this time.

The Tiamat missiles under construction in the Langley shops had been changed from the original ½-scale models to full size. Consequently the Monsanto WF-1 solid-rocket motor planned for the actual missile was scheduled for use in the Wallops firings. This rocket was produced by the Monsanto Chemical Corporation plant in Dayton, Ohio, and the Army Air Forces were asked to provide it. To suit the Tiamat, the basic motor required one modification—addition of a blast tube to the nozzle so that the motor could be located in the missile at its center of gravity. For a booster rocket, Langley had designated a cluster of six British Cordite solid-rocket motors. The Army was asked to supply a quantity of these. After the first launching of the Tiamat, the booster was changed to a single rocket motor system incorporating the Monsanto ACL-1 solid motor, which the Army also provided.

The Navy provided a quantity of standard 3.25-inch solid-fuel aircraft rockets to be used for the training of launching and tracking crews.

Procurement of special rocket motors for the supersonic missiles was not made at this early stage because the missile itself had not been designed. As it turned out, the motors selected were the 5-inch British Cordite motors already available for the Tiamat. It was only necessary to ask the Army to supply additional rocket motors of this type.

According to an official inventory on December 10, 1945, the following rocket motors were available at Wallops at the end of 1945: 24 Navy 3.25-inch motors, 204 British Cordites, 16 Monsanto WF-1 motors, and 20 Monsanto ACL-1 motors. The basic characteristics of these and all other motors used during the first 15 years of operation at Wallops are given in Appendix A.

References

1. Hearings before Senate Appropriations Subcommittee, NACA First Deficiency Appropriations Bill, Mar. 16, 1945.
2. United States Statute 58–374.
3. Hooker, Ray W., Memorandum to Engineer-in-Charge, Apr. 26, 1945.
4. Rubert, K. F., NACA Langley, Memorandum to Chief of Research, Dec. 19, 1944, regarding trip to Wright Field, Dec. 12–15, 1944, for the purpose of discussing availability of various types of rockets.
5. Rubert, K. F., NACA Langley, Memorandum to Chief of Research, Jan. 9, 1945, with technical notes on visit to Plant No. 2, Monsanto Chemical Company, Dayton, Ohio, Dec. 13, 1944.

CHAPTER 3

OPERATIONS WITH TEMPORARY FACILITIES: 1945–1946

With the appropriation of funds by Congress on April 25, 1945, for the construction of an auxiliary flight test station, and the approval by NACA Headquarters of Langley's recommendation to locate such a station on Wallops Island in the Chincoteague area, the time had come to move forward with acquisition of land and construction of facilities. The project was given highest priority at Langley by John W. Crowley, Acting Engineer-in-Charge. In early May, Crowley decided to establish a separate unit in the Research Department to handle the project, reporting directly to him as Chief of that department. On May 7, 1945, Crowley relieved Robert R. Gilruth of his duties as Assistant Chief of the Flight Research Division and transferred him to the Office of the Chief of the Research Department "to take charge of the Missiles Research Station and to coordinate the Langley Laboratory's missiles research."

Because of the urgency of the project, every effort was made to begin flight operations as soon as possible. Although the overall plan envisioned the construction of permanent facilities at Wallops Island and at Langley, the program could not wait for them to be completed before operations began. The work at Langley had already begun in existing facilities and could continue until the new facilities could be completed. On Wallops, however, there was nothing that could be used. The only thing to do was to rush the construction of temporary facilities to serve until permanent quarters could be built. The temporary facilities were completed in time to launch the first rocket on June 27, 1945, just 2 months after President Roosevelt had signed the bill authorizing the test station. Operations with these temporary facilities continued through 1946, the period covered by this chapter.

ACQUISITION OF REAL ESTATE AND SEA RANGE

The Government could construct temporary facilities on leased land, but permanent facilities could be built only on land owned by the Government. The land used by the NACA in the early days at Wallops was of both types. Sites for permanent facilities were purchased, while additional areas were leased. Although some land was obtained by direct negotiation, the fastest procedure for acquiring land was by condemnation. Possession could be taken by the Government the day a condemnation order was issued by a Federal Court.

Congress had placed a limitation of 100 acres on the amount of land to be purchased. This seemed quite sufficient at the time of the hearings on the appropriation bill because it had been planned originally to erect most of the larger buildings on a military base. The new land was to be used principally for a launch pad and for observation stations. With the decision to locate the station on Wallops Island, however, it was evident to Ray W. Hooker, Construction Coordinator, that the 100 acres would have to be distributed with care. Permanent facilities were to be built at the Chincoteague NAAS, at a boat dock area on the mainland across the marsh from Wallops, and on Wallops itself. On Wallops, a boat dock area was required, as well as a main facilities area, a road connecting the two, and a strip of land over which it was planned to build a causeway and bridge, and to run power and telephone lines. Because no permanent facilities were involved at the mainland observation stations and the target area for the freely falling body program, the required land was to be obtained by lease.

Real estate was needed, therefore, for the following list of facilities:

1. Receiving building at Chincoteague NAAS
2. Tracking stations on the mainland
3. Mainland boat dock
4. Target area on Assawaman Island
5. Launching area on Wallops Island

The general area of Wallops Island as it existed in July 1945 is shown in figure 6. At the top of the map may be seen the runways of the Chincoteague NAAS and the proposed location of the NACA receiving building, identified as NACA Bldg. The air station was reached by State Road (SR) 175, which ran into U.S. Highway 13 a short distance north of Oak Hall. Beyond the air station, SR 175 continued to the town of Chincoteague on Chincoteague Island, with a causeway over the water and marsh areas. On the Pennsylvania Railroad near Oak Hall is shown the Le Cato station, which was a passenger stop in 1945. Freight and express were shipped through the station at Hallwood, 2 miles to the south. State Road 175 midway between the air station and US. 13 crosses a sandy clay local road called Seaside Road, which was the normal route from NAAS to Wallops Island for NACA people. Approximately 4 miles south of this intersection is shown the village of Assawaman and a road leading into a "proposed

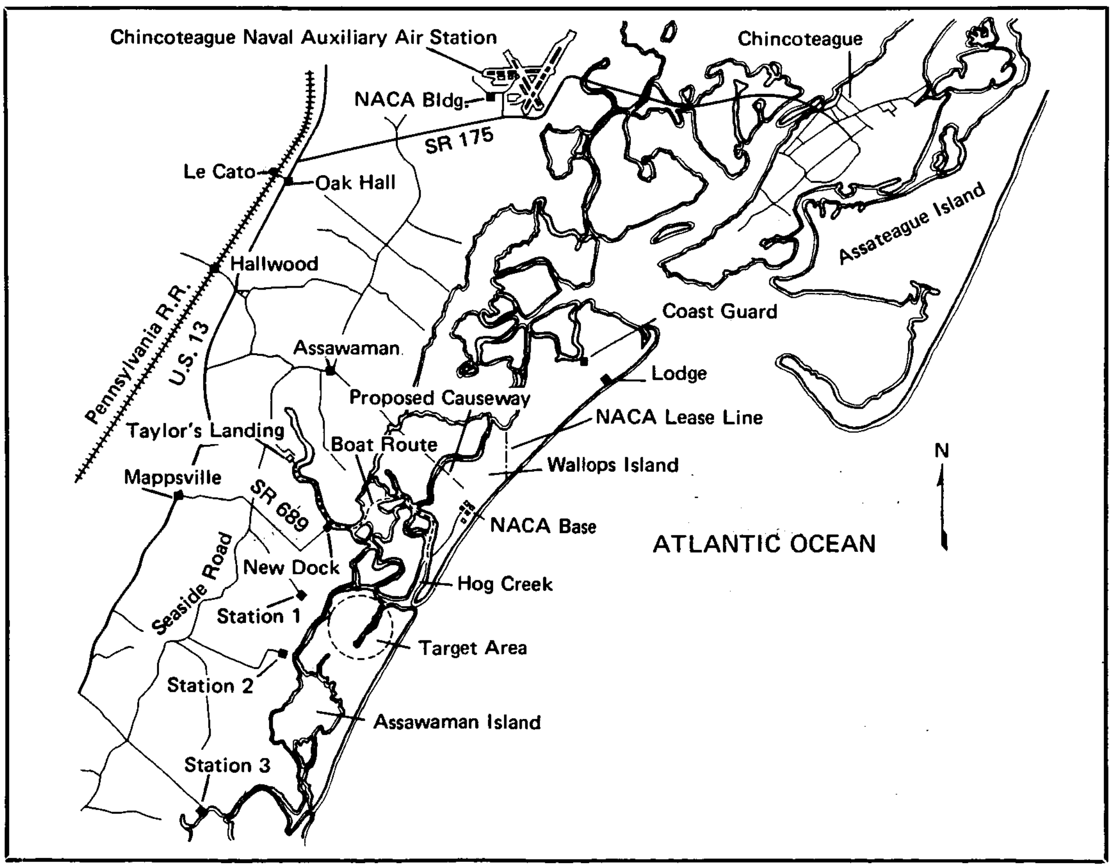


FIGURE 6. Map giving general information on Wallops Island and vicinity, 1945.

causeway." Although this causeway was proposed many times, it was not approved and constructed until the NACA became NASA in 1958. It is of interest here that this is the location actually used in 1959.

Continuing along Seaside Road another mile beyond Assawaman is a road leading to Taylor's Landing, an existing dock used by Wallops-bound NACA boats until the NACA permanent dock was built. This latter dock, located approximately 1 mile downstream from Taylor's Landing, is identified as "New Dock" and is connected with Seaside Road and U.S. 13 at Mappsville via State Road 689. The location of three tracking stations on the mainland (Stations 1, 2, and 3) may be seen at the edge of the marsh. Each is connected to Seaside Road by a local road.

The 1-mile circle shown seaward from Station 1 at the north end of Assawaman Island, and identified as "Target Area," was used as a target for dropping bombs and other bodies from airplanes at high altitudes.

From Taylor's Landing, the boat route is identified as it meanders along the waterways to the NACA dock on Hog Creek. A temporary sandy clay road is shown on Wallops Island from the dock to the NACA base.

On May 21, 1945, the Navy was asked to give permission for construction of a receiving building on the Chincoteague Naval Base. Permission, revocable at will, was granted by the Navy Department on July 12, 1945.[1] A building 50 feet by 100 feet was envisioned, to be erected on 2.64 acres of land. The permit stated further that the NACA should make arrangements to pay for any utilities furnished by the Navy. As it turned out, the only use made of this permit was to erect a temporary shed to serve as an office for the Langley Resident Engineer. It was found unnecessary to locate a receiving building at the base; shipments were made directly to Wallops.

Land for a permanent boat dock on the mainland was obtained by direct purchase. Although Taylor's Landing filled a need for temporary use, it was too small for the expected activities. Rather

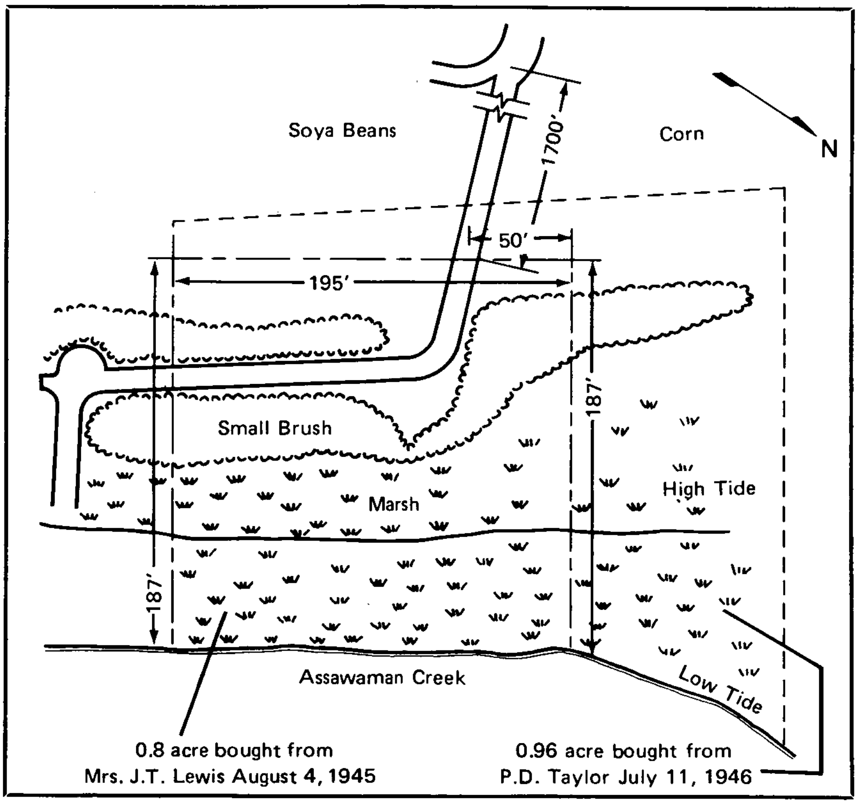


FIGURE 7. Sketch of Mainland Dock site.

1. Letter from Navy Bureau of Yards and Docks, Real Estate Division, to the NACA July 12, 1945, with regard to land allotment at Chincoteague NAAS for auxiliary flight station receiving building.

than to enlarge this dock, Langley elected to construct a completely new dock closer to Wallops, at a point where SR 689 touched Assawaman Creek. An option to buy 0.8 acre of land for this purpose was signed with Mrs. J. T. Lewis on August 4, 1945, and on October 13, 1945, the land was deeded to the Government for $100. This plot of land is shown in figure 7.

The road leading to the dock area was in poor condition. On June 26, 1945, the NACA asked Navy BuAer for assistance in submitting a request to the Government to improve the road. The request resulted in a letter from Secretary of the Navy James Forrestal on September 18, 1945, certifying the need for such improvement. Eventually the road was graded and given an asphalt topping.

Because Langley found that there was insufficient space at the Mainland Dock site, NACA Headquarters was asked, in May 1946, to purchase additional land adjoining the site. This additional parcel is also shown in figure 7. The land at that time belonged to Pierce B. Taylor, who had acquired it from Mrs. J. T. Lewis. Taylor wanted $200 for the additional area, approximately the same size as that purchased from Mrs. Lewis for $100. Taylor's offer was refused, condemnation proceedings were instituted, and the land was taken on July 11, 1946. After much discussion and negotiating, the price of $200 was accepted and the case was settled.

Land for observation stations was acquired by lease. As shown on figure 5, early plans envisioned the need for perhaps a dozen such stations, so that guided missiles such as the Tiamat might be tracked as they were flown down the coast from Wallops. The requirements for the stations were that they be located at intervals of 2 to 5 miles parallel to the line of flight of the missiles, and that they have line-of-sight vision to the launching site. Each station was to have approximately one-half acre of land and was to be accessible by road. Locations for the first four stations were agreed upon, and leases were obtained for the first three. Actually, only one mainland station was used—Station 2 as shown in figure 6. Hooker, Buckley, Krieger, and Brown inspected the sites for four stations; and a few days later Brown negotiated a lease for Station 1 with C. W. Sandifer, for Station 2 with John Northam, and for Station 3 with a Miss Baker.[2] The site for Station 2 is shown in detail in figure 8.

The target circle one mile in diameter for bomb dropping was laid out on land leased from H. E. Kelly for $100 per year. Brown arranged for this lease on June 15, 1945. The target circle was identified by simple piling, on which squares of plywood were attached. This target was used in the early period at Wallops when the freely falling bodies were dropped from airplanes at high altitude under the direction of a bombardier using a bombsight. Later, it was found that the airplane could be directed with sufficient accuracy from the ground with the assistance of a radar plot board. The target area then was abandoned.

The acquisition of land on Wallops Island itself was complicated by the fact that the Navy's Bureau of Ordnance stated repeatedly that it was going to purchase the entire island and would allow the NACA to use the lower half. On May 3, 1945, Hooker, accompanied by J. J. Kelly, Jr., of NACA Headquarters, visited the Real Estate Division of the Navy Bureau of Yards and Docks to ascertain when the Navy planned to acquire Wallops Island. The Navy had taken no action and would not predict when it would. Consequently, Hooker and Kelly decided that the NACA should take independent action to obtain land, at least for temporary facilities. Negotiations were conducted with Frank Hunter, President of the Wallops Island Association, Norristown, Pennsylvania, which owned the island. Plans were made to lease the lower 1,000 acres so that temporary construction could be started.

A lease was signed on May 11, 1945, for $2,000 per year for the 1,000 acres. The lease read: "The Lessor hereby leases to the Government the following described premises, viz: that part of Wallops Island, Accomack County, Virginia, lying south and west of a line running due north and south from Bogues Bay on the north to the eastern shore of Wallops Island on the south, at 75°28′15″ west longitude, which tract is estimated to contain one thousand (1000) acres, more or less, Reserving to the Lessor, however, (1) the right to use or lease for the use of others the grazing rights on said tract to such an extent as will not interfere with the use of said tract by the Government: and (2) the right of Lessor, its stockholders, and guests to use and enjoy the beach along the eastern shore of said tract, but only when, and to the extent that, such use and enjoyment will not interfere with the use of said tract by the Government."

Wallops Island was described in deed records as being bound by "Chincoteague Inlet on the north,

2. From personal diary of G. S. Brown, in historical files at Wallops Station.

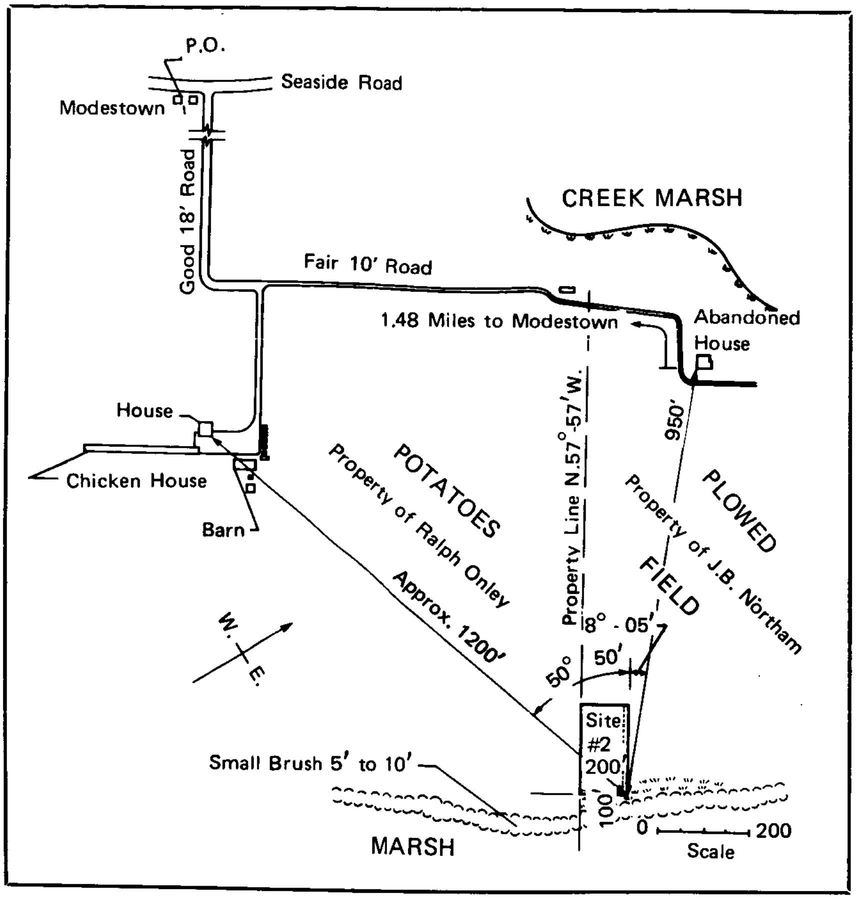


FIGURE 8. Sketch showing location of Tracking Station No. 2 on mainland.

Assawaman Inlet on the south, Atlantic Ocean on the east, and Assawaman Narrows, Cat Creek, Bogues Bay, and Island Narrows on the west." Wallops Island was originally granted to John Wallop by a Crown Patent from King Charles II of England in 1672. It was described at that time as "Kegotank Island, alias Accocomson Island" (ref. 1). Ownership changed over the years and the island remained uninhabited until 1883, when the Government acquired land for a Coast Guard Station from Thomas W. Taylor and Orrie A. Brown, who had acquired the island by a land warrant from the Commonwealth of Virginia in 1876. In 1889, the Wallops Island Association acquired the island and constructed a clubhouse on the upper beach near the Coast Guard Station. These were the only buildings on the island when the NACA moved there. It is interesting to note that the first transportation for association members was a sailboat between Chincoteague and the island and an oxcart on the island itself.[3]

The lease of 1,000 acres on Wallops Island was sufficient for the early temporary construction but would not suffice for permanent construction. On July 10, 1945, Hooker and Kelly again visited the Navy Real Estate Division and were informed that the Navy expected to acquire the whole of the island by July 25, 1945. The Navy suggested that the NACA request a land allotment for the southern end of Wallops. This was done on August 6, 1945. The allotment was never made, however, because the plan for the Navy to purchase the entire island fell through. The Navy's plan to locate an ordnance range at Inyokern, California, and a missile range at Point Mugu, California, lowered its interest in Wallops.

Hooker anticipated that the Navy might not acquire the island and had a map prepared showing which portions of the leased area on the island would contain permanent structures and would, therefore, have to be purchased. By design, the total area fell within the 100 acres authorized by Congress. This map is shown as figure 9. The map also shows the Wallops Island Grid Survey System established

3. Letter from Joseph K. Fornance, attorney, Norristown, Pennsylvania, to the Commandant, Wallops Island, Virginia, Feb. 20, 1962, regarding old papers of the Wallops Island Association. An enclosure with the letter was dated June 22, 1937.

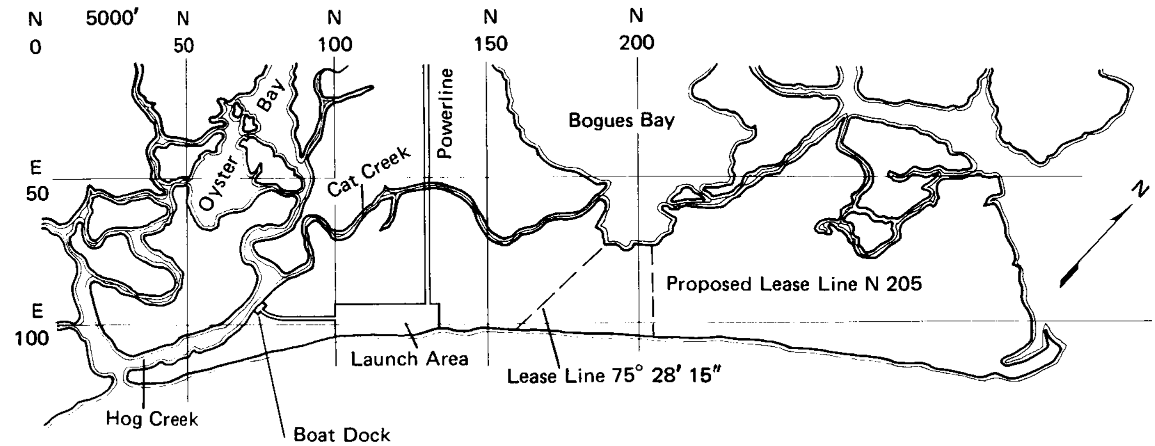


FIGURE 9. Map of Wallops Island showing grid survey system and proposed leasing of property, as of August 1945.

by Langley. In this arbitrary grid system, one unit equaled 100 feet. In preparing the map, Hooker had asked that the launching area be limited to 85 acres so that land for a causeway and powerline could be purchased later.

The various pieces of land composing the 100 acres allowed were as follows:

Mainland Dock (two parcels)		1.76 acres
Wallops Island		
Island Dock	1.50	
Road	4.95	
Launching Area	78.42	84.87
Powerline		
Wallops Association	4.87	
S. A. Taylor	5.25	
Frank Chesser	2.20	12.32
	Total	98.95 acres

On August 9, 1945, the NACA realized it could wait no longer for the Navy to acquire Wallops Island, because bids for permanent construction on the island were scheduled to be opened on August 14. The NACA therefore proceeded with condemnation of 84.87 acres on Wallops, and the Government took possession on September 18, 1945. Full title was taken on July 29, 1947, after payment of \$1.00 to the Wallops Island Association. In actual operations at Wallops Island, no distinction was made between leased and owned property. Engineering designers, however, had to be careful not to locate any permanent facilities outside the owned area.

Figure 9 identifies the leased area as being bound by NACA Grid North 205. This line is 84.87 acres north of the original lease line at 75°28′15″ west longitude. Selection of the line was an attempt to increase the NACA total holdings in recognition of the purchase of the 84.87 acres within the original leased area. This grid boundary of North 205 was never officially accepted, however, and 75°28′15″ remained the "Mason and Dixon" line until the NACA acquired the island in 1949.

Once the real estate for land operations had been acquired, attention turned to the question of the sea range. In 1945, the NACA was naive enough to think that having a launch base on the Atlantic Ocean automatically gave it an "unlimited range." While this eventually became true in February 1961, under NASA, with the launching of a satellite from Wallops by the Scout vehicle, there were many interferences and "roadblocks" in the path.

The Atlantic Ocean is an open range for ships of the sea, and the air above it is open for the airlines of the world. This is true in theory, but in practice the airlines operate over designated airways and enter the United States along designated corridors under the control of the Civil Aeronautics Administration. Between these corridors, the U.S. Navy has designated training areas for its air and water vehicles and expects the commercial vessels to recognize such areas at certain specified times. The NACA recognized the Navy's interest and made arrangements with them for use of any such areas.

In the early days of Wallops operation, the range of the rockets was so short that interference was no problem. The ocean shipping lanes were far enough out to sea to be beyond range. If local fishing vessels appeared off the island, firings were delayed until the area was clear.

With regard to airplanes, it was general policy to designate "danger areas" around rocket and ordnance testing ranges. In November 1945, Langley asked NACA Headquarters to have a large area southeastward from Wallops a distance of 15 miles declared a "danger area."[4] The reason given was that "miscellaneous aircraft have made a nuisance of themselves by circling the area because of curiosity and because of ignorance of the nature of the operations being carried on in the vicinity." The NACA, in turn, on November 28, 1945, recommended to the Chief of Naval Operations that such a danger area be established. On February 6, 1946, the Interdepartmental Air Traffic Control Board approved a danger area 3 miles in radius, to be centered off the lower end of Wallops.[5] The Chief of Naval Operations observed that this danger area in addition to the "offshore danger area previously established for NAS Patuxent and NAAS Chincoteague should give adequate protection to the activities being carried on by the NACA." Although this was a much smaller danger area than was requested, it did provide the NACA with a definite sea range over which the Navy recognized NACA control.

MANAGEMENT ORGANIZATION AND PLAN FOR PROJECT OPERATION

On May 7, 1945, Robert R. Gilruth became the first employee and head of the Auxiliary Flight Research Station (AFRS). As mentioned at the beginning of this chapter, John W. Crowley, Chief of Research at Langley, transferred Gilruth from the Flight Research Division to take charge of the "Missiles Research Station," a unit reporting directly to Crowley.[6]

At first, Crowley thought that the guided missile tests could be conducted by an existing research division just as the freely falling body program was being carried out by the Flight Research Division. In May, however, he decided to establish a completely new unit to conduct and coordinate all missile research at Langley. Langley had received the appropriation for the new missile station and was committed to constructing rather extensive facilities and embarking upon a new missile research program. Soulé, Hooker, and Jones had paved the way with preliminary planning; it was now up to Gilruth to organize a group to take over responsibility for construction and operation of the new station.

In selecting Gilruth for this assignment, Crowley picked a man whose career he had followed closely from the time Gilruth reported for work in the Flight Research Division on January 4, 1937, under Crowley, who was at that time Chief of the division. Gilruth had just received a master's degree in aeronautical engineering from the University of Minnesota. During the war years, he earned an international reputation as an expert in the flying and handling qualities of airplanes, and his NACA Technical Report 755 entitled *Requirements for Satisfactory Flying Qualities of Airplanes* was a handbook in this field. Practically all military airplanes went through special handling quality flight tests at Langley during this period. Gilruth recognized the need for high-speed data and the inadequacy of existing wind tunnels and airplanes for gathering data in the transonic speed range. He was associated with the freely falling body program to obtain such data, and proposed the "wing-flow" technique in 1944. Although Gilruth had not been involved directly with the guided missile program at Langley, Crowley

4. Letter from H. J. E. Reid, Langley, to the NACA, November 13, 1945, regarding establishment of a danger area in the vicinity of Wallops Island.
5. Letter from Chief of Naval Operations to the NACA, February 20, 1946, concerning establishment of a danger area in the vicinity of Wallops Island.
6. This is the only reference to the station by this name. In earlier and later papers it was called the Auxiliary Flight Research Station, (AFRS).

felt that he had the practical ability to operate the new missile station and to get the most out of this new technique in aeronautical research.

On May 10, 1945, Ray W. Hooker became the second man to be assigned to the Auxiliary Flight Research Station, leaving his position as Assistant Chief of the Engineering Services Division at Langley. The official memorandum assigning him to AFRS was dated May 29, 1945. Hooker had come to Langley in 1930 after obtaining a degree in aeronautical engineering from Purdue University. He was engaged in wind-tunnel research for a number of years before he became involved with the engineering design of research facilities. He remained Gilruth's number two man until early in 1948.

When Gilruth took over the AFRS, he was committed to a flight program consisting of the subsonic Tiamat and Gorgon missiles, a supersonic missile, an unspecified ramjet flight program, a series of F8F-1 drop models, and a general research program not yet implemented (ref. 2). In his new position he had to build an organization to handle the program and to plan for future growth.

When the decision was made to establish a special unit at Langley to be responsible for all missile research, it was immediately recognized that the original plan for construction would have to be modified to include a "home base" for the people assigned to AFRS at Langley. Approval was obtained for a permanent laboratory to be built as an addition to the Missile Construction Shop (item 371-A-2). The request for approval for this "missile research laboratory" contained a flow diagram which showed quite clearly the plan for handling the various phases in a missile test program, and the types of assistance required.

The missile laboratory, essentially the Langley portion of AFRS, was responsible for (1) coordination of missile research, (2) preparation of missiles for flight tests, and (3) engineering and analysis. This latter item also included post-flight analysis and reporting. Responsibility for the detail design of all missiles and facilities was given to the Engineering Services Division. The Instrument Research Division (IRD) was given responsibility for all instrument selection, development, construction, and installation. Wind tunnel divisions retained responsibility for any tests of missiles in their facilities. All the Langley shops were used in construction of the missiles. The AFRS retained responsibility for staffing and operating the launch base at Wallops and, of course, was responsible for the research experiment itself from original proposal to final report. The AFRS also retained direct responsibility for all matters pertaining to rocket motors and pyrotechnic devices and the development of new techniques.

Gilruth was required to build up a staff of research engineers at AFRS, Langley, and an operations crew at AFRS, Wallops Island. Fortunately, at Langley he was able to obtain, by transfer from other research divisions, a group of experienced research engineers which he augmented by hiring new engineers. By the end of 1946, there were 40 research engineers at AFRS, over half of whom had had prior research experience at Langley.

At Wallops Island, men were hired as needed. The first employee assigned there was Germain S. Brown, who was sent to the Chincoteague area on May 24, 1945, from Langley Engineering Services Division, to serve as Resident Engineer in charge of construction and operations. In this assignment, Brown remained on the rolls of the Langley Engineering Services Division and was responsible to Gilruth in a service capacity. This caused no difficulty inasmuch as Brown still received directives from Hooker, with whom he had been working for some time. At first, Brown had an office on the Chincoteague Naval Base; but on July 18, 1945, he moved to an improvised office at Taylor's Landing.

On July 3, 1945, W. H. Reiser visited the Wallops area and helped to establish living quarters and food service for the men. As Head of the Langley Exchange, Reiser established Branch No. 1 at Wallops and appointed Brown head of this NACA Exchange Branch, with authority to sign checks at the Bank of Chincoteague and buy food locally for use on Wallops. The exchange was authorized to run the living quarters and restaurant from funds obtained from the users. Brown was authorized to hire such operations people as boat and crane operators, truck drivers, guards, cooks, and maintenance men. These men were put on the rolls of AFRS. The number of such people increased at a regular rate until, by the end of 1946, there were 65 men on the rolls at Wallops.

During the first year of growth at Wallops Island, some of the responsibilities were delegated to personnel under Brown. An early assignment by Gilruth was the appointment, on July 31, 1945, of L. K. Kellam as Property Clerk with responsibility for all NACA property in the Chincoteague area.

In February 1946, Eugene M. Reading was transferred from the NACA Headquarters to Wallops. On February 14, 1946, he was authorized to administer the oath of office to new employees; and on March 6, 1946, he relieved L. K. Kellam as Property Clerk. On April 12, 1946, he was appointed Safety Coordinator for Wallops, and, on April 18, was made supervisor of the NACA Exchange Branch No. 1. These several special assignments were in addition to his job as Administrative Officer.

Through 1946, large numbers of men from Langley accompanied each missile to Wallops for the flight launching. In the early days, Wallops people provided only supporting services; but as time went on, more and more of the operations connected with flight tests were turned over to permanent Wallops crews. This point will be discussed in more detail later.

Until the middle of 1946, AFRS remained a unit of the Research Department. On June 10, 1946, AFRS was converted into a division of the Research Department and was entitled Pilotless Aircraft Research Division. Gilruth was designated Division Chief, and Hooker, Assistant Division Chief. The name "Pilotless Aircraft" stemmed from use of this name by the Navy BuAer and the Army Air Forces for all types of guided missiles.[7] Almost immediately the division was called "PARD," an acronym that became familiar to aeronautical people throughout the nation.

On August 11, 1946, a formal organization within PARD was authorized, as follows:

Division Chief	Robert R. Gilruth
Assistant Division Chief	Ray W. Hooker
Division Engineer	William J. O'Sullivan, Jr.
Head, Stability and Control Section	Marvin Pitkin
Head, General Aerodynamics Section	Paul E. Purser
Head, Propulsion Aerodynamics Section	Paul R. Hill
Head, Operations Section	Charles A. Hulcher
Superintendent, Pilotless Aircraft Research Station	Clarence O. Green

Wallops Island was placed under the Operations Section and was named the Pilotless Aircraft Research Station (PARS). Clarence O. Green was named Station Superintendent, reporting to Hulcher. Although PARD was quickly accepted as the designation of the overall organization, PARS was never accepted by the employees—the station was simply called "Wallops."

With the appointment of Green as Superintendent of Wallops, Brown was able to devote full time to the construction of facilities. In fact, Brown turned over operation details to Green as soon as he arrived at Wallops, without waiting for the formal assignment as Superintendent.

Green was transferred from the Langley Technical Service Department to Wallops on February 25, 1946, and was placed on the rolls of AFRS. He had had many years of experience at Langley in wood model building, and the Langley Technical Service Department wanted someone with such Langley experience to coordinate the operations at Wallops which, at this time, were mostly of a technical service nature. On October 2, 1946, Harry C. Shoaf was transferred from Langley to Wallops as Assistant to Green and Head of Engineering Operations. Reading continued as Administrative Head.

The plan for project operation consisted of construction, instrumentation, and preparation at Langley, followed by transportation to Wallops by either air or truck. The plan contemplated a receiving building at Chincoteague, which was never constructed. Instead, air shipments were transferred to a truck at the Naval Station and were transported to the Assembly Building at Wallops according to the same procedure used for direct truck transport. This, of course, involved water transport from the mainland to the Island.

At Wallops, the operation plan called for checkout of the instrumentation, installation of any internal rocket motors, and mating with the booster rocket for launching. It also called for tests in the "Preflight Burner" as needed. Later this was to be called the "Preflight Jet."

The method of operation for PARD was intended to use the talents of each individual for maximum productivity. Assigning the design responsibility and instrument responsibility to separate

7. Letter from Major D. R. Eastman, Acting ATSC Liaison Officer, to Engineer-in-Charge, Langley Laboratory, November 30, 1945, regarding pilotless aircraft nomenclature.

divisions at Langley gave the engineers at PARD nearly full time to devote to their aeronautical research specialty. The research engineers at PARD were assigned to sections according to their area of specialization. Some men specialized in flutter, some in aerodynamic control systems, and others in propulsion aerodynamics or performance. Much of their time was spent in proposing and preparing for new projects, as well as in analyzing and reporting the results of flight tests.

Separation of the engineering aspects of the overall job led to development of specialists in missile design. The Special Projects Group in the Engineering Services Division, which started with design of the Tiamat missile under Harold I. Maxwell, later became the Pilotless Aircraft Group. In November 1951, it became the Dynamic Model Engineering Section (DMES), headed by Caldwell C. Johnson. This section kept design responsibility throughout the years, and even 20 years later, some of the original members were still so engaged. Specialization in the design aspects paid big dividends in reliability, efficiency, and effectiveness. Many original ideas connected with missile and launch vehicle design came from this group.

The second area of specialization was that of instrumentation. PARD assigned complete responsibility for all instruments to the Langley Instrument Research Division (IRD) headed by E. C. Buckley. A key group in the division was the Radio Control and Telemetering Section, headed first by M. J. Stoller and later by C. A. Taylor. Responsibility included not only procurement, construction, installation, and operation of all instrumentation (e.g., all radars, telemeters, radios, radiosondes, and spinsondes) but also development of special sensors and other components as required. The IRD was responsible for the reliability and accuracy of all instruments. They conducted environmental testing and calibration, and specified all components to be used. This overall responsibility produced a continuity of experience by a specialized group which made possible, for the first time, a remote system of flight data acquisition having an accuracy consistent with research data requirements.

The Langley shops, in which the missiles were constructed, were likewise given freedom to develop new processes of fabrication in cooperation with the engineering group. They pioneered in such techniques as accurate spinning and forming of thin-skin magnesium bodies, welding of magnesium, high-strength gluing of metal sheets to wood, and, later on, casting of various plastic shapes, and extensive fiberglass construction.

TRANSFER OF EQUIPMENT FROM MILITARY SERVICES

Establishment of a missile research station had the full support of the Army and Navy and the initial program included specific missiles under development by both services. In accordance with long-standing procedures, both the Army and Navy were expected to provide much of the equipment required in the program. In fact, the Navy request letter of December 19, 1944, stated "The Bureau is prepared to underwrite the design and procurement of any special models of airplanes or rocket units that may be required in this program." Accordingly, the NACA made every attempt to fill its needs for equipment from the military supply.

When the AFRS was established, much of the equipment was available only from the military. This included such items as radars, airplanes, trucks, and boats. Before the station was completed, the war was over and many items of equipment became available from military surplus—a situation on which the NACA capitalized.

An SCR-584 radar had already been obtained for use in the freely falling body program and an M-2 optical sight and M-9 computer and plot board were added. This equipment was moved to Wallops in late June 1945, for use in the rocket program as well. In anticipation of the need for several tracking stations, requests were made to the Navy and the Army Signal Corps for additional SCR-584 units.

Two LCM-3 boats, one of which is shown in figure 10, were obtained on loan from the Navy in June 1945 for transporting equipment between Wallops Island and the mainland. They remained in regular service until replaced by a ferry some years later. Two 37-foot plane rearming barges were also obtained in a similar manner and were converted for personnel transport by the addition of a cabin. One of these is shown in figure 11. Two Navy 26-foot plane personnel boats were also obtained on loan for

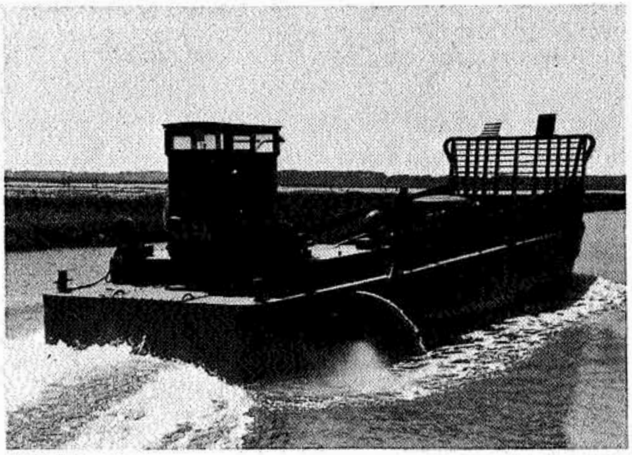


FIGURE 10. Navy LCM–3 boat transporting a truck along the dredged channel from Wallops Island to the mainland.

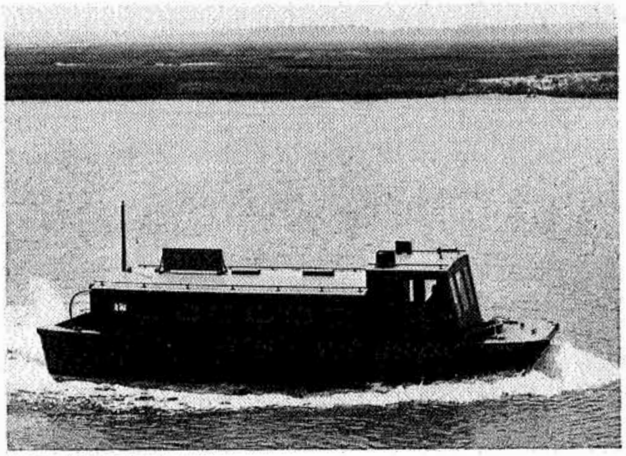


FIGURE 11. Wallops 37-foot personnel boat converted from a Navy plane rearming barge. Craft is shown in the Wallops channel.

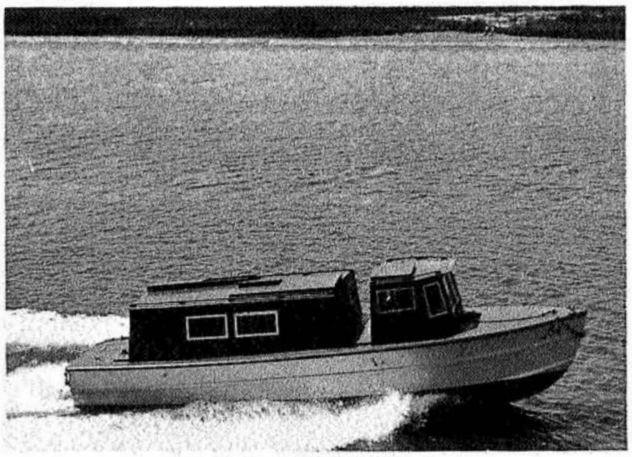


FIGURE 12. Navy 26-foot plane personnel boat shown operating in the Wallops-Island-to-mainland waterway. Craft was fitted with cabins for passengers and crew.

FIGURE 13. Grumman Goose JRF–5 amphibian used for air transportation between Langley and Wallops.

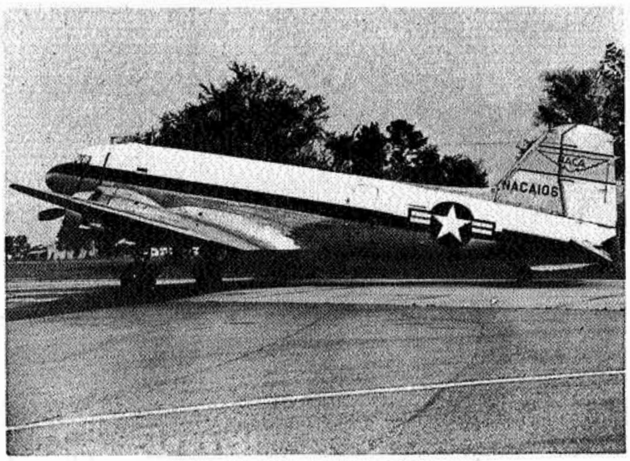


FIGURE 14. Douglas C–47 transport used for carrying personnel between Langley and Wallops.

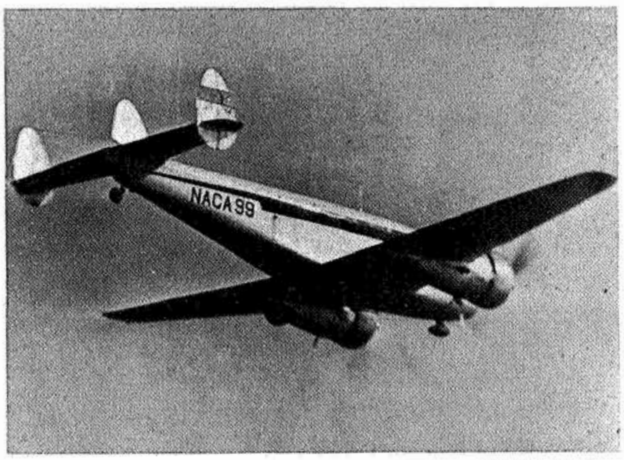


FIGURE 15. Lockheed 12 airplane available for use between Langley and Wallops.

faster transportation of a few people or a small cargo. As obtained, these were open boats, but one of them was fitted with two separate cabins, one for passengers and one for the crew, as shown in figure 12.

For land transportation, four-wheel-drive vehicles were required because of the lack of paved roads and the need to travel through beach sand. Five jeeps were obtained from the Army and one from the Navy. The Navy also provided a ½-ton truck, a ¾-ton carryall truck, and a 1½-ton cargo truck. The Army provided four 2½-ton trucks, a 6-ton tractor crane, a water trailer, a 1½-ton fire truck, and several miscellaneous vehicles such as a concrete mixer, an air compressor, and a welding machine. The Army also provided large quantities of perforated steel landing mats.

The Army Air Forces obtained for Langley a number of sets of binoculars and telescopes, radio sets, transmitters and receivers, meteorological observation sets, cameras, and stopwatches. The Navy BuAer provided two special Mitchell motion picture cameras and two K-24 aerial cameras.

The Navy also provided two Quonset huts and six munitions storage igloos.

For air transportation of personnel, a Grumman Goose JRF-5 amphibian (fig. 13) was provided by the Navy, and a C-47 airplane (fig. 14) by the Army Air Forces. Later, the Navy furnished a similar R4D transport. These airplanes were on loan to the NACA, which meant, fortunately, that replacement parts or even complete airplanes were provided whenever major repair was required. A Lockheed 12 airplane already on hand at Langley was also used. (See figure 15.) These airplanes were operated by the Flight Research Division at Langley.

TEMPORARY CONSTRUCTION AND FIRST ROCKET FIRING

The original plan for facilities in the Wallops Island area, as submitted to the Bureau of the Budget, was based on permanent construction. Pending completion of these facilities, minimum temporary construction was undertaken to enable missile launch operations to begin as soon as possible. Under NACA policy, facilities were constructed by outside contractors. In May 1945, Virginia Engineering Company (Basic Construction Company) of Newport News, Virginia, was awarded a contract for this initial temporary work for an eventual cost of $51,999. The bids on the construction of permanent facilities were opened on August 14, 1945, the day World War II ended. With the ending of the war, the urgency connected with all military activities dropped almost to zero, and NACA priorities also were affected. As a result, permanent facilities were not completed until the winter of 1946–1947, and Langley had to operate for 18 months with temporary quarters.

The first headquarters for the NACA operations were located on the Chincoteague Naval Auxiliary Air Station. A small wooden shed was put together to serve as an office for the Resident Engineer, G. S. Brown. The Coast Guard and the Wallops Island Association personnel traveled to Wallops from a dock in the town of Chincoteague. Early NACA travel was also by this route. Inasmuch as the NACA base was to be located on the southern end of the island, however, it was found that much time could be saved by starting out from Taylor's Landing rather than from Chincoteague. Taylor's Landing, therefore, became the first regular departure point on the mainland.

An aerial view of Taylor's Landing while it was in use in January 1946 is shown in figure 16. Brown's headquarters were moved here on July 18, 1945, after a second wooden shed had been constructed for use as an office. The NACA had to do some dredging leading from this landing down Assawaman Creek. By June 1946, the new NACA mainland dock, which was located a mile or so downstream, was usable and operations were transferred there. As a compensation to John W. Taylor for permitting use of his landing, the NACA dredged the small-boat mooring area and the turning basin after operations were moved.

Figure 17 shows the new NACA Mainland Dock under construction. It is evident that the dock area was simply dredged out of the bank of the creek. Figure 18 pictures a typical scene of Langley employees debarking from an open personnel boat after an operation at Wallops. Power for the Mainland Dock was purchased through a direct connection with the Accomack Northampton Electric Cooperative.

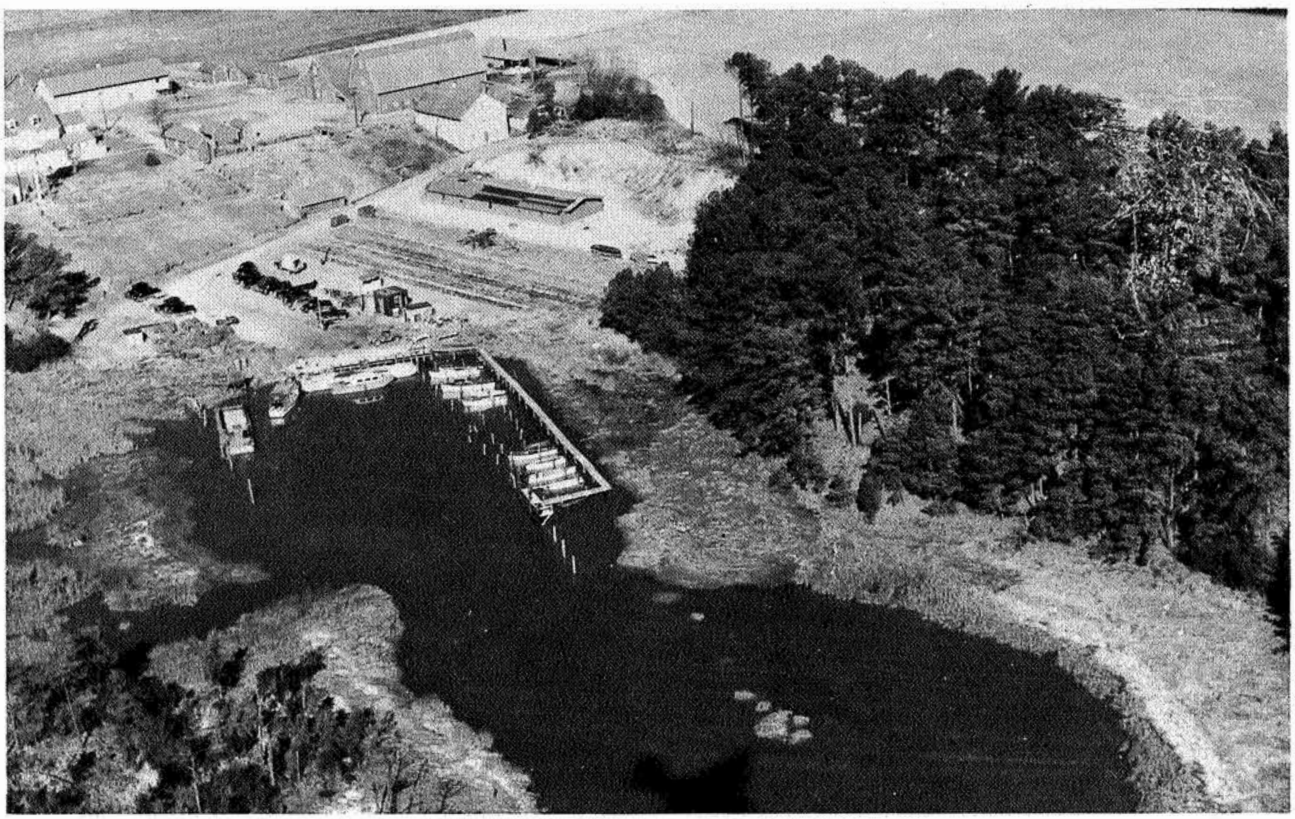


FIGURE 16. Aerial view of Taylor's Landing, January 1946.

FIGURE 17: Mainland Dock under construction, January 1946.

FIGURE 18. Operations crew debarking at Mainland Dock, August 1946.

In prepartion for use of the tracking stations on the mainland, roads were graded to Station 1 and Station 2. Station 2 was selected as the first mainland station because its location permitted tracking missiles for a longer part of the flight path. A concrete slab was poured and a temporary shed was erected. Road grading and paving, both here and on the island, were performed under subcontract by Bero Engineering and Construction Company of New York, which had other paving contracts on the Eastern Shore at that time.

At Wallops proper, the LCM boats at first were driven right onto the beach from the creek, for the unloading of construction equipment and four-wheel-drive trucks. Later, extensive use was made of pierced-steel landing mats. A temporary dock and pier were thrown together, as shown in figure 19. In this figure, an LCM is shown in place, ready to receive its cargo. This little pier was used for many months while the permanent dock, shown under construction in this same photograph, was being prepared.

Northward from the Island Dock was nothing but sand, sand dunes, marsh grass, and undergrowth. The NACA had selected the southern end of Wallops Island because there were no trees to limit the visibility necessary for tracking missiles from the mainland. A general aerial view of Wallops Island, taken after temporary construction was completed, is shown in figure 20, looking north from Assawaman Island. This view clearly shows Hog Creek behind the island, the long beach strip fronting on the Atlantic Ocean to the east, the trees on the nothern part of the island, and the extensive marshland separating Wallops from the mainland to the west. Chincoteague Island and the town of Chincoteague are due north of Wallops, being separated by Chincoteague Inlet. The large sandy area at the southern end of Wallops was not usable because it was frequently covered by the ocean during high tides. The Grumman Goose amphibian (figure 13) landed in Hog Creek and taxied onto the sandy area a few hundred feet downstream from the Island Dock. Pierced steel mats were fashioned into a makeshift ramp.

Temporary construction on Wallops was divided into three separate areas: the dock area, the launch area, and the work area. The living quarters were in the work area. A temporary road was

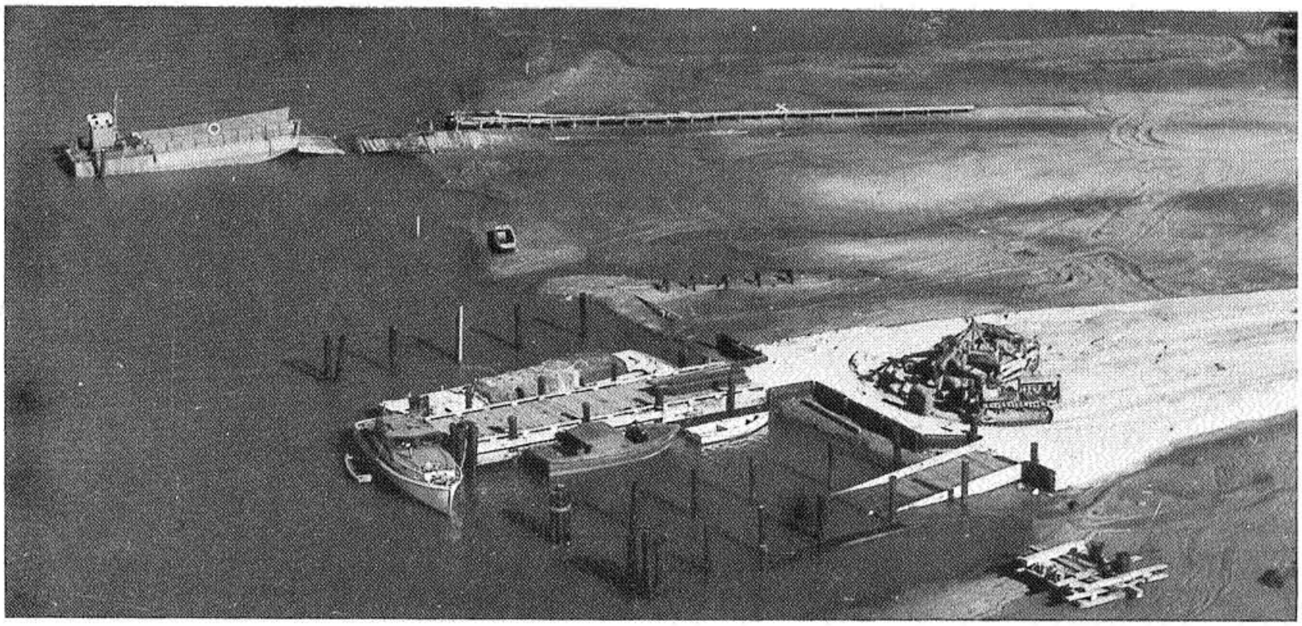


FIGURE 19. Site of Wallops Island Dock, January 1946.

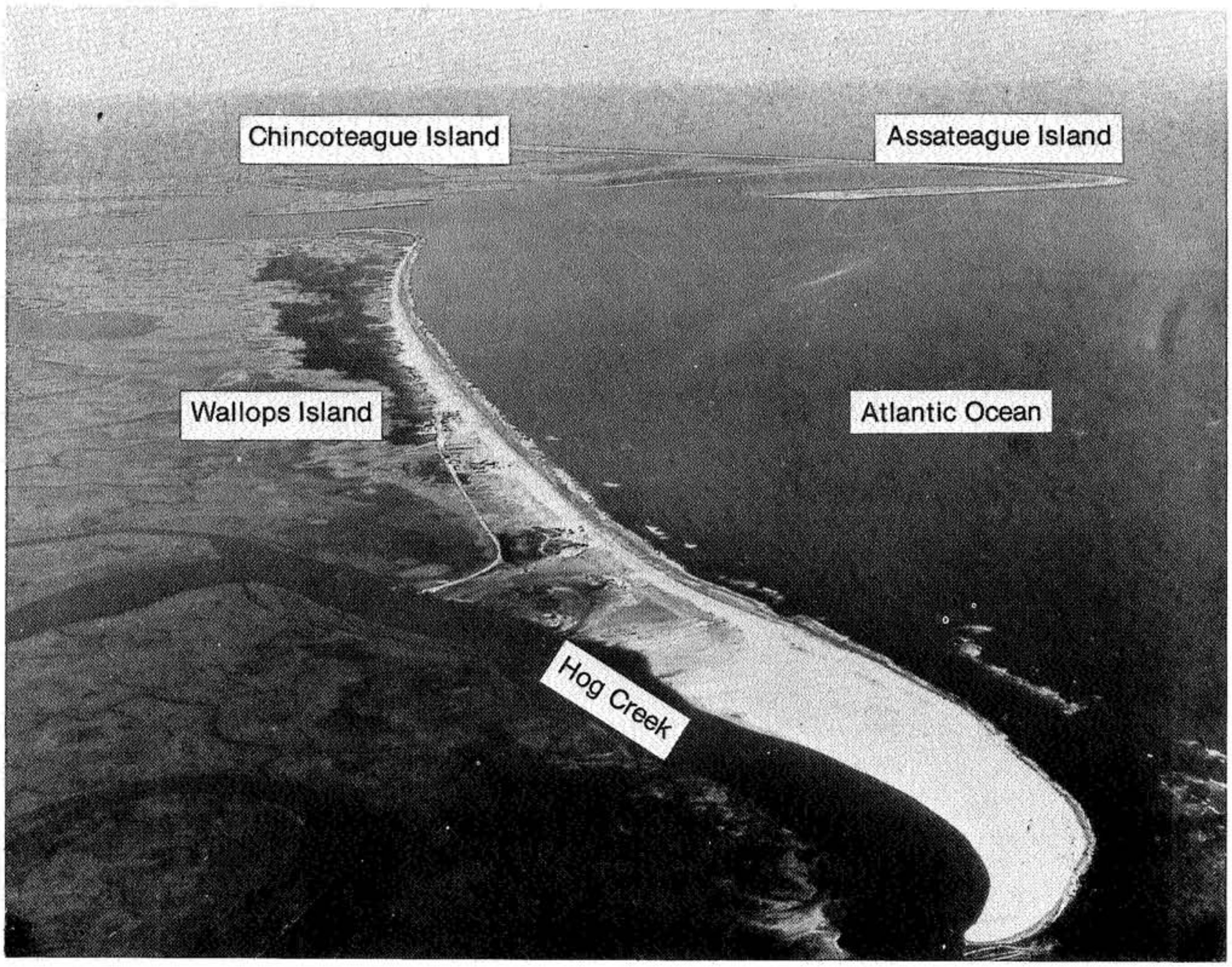


FIGURE 20. View of Wallops Island and surrounding area, January 1946.

graded from the dock to the other areas. Even so, four-wheel-drive trucks and jeeps were required for transportation for many months to come. The launch area was separated from the work area by a "no-man's-land" for safety purposes. Unfortunately, the launch area was established between the dock and the work area, which later caused considerable interference for routine traffic to and from the dock.

The launch area was the primary area on the island—in other words, the station's "reason for being." The initial construction here consisted of a 50-foot by 50-foot slab of concrete for use as a launching platform, an 8-foot by 10-foot observation station covered with sandbags, a rocket-motor storage igloo, and a final loading building. The concrete launching slab became a permanent part of the final permanent facility and, in fact, remained in use as a part of what is now called "Launching Area 2," under NASA.

The work area consisted of five wooden shacks (figure 21): (1) operations office; (2) assembly shed; (3) general warehouse shed; (4) radio, dispensary, and darkroom shed; and (5) power generator house with a 15-kw generator. For living quarters, tents were erected over wooden floors in late June and were used until Quonset huts could be erected. The Quonset huts were ready by the end of July and were located at Wallops Grid 120-121 N.. 99 E. (figure 9). Powerlines were run from the generator building to the other buildings in the area. Water was hauled from the mainland and stored in four water barrels mounted on wooden saddles. Four oil drums were erected on saddles for oil storage, and four more were provided for gasoline storage. Latrines, or "Chick Sales," were erected as required, according to an entry in Brown's diary.

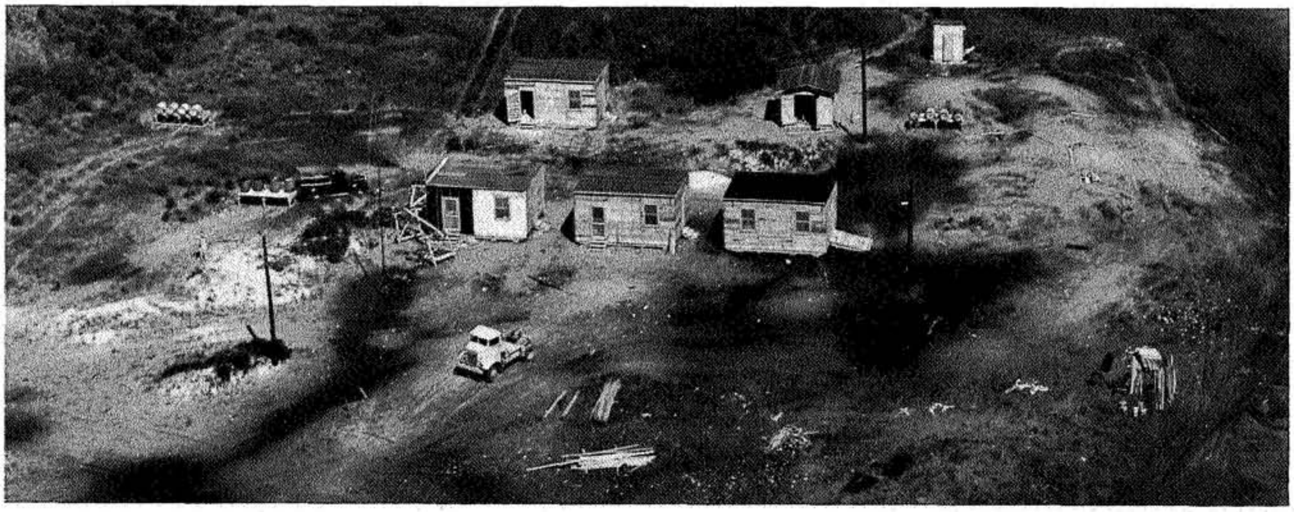


FIGURE 21. Temporary shacks at Wallops work area, June 1945.

Communication with the outside world was made possible by a connection with the Coast Guard telephone lines on the island, and by a radio link directly with Langley. The NACA paid the Coast Guard for connecting the Wallops Island buildings to the existing Coast Guard system, which extended to the town of Chincoteague. At Chincoteague, the lines were connected with the Chesapeake and Potomac Telephone Company system. This arrangement continued until 1948, when the powerline was run from the island to the mainland and telephone lines were strung on the same poles. The radios used were obtained from the military, with receiving and transmitting sets at PARD and IRD at Langley.

An aerial view of the launch and work areas on the island is shown in figure 22. The launching slab and blockhouse may be seen on the beach left of center, nestled among sand dunes. A single power pole is visible. The work area is identified by the numerous small shacks to the right of center. This photograph was taken on June 27, 1945, the day the first rocket was launched from Wallops Island.

A better view of the launch area is given in figure 23. In the left foreground is a 3.25-inch rocket mounted on its rail launcher with firing leads running to the sandbagged observation shelter or blockhouse.

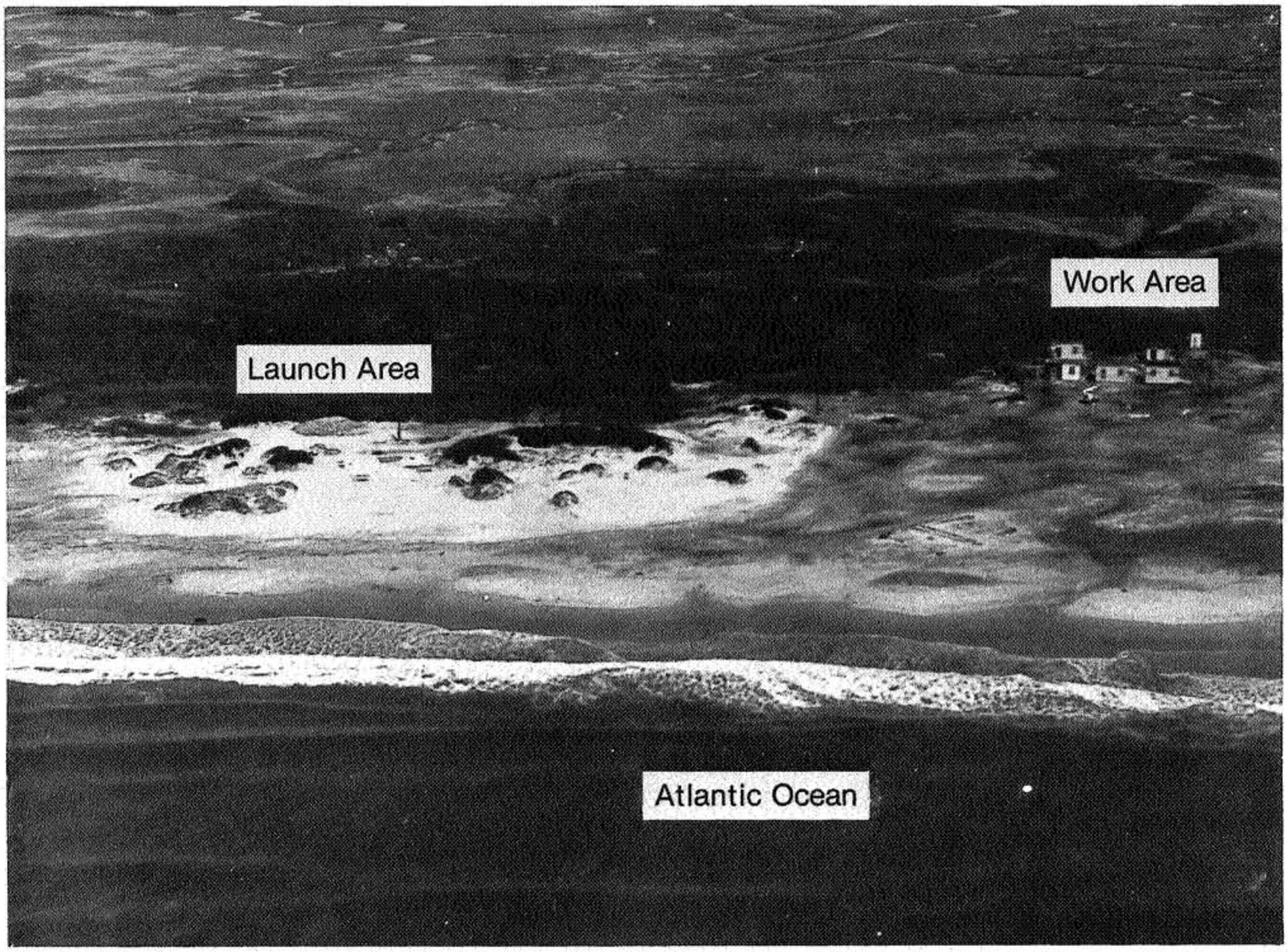


FIGURE 22. Aerial view of Wallops launch and work areas, June 1945.

FIGURE 23. Wallops launch slab and blockhouse, June 1945.

For this operation, the rockets and the ordnance personnel were supplied by the Patuxent Naval Air Station. The Navy BuAer had established a special project to cover this cooperation with the NACA.

The initial operations on Wallops on June 27, 1945, were to check the tracking station location and operation, to check the use of CW (Doppler) radar for measuring velocities of missiles, and to gain experience with actual rockets. Five 3.25-inch rockets were fired at an elevation angle of 39.4 degrees, and one each at 33.7 degrees, 29.3 degrees, and 21.5 degrees. All were fired in a direction parallel to the beach, to simulate the initial flight path planned for the first Tiamat missile launching. Four of the eight rockets were tracked satisfactorily by the SCR-584 radar located at the mainland tracking station 2, and a strong signal was obtained on the CW radar. As Hooker stated in his official report on the operations, "In general, the operation was successful" (ref. 3). Brown, in his diary, expressed it this way: "Hooker and gang arrived by B24 at 10:30. Went to Island and launched about eight rockets with satisfactory results. Lt. Rucker and 3 Navy enlisted men assisted us." The launching of the initial rocket is shown in figure 24.

INSTRUMENTATION

For initial operations at Wallops, the SCR-584 radar that had been used at Langley in the freely falling body flight program was moved to tracking station 2 on the mainland near Wallops Island. This location was selected to allow visual tracking of rockets from the time of launch until the radar could acquire the target and track it automatically. It was the first of a planned series of stations paralleling the coast to allow tracking of missiles such as the Tiamat as they flew down the range. The location would also allow tracking of bodies dropped from airplanes onto the target at the northern end of Assawaman Island. A typical view of an SCR-584 radar with the M-2 optical tracker, taken some time later, is shown in figure 25.

The CW radar acquired in early 1945 for direct velocity measurement was also moved to Wallops for the initial operations. This unit, shown in figure 26, was located among the sand dunes near the

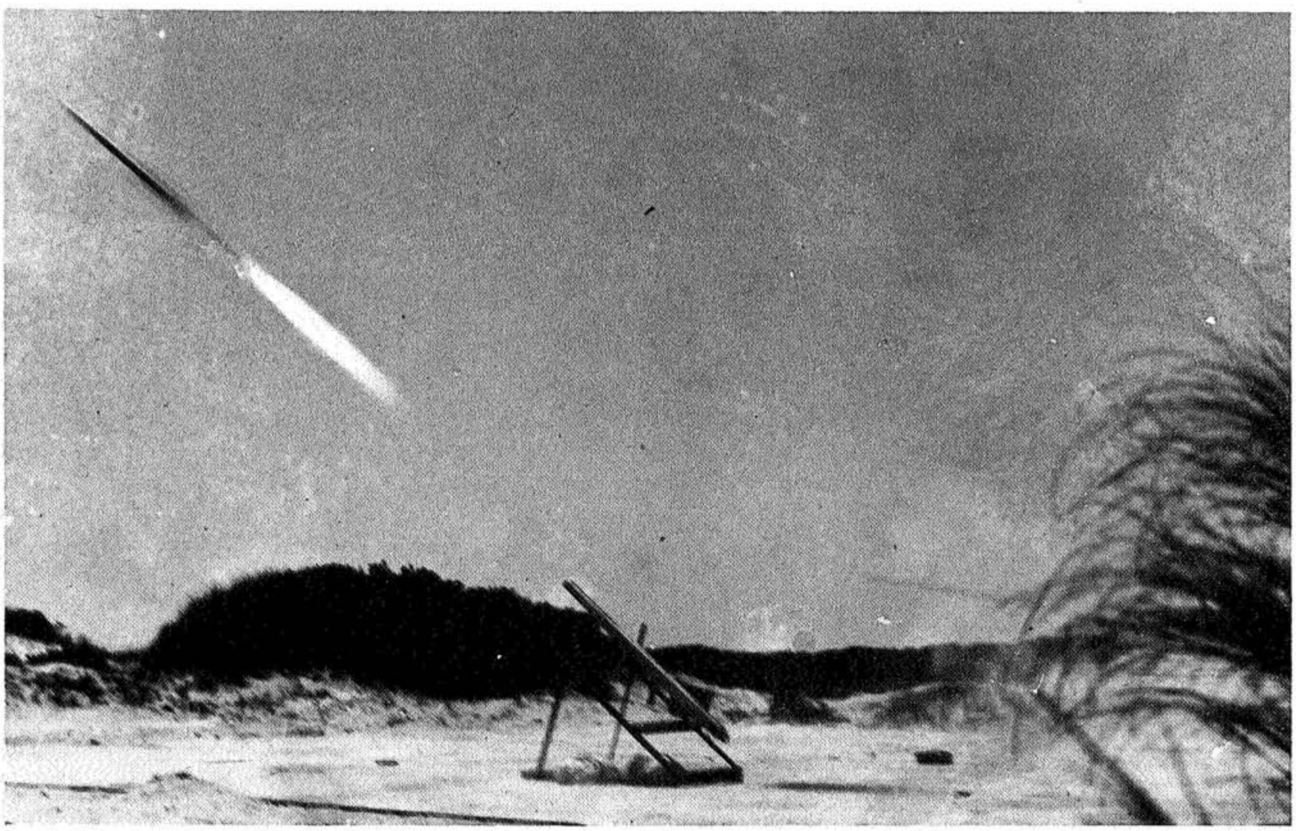


FIGURE 24. Launch of first rocket at Wallops, June 27, 1945.

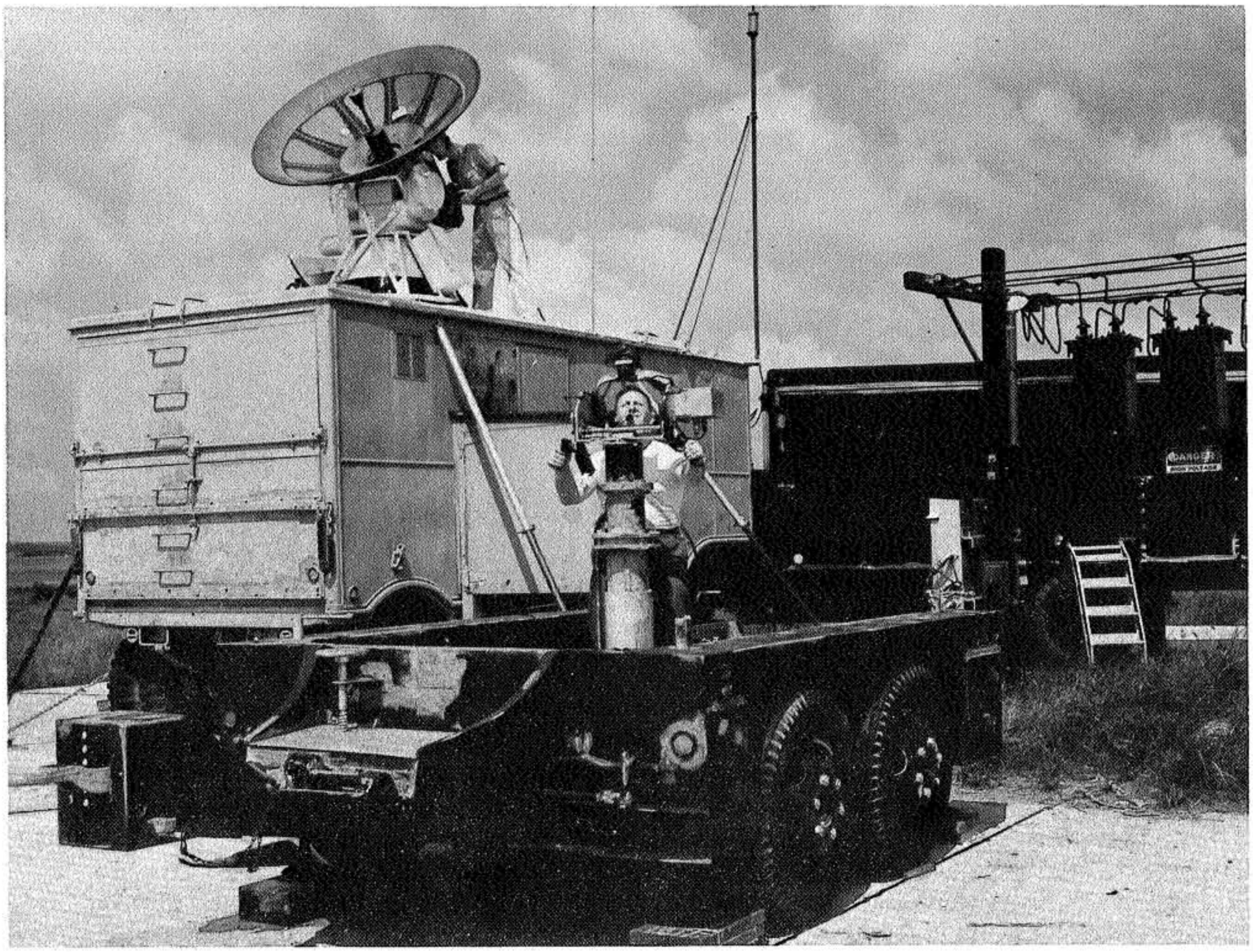


FIGURE 25. View of SCR–584 radar and M–2 optical tracker.

FIGURE 26. View of AN/TPS–5 radar at Wallops, June 1945. Engineer P. F. Fuhrmeister is shown beside the control van.

launchsite. This radar was the AN/TPS-5 model which was nicknamed "Tipsy" by its crew. In fact, all Doppler radars at Wallops were called "Tipsy" from this time on. The radar operated on a frequency of 2640 mc (10 cm).

The Doppler radar operates on the principle that a continuous radio signal directed at an object moving away from the radar will be reflected at a different frequency that is proportional to the velocity of the moving object. The radar is equipped with two antennas, one for transmitting and one for receiving the return signal (ref. 4).

The FM/AM telemeter developed at Langley for the freely falling body program was adapted for use in the free-flight missile program. The first instrumented missiles used practically the same telemeter as the free-fall bodies. The higher accelerations and rough vibrations during rocket burning, however, made it necessary to modify the telemeter. In fact, a continuous program of telemeter development was necessary to meet the requirements of a continuously expanding missile program. Special environmental testing techniques also had to be developed.

One special technique used for telemeter testing was the so-called "cable test." A two-channel telemeter under development for use with high accelerations was attached to the front end of a 2.25-inch rocket motor which, in turn, was hung from a cable stretched between poles on the beach at Wallops. The downstream part of the cable branched into a Y which tied into two separate poles. The branched cable served as a brake or decelerator to stop the rocket and allow a study of any malfunction of the telemeter. The system was used quite successfully in the winter of 1947–1948 but was abandoned for safety reasons after the cable broke in one test.

SAFETY CONSIDERATIONS

The initial operations at Wallops were carried out in accordance with standard Navy rocket firing procedures. In fact, Navy men handled the actual firing. NACA personnel had had no experience with rocket motors, but realized that they would have to acquire such experience and eventually take over all responsibility. One of W. J. O'Sullivan's jobs was to develop such a capability at AFRS.

One of the first engineers assigned to work on rocket firing and other operational problems was William K. Hagginbothom, who was to continue as an active participant in solid-rocket propulsion research for 20 years. The day after the initial operations at Wallops, he prepared some recommendations to improve operations, and suggested a set of safety rules (ref. 5). These were the first such rules prepared for Wallops and were to be followed for years to come:

1. Clear target area of boats and people.
2. Minimum distance from the launching site for all unprotected personnel not actively engaged in firing shall be at a minimum of 150 feet.
3. The firing pit shall be cleared of unauthorized personnel at all times during firing operations.
4. At all times during operations one man shall be stationed at the firing pit to make certain that the firing circuit is shorted out, and that no possibility of contact with the voltage source exists.
5. Before each rocket is connected to the firing circuit, a check by means of a circuit tester shall be made to make certain that the firing circuit is dead.
6. It shall be the responsibility of the person in charge of the firing to enforce the safety regulations in effect.

The effectiveness of the safety program at Wallops is attested to by the fact that through 1971, after the firing of more than 10,000 rocket motors, not a single life had been lost although the operations were not accident-free.

For the sake of safety and reliability, specialists were developed in the area of solid-rocket propulsion. The research engineers turned over rocket motor responsibility to these specialists, who included rocket propulsion engineers as well as technicians. Specialization in this field still continues at Wallops. When PARD was organized into sections on August 15, 1946, the rocket activity was assigned to the Propulsion Aerodynamics Section headed by Paul R. Hill.

With regard to hospital availability in the Wallops area, Brown determined on June 19, 1945, that the Chincoteague NAAS hospital was available for emergency treatment of personnel of the NACA. Over the years, the hospital was used for this purpose. On the island itself, a first-aid station was established at the beginning of operations. The Safety Engineer at Langley informed the Chairman of the Langley Executive Safety Committee that as of August 29, 1945, a first-aid station was manned on the island by a holder of a Red Cross certificate, and that permanent construction would "provide for a complete dispensary manned by either graduate nurses or a physician or both. Portable water showers for the immediate neutralization of chemical burns have been constructed and will be ready for use at such times as operations may require." The Safety Engineer, Harry N. Henry, appointed Eugene M. Reading Safety Coordinator under a new Langley-wide plan effective April 12. 1946.

TEST OPERATIONS

During the months of operation with temporary facilities, the missiles launched were the Tiamat for the Army Air Forces, the Lark for the Navy BuAer, and a supersonic research missile designed by AFRS and named "RM-1." In addition, the need for basic aerodynamic information on wing drag and control effectiveness in the transonic range promped Gilruth to expand the missile program to include generalized component investigations and development of special techniques to make them possible.

Both the basic research program at Wallops and the specific research programs relating to military development over the first 15 years of operation (1945–1959) are covered in the list shown in Appendix B. A more complete description of each program is included as a part of the discussion in specific chapters. A list of flight operations at Wallops during the same 15-year period is given in Appendix C. A list of all test operations in the Preflight Jet appears in Appendix D. Technical reports generated by Wallops test operations are listed by program and year in Appendix E. Individual reports are referenced as they are discussed. For the most part, the accomplishments of Wallops as discussed in this account are based on these reports.

TIAMAT MISSILE PROGRAM

The initiation of the Tiamat guided missile (MX-570) and a proposal for its developmental testing by Langley have been discussed in Chapter 1. The Tiamat, the Army Air Forces' first air-to-air guided missile, was the first missile to be tested at Wallops. This ambitious project "to develop the MX-570 for combat use" was originally planned around the launching of 36 missiles, and arrangements for their production were made in the Langley shops. Before the project was very far along, however, the war ended, a general cutback was made in military development, and this subsonic missile was reduced to low priority. As shown in Appendix C, 4 were flown in 1945, 3 in 1946, 2 in 1947 and 1 in 1948, for a total of 10 missiles. The original purpose of the project was changed from development for combat use to research on automatic control systems.

The Tiamat, as designed by Langley for test at Wallops, contained all the elements of an actual missile except a warhead and a guidance system. A booster was developed for ground launching. In effect, then, this gave the Tiamat the capability for use as a ground-to-air missile in addition to its original intended use for air-to-air launching. Responsibility for the Tiamat project was initially assigned to R. T. Jones of the Stability Research Division, but after AFRS was established the responsibility was transferred to Charles L. Seacord, Jr., of AFRS. Robert A. Gardiner of the Instrument Research Division was responsible for the automatic control system, which he assembled from German V-1 autopilot components. He also served as firing officer for the early tests.

The aerodynamics of the original subsonic Tiamat design were verified by wind-tunnel tests before launching and, except for the possibility of some high-speed effects, no problems in this area were anticipated. The only problem with aerodynamics was encountered during tests in the Langley Free Flight Tunnel when the original three-wing panel design was found to suffer a loss in directional stability as the angle of attack was increased (ref. 45, Chapter 1). A four-panel arrangement overcame this problem, and all flight Tiamat missiles were changed to this design after the first missile. Later in the program, the sweepback of the wings was changed from 0 degree to 41 degrees to provide data applicable to missiles designed for higher speeds.

Because the chief problems encountered with other guided missiles under development during the war had to do with the automatic control system, the test program for the Tiamat centered around that system. The only definite flight plan was to find out whether the control system could stabilize the missile while it was performing a turning maneuver. The many other things learned in the program were byproducts.

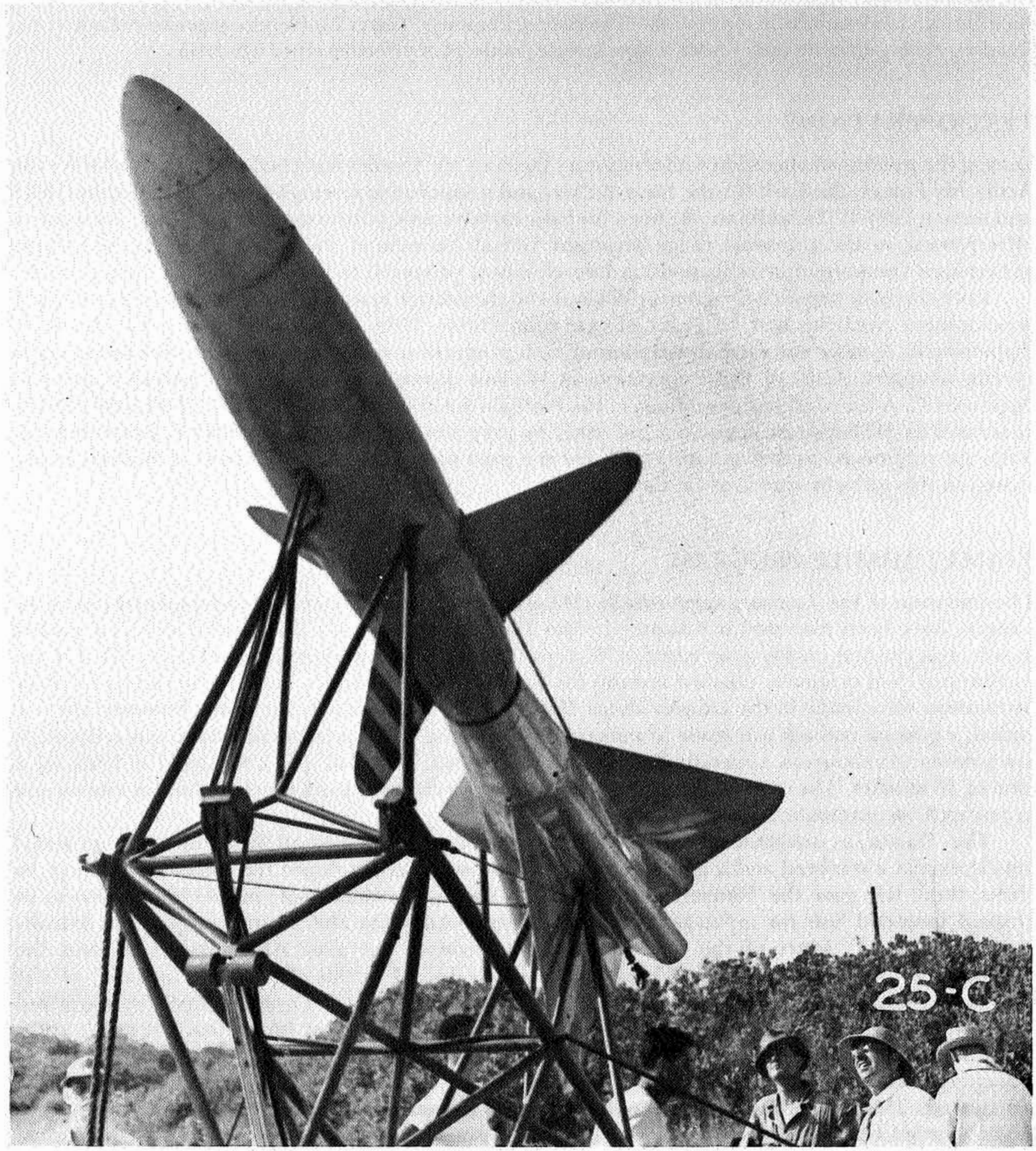


FIGURE 27(a). Front view of first Tiamat missile and booster on launcher, July 1945.

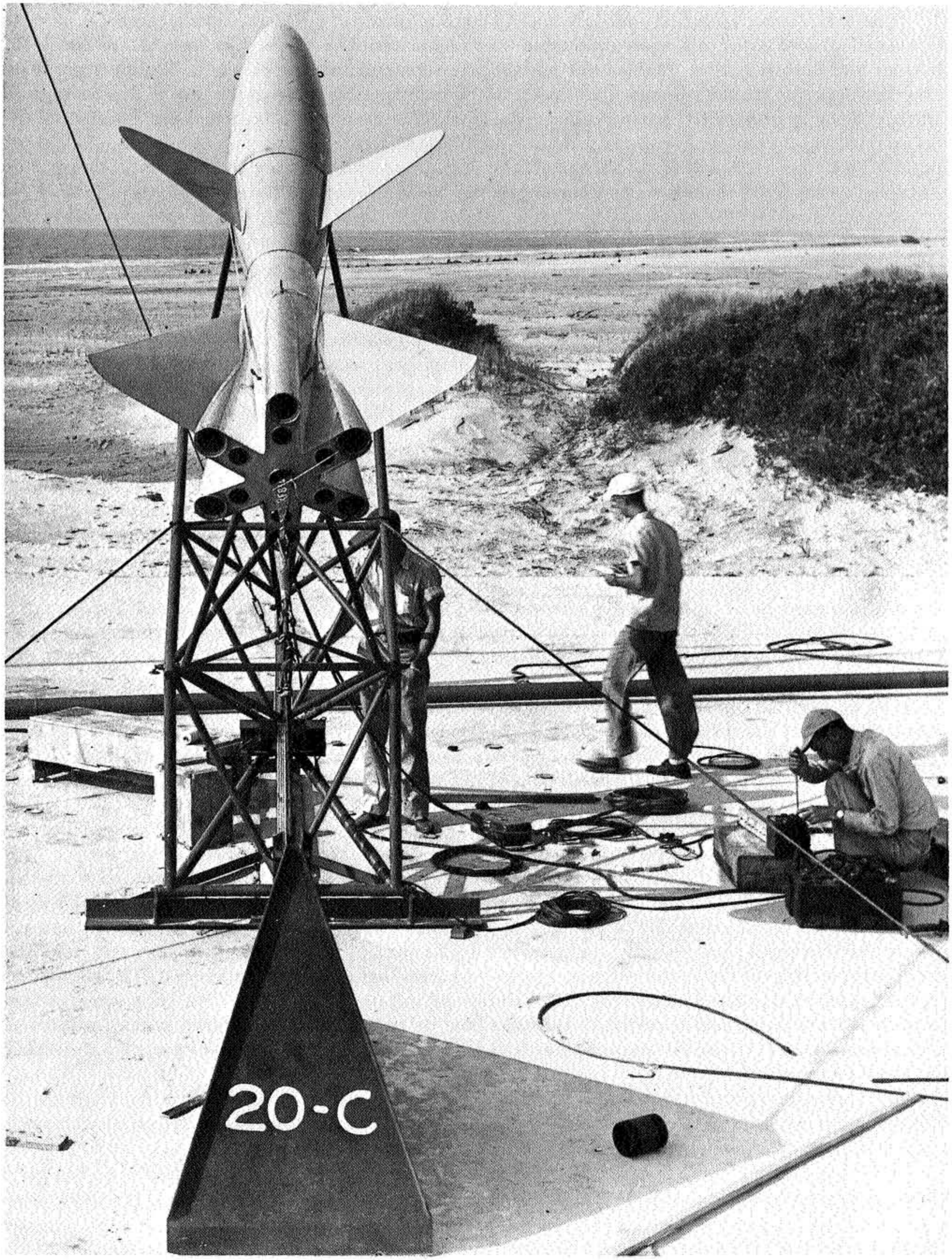


FIGURE 27(b). Rear view of Tiamat and booster shown in figure 27(a).

The first Tiamat launched—on July 4, 1945—was a "dummy" missile without a control system. In figures 27(a) and 27(b), it is shown mounted on its launcher. The missile was launched to verify the booster and launch system. The booster was supposed to accelerate the missile to 500 miles per hour and then separate from it; the sustainer rocket would maintain this speed as the missile flew at constant altitude along its prescribed course parallel to the coast.[8] The dummy was launched successfully, but the booster failed to separate. For the next flight—the first with a complete missile—on July 8, 1945, some fixed drag brakes were added to the central tube of the booster to increase the separation force as the sustainer motor fired. In this second launching, the booster separated but, as it did, it disturbed the missile and "tumbled" the gyroscopes within, terminating the flight (ref. 6). This trouble was believed to have been caused by the fact that although the booster-missile combination was stable, the empty booster alone was unstable and started to diverge as soon as it began to move rearward from the missile.

A four-channel telemeter was contained within the missile to monitor flight behavior. The following items were measured continuously: (1) normal acceleration, (2) transverse acceleration, and (3) roll attitude. Impact pressure and rudder servo position were measured alternately on the fourth channel by switching at a rate to give 10 readings of each item each second. Starting with the third missile, elevator position was also measured by switching alternately with another item. The SCR-584 radar and motion-picture cameras tracked each missile in flight, and the TPS-5 radar was used experimentally, when operational, to measure velocity during the boost phase.

Although these flights were failures, several new concepts were proved and the need for changes was shown.

A cluster of six rocket motors was used for the first time. The cluster was so mounted that the thrust of each motor passed through the center of gravity of the missile-booster combination. A tie-down link also was used for the first time. The link had been designed to hold the missile in case all of the booster motors did not fire. The zero-length launcher was the first of its type ever used. It was entirely satisfactory. The launching also demonstrated the successful operation of a separation system—a four-strap system which tied the booster to the missile during launch, but which was broken free by blasting caps at the prescribed time (ref. 7).

The telemeter did not function properly in the first launch. Although it had been working satisfactorily on external power prior to launch, it stopped working at the instant of launch. In the process regularly used at that time, a plug pulled out and transferred power to batteries in the missile. The failure necessitated a change in launching technique that is still followed in all similar launchings; i.e., to shift from external to internal power a few minutes prior to launch. A "hold" can then be called if operation is unsatisfactory.

The third Tiamat launching, on August 24, 1945, is shown in figure 28. A new booster incorporating a single Monsanto ACL-1 rocket motor replaced the cluster of six Cordite motors. This booster was also used by the Army Air Forces on their JB-2 "buzz-bomb" guided missile, an American copy of the German V-1 missile. This time, the booster was designed to be aerodynamically stable after separation, to avoid the disturbance encountered earlier. In this flight, everything worked as planned, except the automatic control system. There were continuous oscillations in pitch, yaw, and roll. The oscillations in roll overrode the altitude signals, and level flight was not maintained. The maximum altitude reached was 600 feet, and the distance traveled was two miles (ref. 8). The continuous oscillations in roll are explained in reference 9 by the time lag in the automatic control system, which was copied from an AZON missile and was electrically operated with full deflection of the ailerons (flicker or "bang-bang" system).[9]

Difficulties continued to beset the Tiamat. Several flights were completely unsuccessful because of failure of one or more of the automatic control components. One failure was caused when the straps connecting the missile and booster failed to break as planned.

The next successful flight, and the only one to demonstrate the programmed turn as originally planned, was made on August 7, 1946. For this flight, the external straps were replaced by a central tail

8. The internal rocket in a system was called a "sustainer" rocket from this time on, even though, in most cases, it was used only as another acceleration rocket.
9. In such a system, the ailerons were either fully up or fully down, and flopped from one position to the other with a "bang."

FIGURE 28. Launch of Tiamat B missile, August 24, 1945.

cone connection containing a preloaded spring that was cocked by an explosive bolt during burning of the booster rocket. In this flight, the control system was satisfactory in yaw; but in pitch the rate gyro appeared to fail in the middle of the flight, and oscillations developed. Continuous hunting oscillations in roll were also present (ref. 10). The launching of this missile is shown in figure 29. A "split-house," which was opened for launching, had been added to the launch area by this time to provide a cover for the missile during preparations for launching.

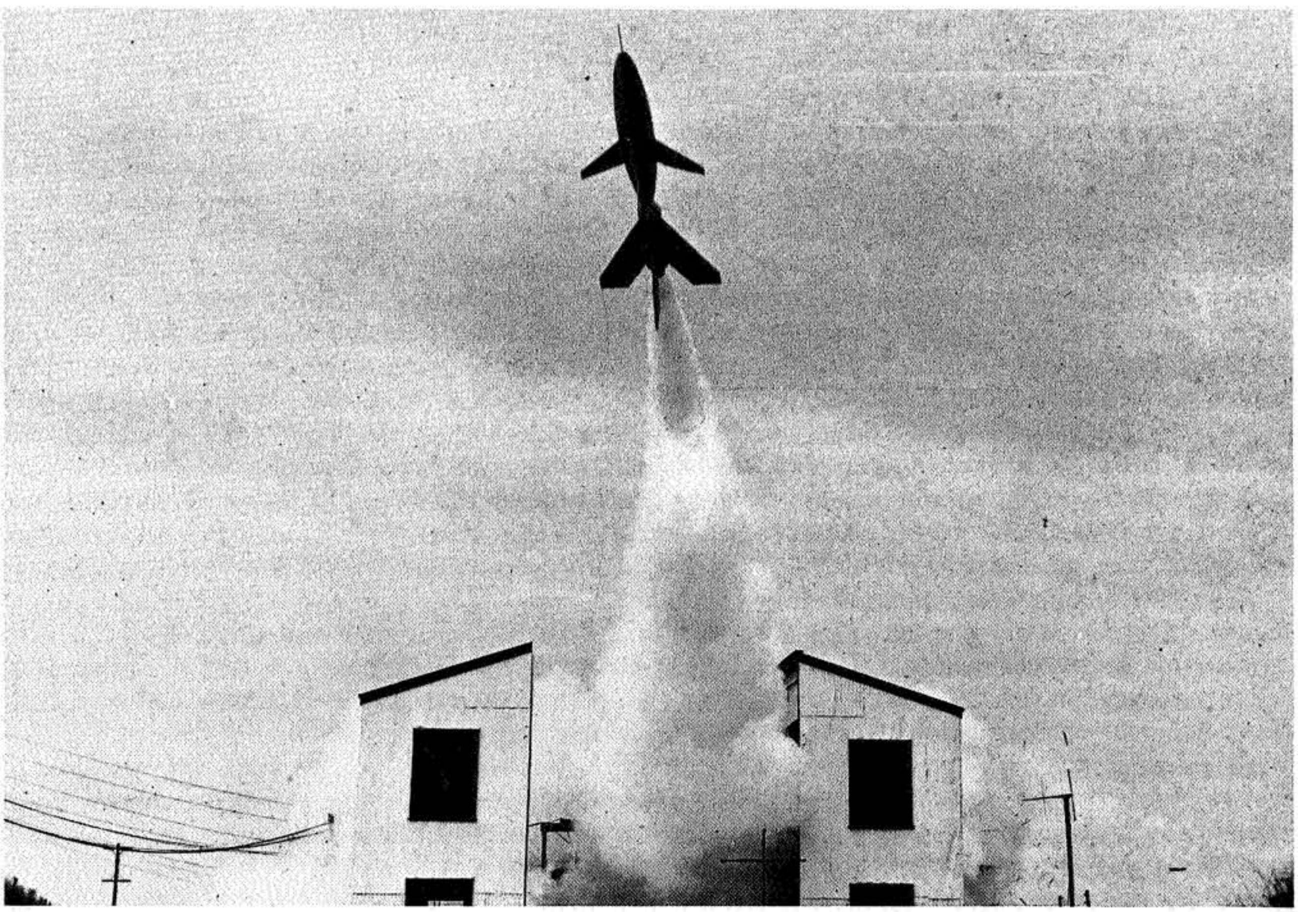


FIGURE 29. Tiamat C launching from Wallops split-house.

The last flight of a Tiamat missile was conducted in June 1948. The Tiamat was not flown as a completely stabilized missile but simply as a test vehicle for a special type of roll stabilization system. The many failures with the complicated control system previously used led Gilruth to propose that a flight test be made of a roll-control system that had the ailerons connected directly to a displacement gyroscope with a torque motor to limit gyroscope precession. This arrangement provided a proportional system without lag. A servomotor was connected to the controls on the vertical wings to move them periodically, to give a roll disturbance for the stabilization system to work against. Although the pulsing system did not work and the telemeter failed after 8 seconds of flight, the test did demonstrate that this type of stabilization system would work. Motion pictures showed no noticeable rolling (ref. 11).

By this time, a six-channel telemeter was available and was used for continuous measurement of the following quantities: (1) lower vertical control position, (2) right horizontal control position, (3) bank angle, (4) dynamic pressure, (5) transverse acceleration, and (6) rate of roll.

The early failures in the Tiamat program were quite disappointing to the engineers at Langley as well as to the crew at Wallops, but they were indicative of the general status of missile development at that time. Although the priority of Tiamat became very low when the war ended, it was not apparent how a successful missile of this type could have been developed earlier, with the unavailability of reliable automatic control components. Concurrent flight tests conducted by Hughes Aircraft Company were likewise beset with difficulties, and the development contract for this subsonic missile was terminated. Interest at Hughes in air-to-air missiles continued, however, and later their supersonic Falcon air-to-air missile was to become a most effective weapon in the Air Force arsenal. Interest at Wallops likewise shifted to the supersonic range.

NACA SUPERSONIC MISSILE: RM–1

When the Auxiliary Flight Research Station was established, the approved research program included a "supersonic missile." Initial plans were centered around the ramjet-powered supersonic missile proposed by M. C. Ellis and C. E. Brown,[10] and the design of such a flight missile was begun in February 1945. Lacking detailed information required for design of the supersonic ramjet engine, and pending development of such an engine, Gilruth proceeded with a supersonic missile flight-test program incorporating solid-rocket motor propulsion. This was the first new program to be initiated by AFRS, and was the first of a series of Research Missiles (RM-1). Figure 30 shows a typical RM-1 missile mounted with its booster on a special zero-length launcher.

Research Authorization 1224 was issued in March 1944 for the freely falling body program, but it was also used for some of the rocket-model programs involving experimental body structures. The requests of the Army and Navy in December 1944 for an accelerated program of high-speed research[11] led to the issuance of RA 1333, "Studies of Bodies Suitable for Supersonic Flight." The purpose of the research was "To determine the characteristics of wings, bodies, and controls suitable for flight at supersonic speeds . . . to provide the fundamental data required for the design of missile or airplane-like bodies." The RM-1 was charged to this RA. In fact, RA's 1224 and 1333 provided the authorization for most of the general research of AFRS and PARD for several years.

The RM-1 was smaller in diameter than the Tiamat (6 inches, compared with 20) and lighter (124 pounds, compared with 600) although it was longer (136 inches, compared with 120). With a 5-inch Cordite sustainer rocket alone, it attained a speed of Mach 1; with a similar motor used as a booster in addition, a speed of Mach 1.4 was obtained. In the case of the RM-1, the function of the sustainer rocket motor was quite different from that of the sustainer in the Tiamat missile. With the RM-1, each of the two rocket stages provided approximately one-half of the speed during the 3.5 seconds of burning time of each motor. Flight times of just a few seconds were quite acceptable for this research missile in contrast to the flight of 45 seconds originally specified for the Tiamat development.

10. See footnote 7, Chapter 1.
11. See footnotes 14 and 15, Chapter 1.

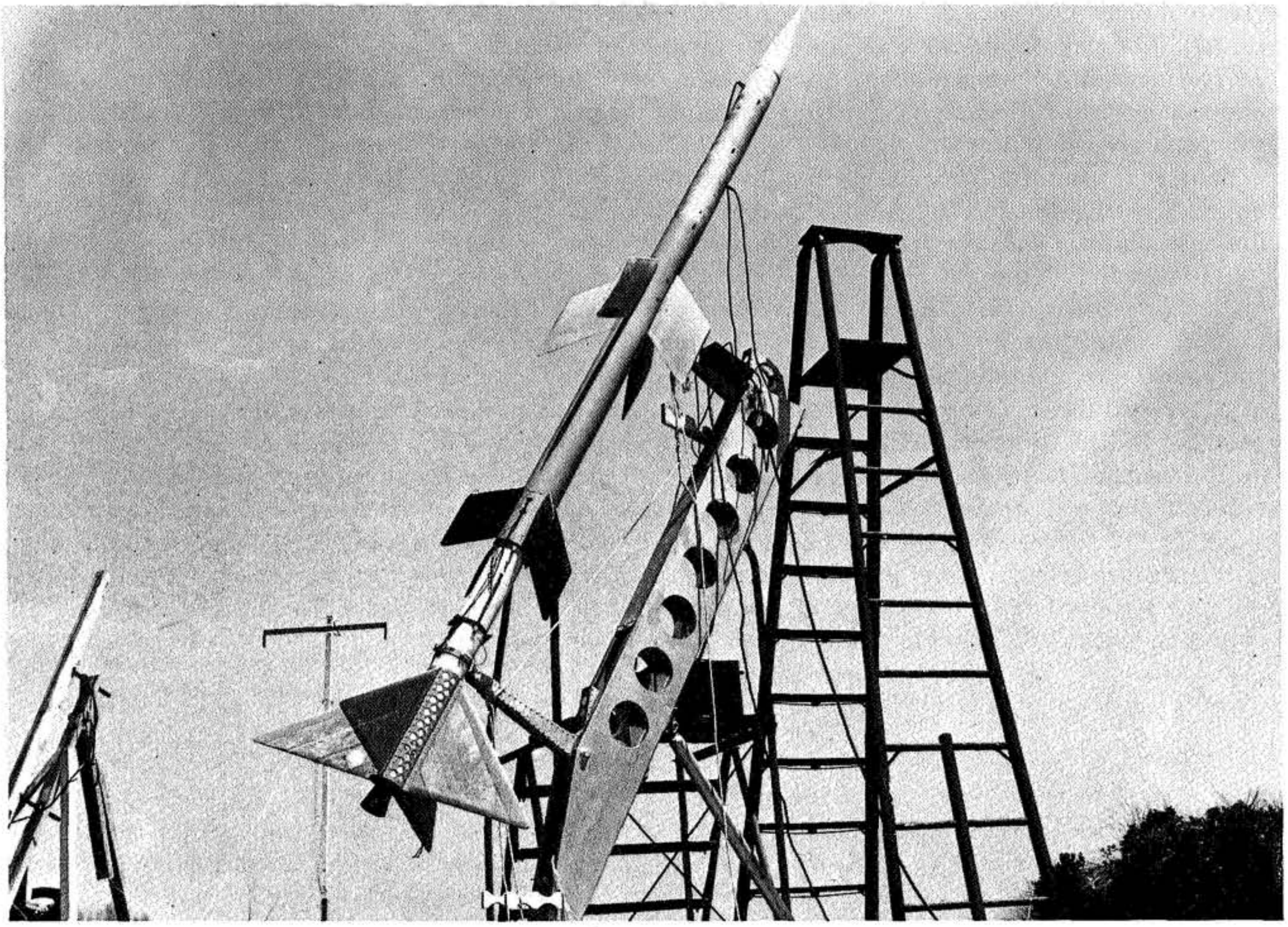


FIGURE 30. Typical RM–1 missile on launcher.

The RM-1 had four sweptback wing panels and four sweptback tail panels interdigitated with respect to the wings. The wings and tails were NACA 65-010 wing sections normal to the leading edge, which made them 7 percent thick in a streamwise direction. Because of difficulties other missiles had encountered in roll stabilization, the first program for the RM-1 was concerned only with roll. Leaving out stabilization in pitch and yaw greatly simplified problems and increased the chances of successful flights. Roll stabilization was provided by an autopilot using rate and displacement gyroscopes commanding an electromagnetic servomotor connected to a single trailing-edge aileron.

The RM-1 was planned as a generalized test vehicle, not only for different autopilots but also for aerodynamic investigations of different wing shapes and control types. It was the first supersonic missile the NACA developed, and great things were expected of it as a research tool. A four-channel telemeter was part of the standard equipment.

Several flights with dummy missiles were made to verify the design and general technique—the first being conducted on October 17, 1945. The launcher was a simplified version of the Tiamat launcher, and the booster was designed from lessons learned with the Tiamat. The booster attachment fitting incorporated a spring rejection mechanism as in the Tiamat, and the booster thrust was transmitted directly to the nozzle of the sustainer rocket motor.

After several successful flights with dummy missiles, the first instrumented version was launched in May 1946. Everything worked fine until the missile approached Mach 1. The roll stabilization system performed as expected, with a low-amplitude continuous oscillation up to this point. Near Mach 1, the missile went into a continuous roll that lasted until the speed had returned below Mach 1 and stability was restored. At this time, it was not clear whether the trouble at supersonic speeds was caused by lack of control or by excessive hinge moments which prevented the servomotor from moving the ailerons (ref. 12). The next flights were designed to answer the question.

The next RM-1 was launched on August 9, 1946. It was equipped with a wing rolling-moment balance and a control-position indicator to measure the rolling moment produced by aileron deflection. Unfortunately, the power supply to the autopilot failed, and the ailerons were left free-floating with no mechanical restraining force except friction in the bearings. In flight, the ailerons experienced high-frequency oscillations in the transonic and low supersonic speed ranges (Mach 1.03 to 1.40) (ref. 13). This "aileron buzz" was similar to that encountered earlier in flight with the P-80 airplane.

Another flight attempt was made to explain the loss of stabilization in roll of the early RM-1 flight. This time, the aileron hinge moments were measured along with the control deflection and wing rolling moments. This flight, made in January 1947, ended the RM-1 series of 10 flights. In the flight, the roll stabilization was again lost at supersonic speeds. The hinge moments became quite high at such speeds and prevented the servomechanism from maintaining full aileron deflection. But this was not the main reason for failure to stabilize. The rolling moment balance showed that at Mach numbers greater than 0.90 the control effectiveness was reversed; that is, an aileron deflection to produce a right roll actually produced a left roll. At this time, it was believed that the main cause of the reversal was lack of torsional rigidity in the wing, although loss of aerodynamic effectiveness was not ruled out as a possibility (ref. 14). It now appeared that at transonic and supersonic speeds aerodynamics and structural rigidity were more important than the type of stabilization system used. Emphasis therefore was shifted to component testing with simple models, as will be discussed later.

NAVY LARK MISSILE SUPPORT

The Navy Lark guided missile was BuAer's designation for its surface-to-air subsonic interceptor missile. The Lark development was initiated in January 1945, with top priority for use against the Japanese. Fairchild was the main contractor, and eventually the Lark was placed in production, but not in time for use in World War II. As reported in *Guided Missiles Volume and Directory*, 1963, it had the distinction of "scoring history's first aircraft interception and destruction by a guided missile."

Like the RM-1, the Lark had four wing panels and four tail panels. In flight, the missile was maneuvered by deflecting flaps on the wings, while the fuselage was kept aligned with the direction of flight by the controls on the tail surfaces. Assistance in control system analysis was requested by BuAer on May 11, 1945, and the Langley Stability Analysis Section submitted three reports on this work (refs. 48, 49, and 50, Chapter 1). Assistance in flight tests was requested by the Navy BuAer on August 3, 1945. The purpose of this series of flight tests was stated on RA 1375 issued by the NACA: "To obtain information by actual flight tests of the stability and control characteristics of models designed to comply with the specifications of the 'Lark' pilotless aircraft."

The details of the Lark program were discussed with BuAer personnel on November 5, 1945, with Gilruth representing the NACA. His memorandum of November 9 stated, "Inasmuch as flight tests of the actual Lark missiles are set up for Inyokern Naval Station, it was suggested by the Bureau Of Aeronautics personnel that NACA flight tests concentrate on obtaining aerodynamic information for correlation or explanation of full-scale Lark behavior."

A flight program was arranged, under which Langley was to measure such items as static stability, maximum maneuvering lift coefficients, and effects of tail orientation on stability and control for generalized models of the Lark. The models to be flown were to be 0.5-scale versions patterned after the RM-1 missile and constructed at Langley. Four configurations were flown between May and October 1946. The results are reported in references 15 through 19, listed at the close of this chapter.

The Lark missiles flown at Wallops weighed 125 pounds and were propelled by a single internal Cordite rocket motor. The RM-1 launcher was used, and the maximum Mach number attained was 0.90. Figure 31 shows the Lark mounted on its launcher.

A special "pulsed-control" technique was developed for this project, to obtain stability and control information. In the technique, the control surfaces were moved rapidly from one fixed position to another and then returned to the original position. The controls were kept at each position long enough to allow the natural oscillations to cover several periods. For the Lark, the time between

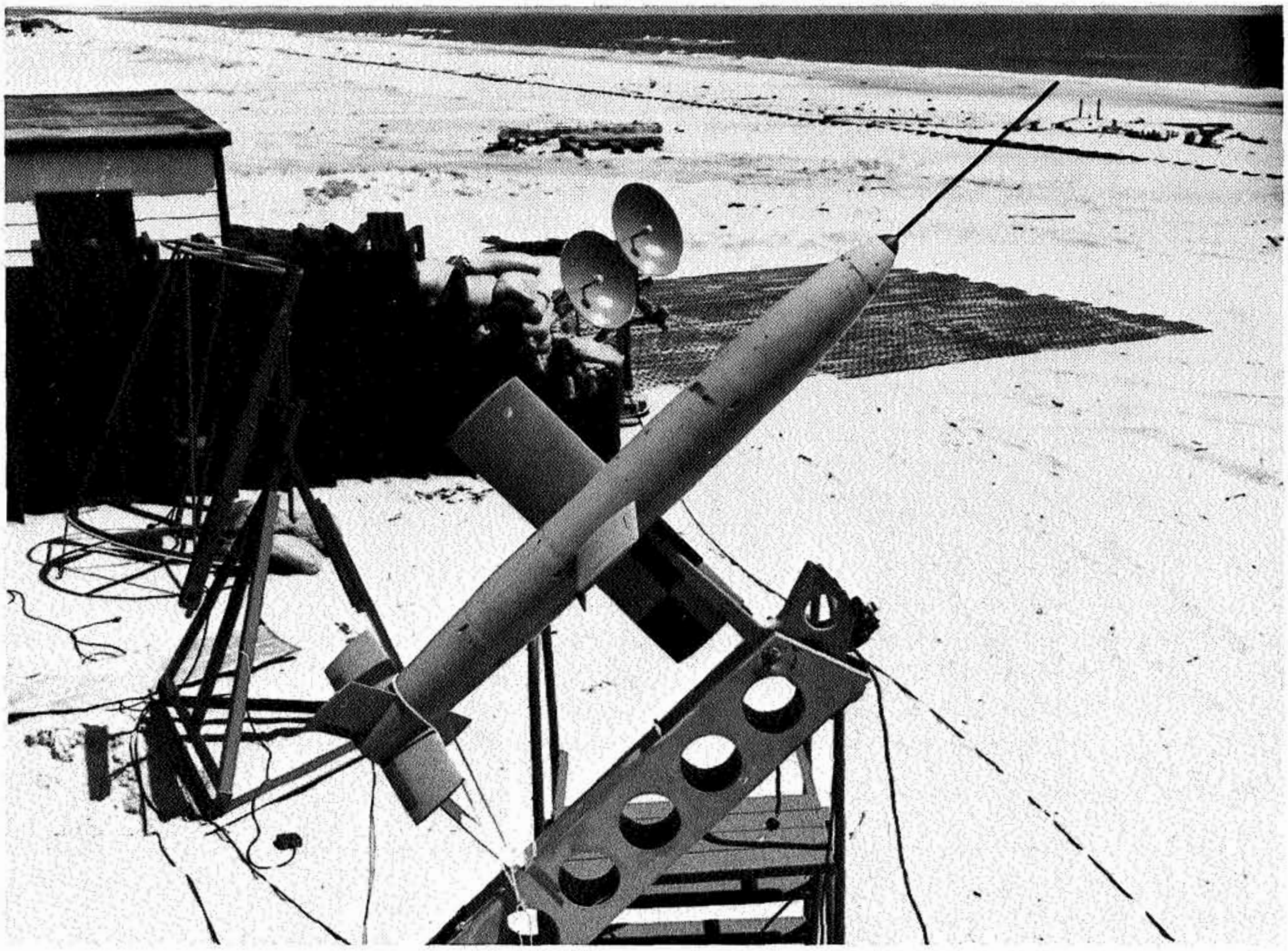


FIGURE 31. Typical 0.5-scale Navy Lark missile.

movements was 1.2 seconds. A four-channel telemeter transmitted readings of control position, normal acceleration, longitudinal acceleration, and impact pressure. SCR-584 and TPS-5 radars were used. Static pressure was taken as sea-level pressure inasmuch as the maximum altitude was only 500 feet. Although five reports were prepared, as shown in Appendix E, all results were summarized in the final report (ref. 19). A typical set of basic flight measurements is shown in figure 32. From these data, static and dynamic stability could be determined, and such data were obtained for BuAer for various configurations of the Lark missile. The procedures for analyzing the flight records are described in reference 4 in the list following this chapter. The Lark project was unique in this period in that every flight was a success.

BEGINNING OF A DRAG RESEARCH PROGRAM: RM–2

The difficulties associated with constructing and testing complete missiles such as the Tiamat, and even the RM-1, led Gilruth to search for ways of obtaining aerodynamic data at supersonic speeds by even simpler techniques. The success of the TPS-5 radar in directly measuring velocity led him to examine this radar further, and he found that it had the accuracy for determining acceleration as well as velocity. This alone, then, was sufficient to determine the variation of aerodynamic drag with speed or Mach number. When the missiles were launched almost vertically (at a 75-degree launch angle), the flight became so close to a straight line that detailed corrections for flight path variations were not required. The TPS-5 radar had a short range, however, and it was necessary to power the missile with a short-burning rocket motor. The 3.25-inch motor, already being used for training purposes, was found to be ideal for these early tests. Its small diameter and burning time of less than one second allowed supersonic flight to be achieved and the experiment to be concluded within radar range. A 58-pound model could be propelled to a Mach number of 1.4 with a single rocket.

The program for determining aerodynamic drag characteristics with simple models was called RM-2. The first RM-2 was launched on October 18, 1945. An early RM-2 model in its special launcher is shown in figure 33. The launcher was a simple guide rail with no moving parts, and was set at a fixed launching angle of 75 degrees.

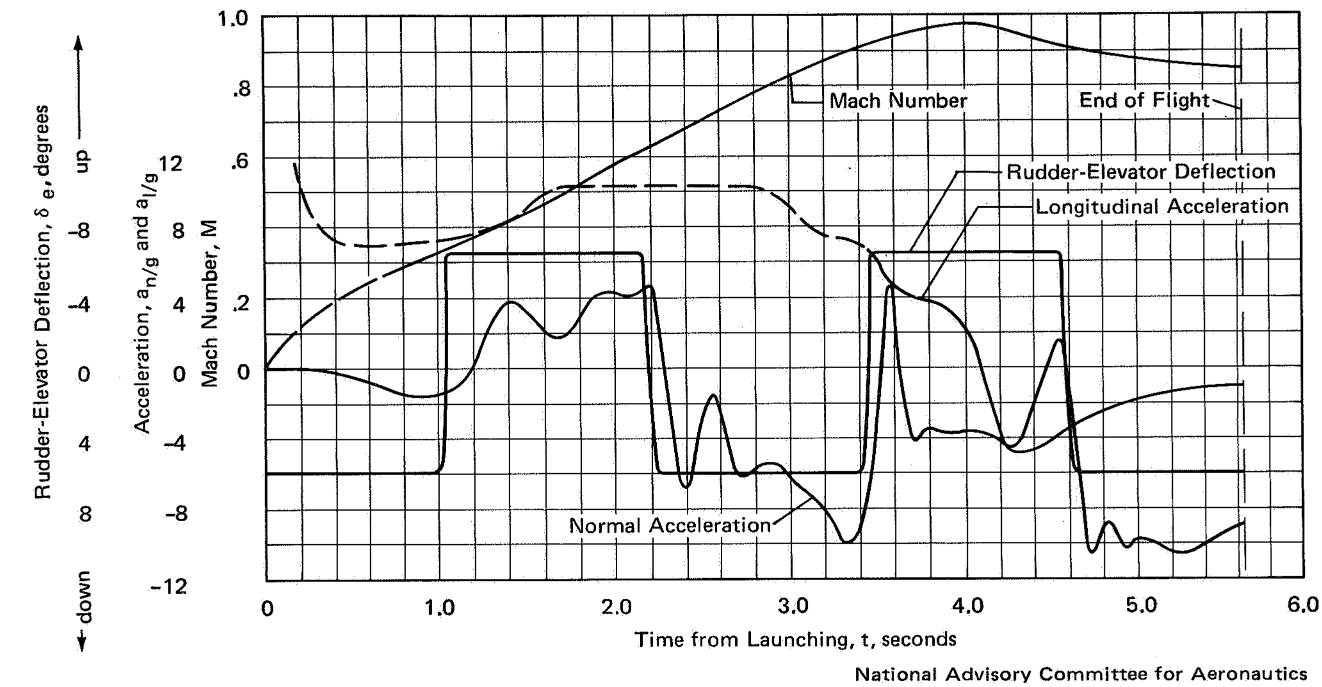


FIGURE 32. Flight test results showing variation in Mach number, rudder-elevator deflection, and normal and longitudinal accelerations with time, for 0.5-scale model Lark of standard configuration.

John Stack was an enthusiastic supporter of the program because it would allow a rapid evaluation of such variables as wing section, aspect ratio, sweepback, and wing taper from high subsonic speeds through the transonic speed range and into the low supersonic speed range. In the early tests, the fuselage and tail surfaces were kept the same, and the wings were varied. As shown in Appendix C, 146 models were flown in 1946 alone. The RM-2 designation later was changed to E2, which is used in the appendix listing.

Figure 34 shows a typical variation of velocity with time for one of the RM-2 models in flight. As the figure indicates, the entire test is over in less than 4 seconds. The slope of the curve is the acceleration or deceleration, while the area under the curve is a measure of the distance traveled along the flight path. From curves such as this, the variation of total drag coefficient[12] with Mach number may be determined for a number of different configurations, as shown in figure 35. In this figure, the drag coefficient is based on a constant exposed area of 200 square inches. The wing section was an NACA 65-009 at right angles to the leading edge of the wing in all cases (ref. 16). A significant effect of sweepback is clearly shown. The data are from the research reported by Alexander and Katz (ref. 20).

Inasmuch as tests were conducted with the RM-2 at low altitudes, the results corresponded to those obtained at high altitude with a much larger model, and therefore could be applied almost directly to missiles and airplanes in high-altitude flight.

The RM-2 models were constructed mostly of wood and could be made rather quickly. This, of course, was one of the models' great advantages. Normally, at least two models of each shape were

12. Drag Coefficient, $C_D = D/qS$, where D is drag, q is dynamic pressure, and S is wing area. $q = \frac{1}{2} \rho V^2$, where ρ is air densitv and V is velocity.

FIGURE 33. Project engineer Sidney Alexander adjusts typical RM–2 model on its special launcher at Wallops Island, October 1945.

flown, and the results were averaged to obtain greater accuracy. Because this was the first time that wing drag was easily obtainable in the transonic range, a quite extensive program was prepared. Five additional reports on these tests were prepared in 1946 (refs. 21 through 25).

Considerable difficulty was encountered with structural failures in the early phase of the program. There was no knowledge of the loads to be encountered in flight through the transonic range; design criteria had to be devised from the failures. The main cause of failure was wing flutter near the speed of

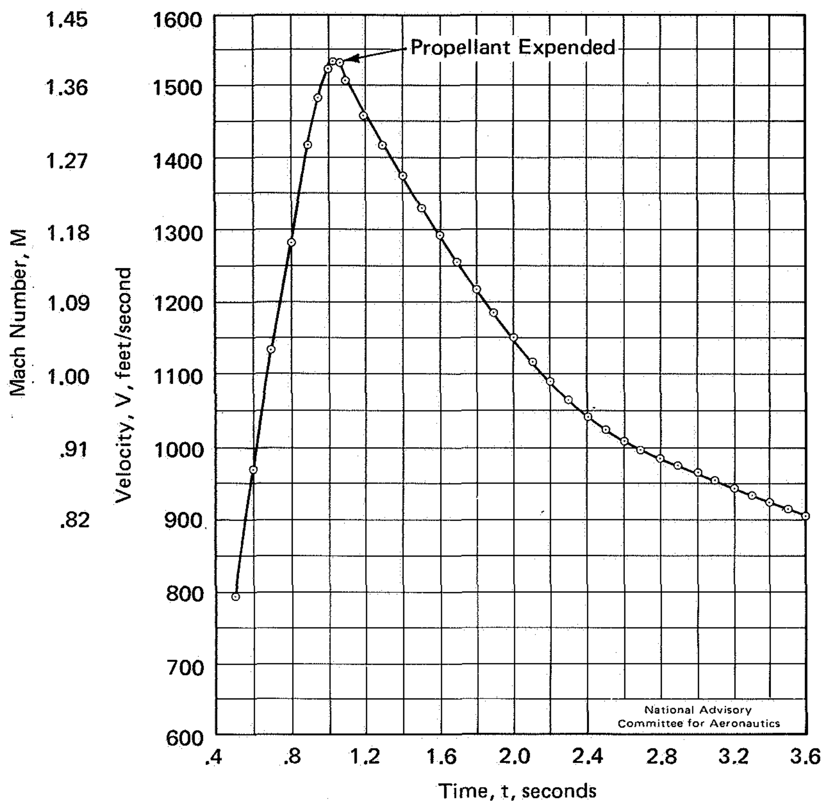


FIGURE 34. Typical RM–2 velocity-time curve.

sound. This flutter was usually an unstable high-frequency coupled bending and torsional oscillation of the wing that frequently resulted in its destruction. In flight, the failures would occur during the first second, and it was therefore difficult to determine the actual sequence of events.

Pending development of more refined calculation procedures, an empirical criterion related to torsional stiffness of the wing was developed from the rocket model data and was used quite successfully. (See refs. 26 and 27.)

The RM-2 models were constructed in the Langley wood shops. To keep construction time to a minimum, the use of metal was minimized. The thick, low-aspect-ratio wings were satisfactory when made entirely of wood; but as the wings became thinner or longer, metal had to be added to provide the stiffness required to overcome flutter.

To allow the use of simple woodworking tools in forming the wing sections, instead of the more time-consuming metal airfoil contouring machines, a "trick" was resorted to that really paid dividends. In order to ensure stiffness in the wood wings, sheets of metal were glued to the upper and lower surfaces. Before gluing the metal to the center core of the wing, the woodworkers glued thin sheets of wood veneer to both sides of the metal. This left an exposed wood surface which could then be contoured with woodworking tools. The gluing of wood to metal made use of the Chrysler Corporation Cycleweld gluing process, especially adapted to AFRS needs by Langley shop personnel. It was a real construction "breakthrough" in this period.

FREELY FALLING BODY PROGRAM

As has been mentioned earlier, the freely falling body program originated at Langley in 1944. Research Authorization 1224 was approved by the NACA on March 25, 1945, to cover the program. Heavy bomblike bodies were dropped from airplanes at high altitudes, and aerodynamic data were telemetered from the bodies as they accelerated through the speed of sound prior to impact. The bodies were tracked by SCR-584 radar.

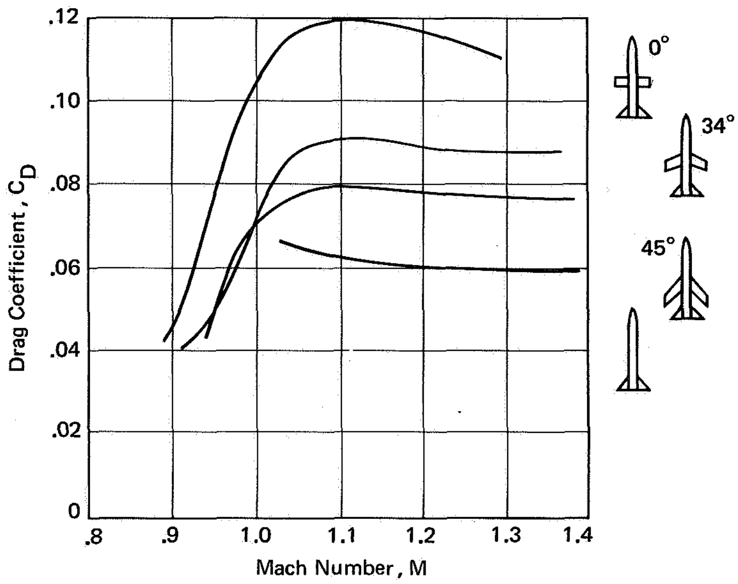


FIGURE 35. Graph of Wallops flight test data for RM–2 rocket models, showing effect on drag coefficient produced by varying sweepback of wings with aspect ratio of 2.7.

At first, the bodies were dropped on the regular Army bombing range on Plum Tree Island near Langley Field, Virginia. When the Auxiliary Flight Research Station was established on Wallops Island and the SCR-584 radar was moved there, the freely falling body program was moved to Wallops and the circular target area on the northern tip of Assawaman Island, just south of Wallops, was used as the impact point.

Although the program was under the direction of the Flight Research Division at Langley, Wallops was responsible for the tracking and data acquisition of the drops made there. For the sake of completeness, the entire program is discussed in this account.

In the beginning, the drop airplane used was a Boeing B-17, complete with crew on loan from the Army Air Forces. With the B-17, drops could be made from 35,000 feet, but this altitude presented a hazard to the crew; the B-17 was not pressurized and the crew had to use oxygen. In addition, the war was on and it was difficult to borrow the airplanes except for short periods. The B-17's were used in the technology development phase intermittently from May 31, 1944, to December 2, 1944, and again in another brief test period near the end of January 1945. The first instrumented body was dropped from a B-17 on December 1, 1944. Earlier, a Brewster F3A-1 airplane was used for environmental tests of the instrumented body, which was mounted on an external bomb rack for high-altitude, high-speed, and dive tests.

Because of the difficulties with "altitude sickness" experienced by the crew of the B-17, a B-29 was requested in March 1945 and was received on May 9, 1945. On October 19, 1945, this airplane was replaced by a second B-29 equipped with fuel-injection engines for better operation at high altitudes (see fig. 36). The plane was used until March 1948. After the war, it was no problem to obtain B-29's; in fact, they were loaned to Langley and were operated entirely by NACA crews shortly after the first one was received. Drops from a 40,000-foot altitude were made with the B-29.

For the first tests in the program, John Stack designed a high-speed body with a fineness ratio[13] of 6.0 (ref. 28). In designing the shape, Stack gave consideration to high critical Mach number, low nose angle for low drag above Mach 1, and low drag in the subcritical range. Figure 37 shows one of these bodies mounted on the bomb rack of a B-17.

Of six bodies dropped in late January 1945, two were instrumented. The telemeter transmitted data on total longitudinal acceleration, longitudinal force in the boom connecting the stabilizing tail

13. Fineness ratio is the ratio of length to maximum diameter.

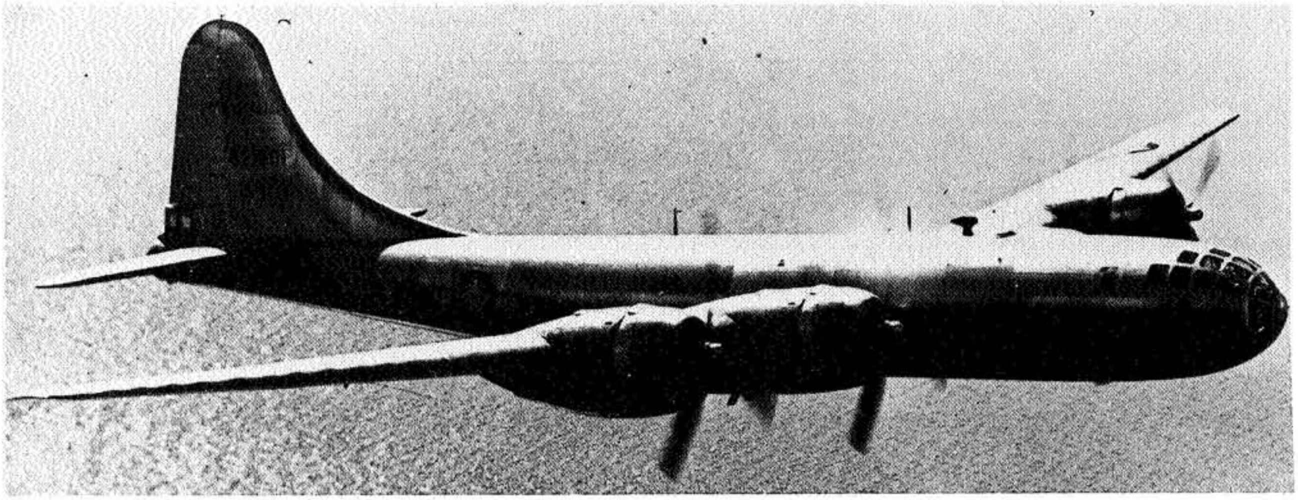


FIGURE 36. Boeing B–29 airplane used in freely falling body program, 1945.

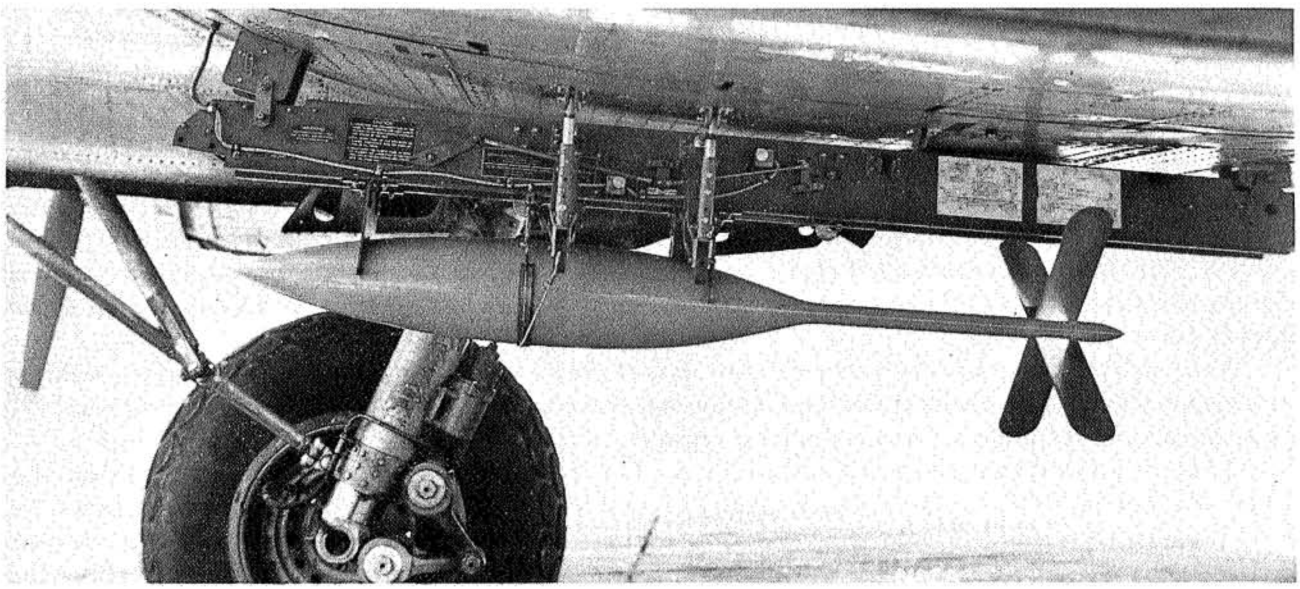


FIGURE 37. Typical freely falling body mounted on bomb rack of Boeing B–17 airplane, June 1944.

surfaces with the body, and a differential pressure reading between orifices on opposite sides of the body at its maximum diameter. The latter readings gave an indication of any yaw oscillation (ref. 29).

A second part of this program was the test of a body having a similar shape but a fineness ratio of 12.0. The longitudinal coordinates of the body of fineness ratio 6.0 were doubled to form the body of fineness ratio 12.0. Five of these bodies were dropped, and typical data from one of them are shown in figure 38. The total drag characteristics of the bodies of fineness ratios 6.0 and 12.0 are shown in figure 39. These were the first data to show the powerful effect of fineness ratio on body drag in the transonic range (ref. 30).

The second series of bodies dropped in this program was designed to verify the favorable effects of sweepback on wing drag, as predicted by R. T. Jones (ref. 31). In the first test, a wing with 0-degree sweepback was mounted on a body of fineness ratio 12; in the second, a wing of 45-degree sweepback was similarly mounted. In each case, the wing was attached to an internal balance to measure wing drag. The body had a cylindrical midsection to minimize interference effects between the wings and the body (ref. 32).

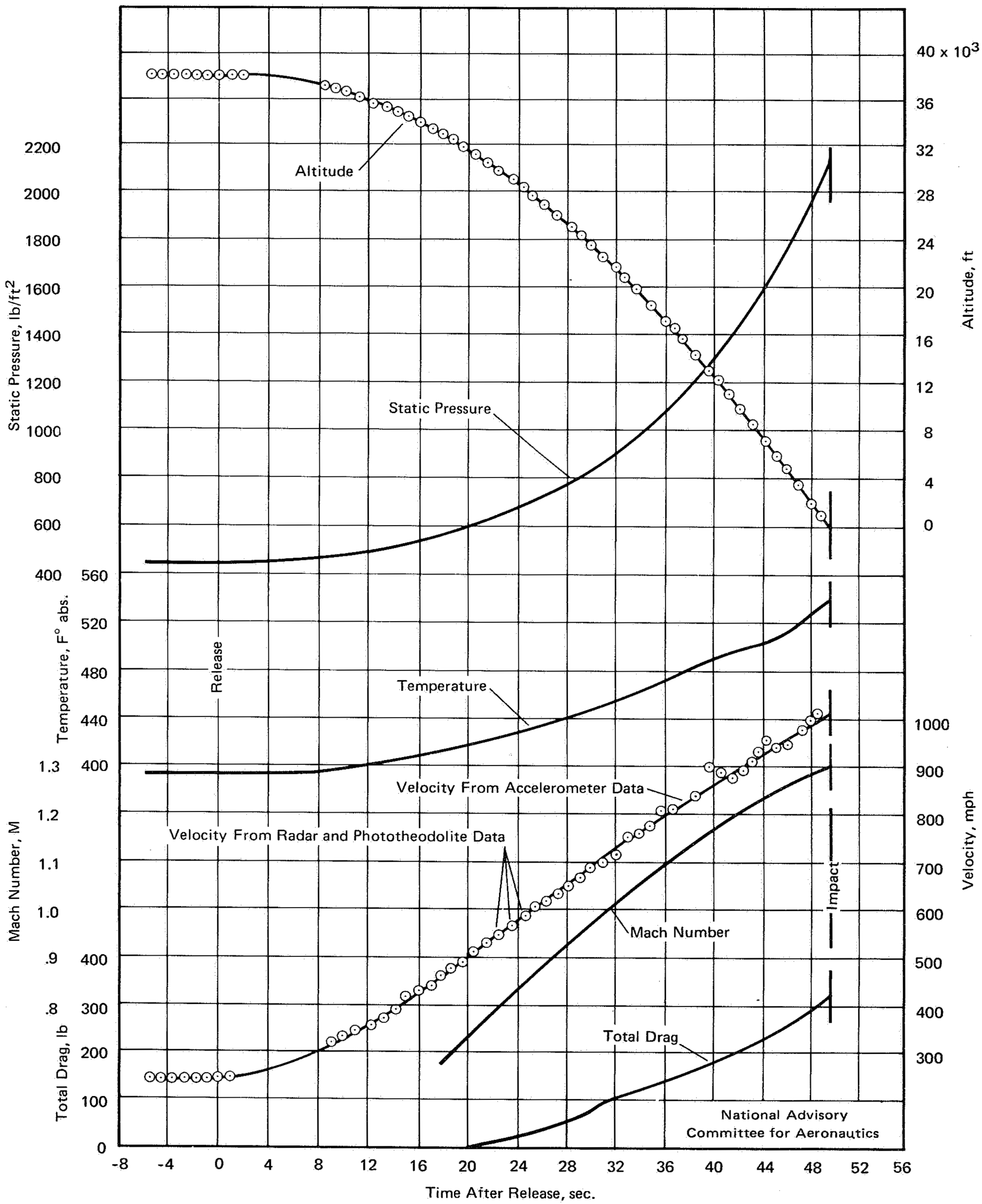


FIGURE 38. Time history of free fall of 805-pound test body with fineness ratio 12.

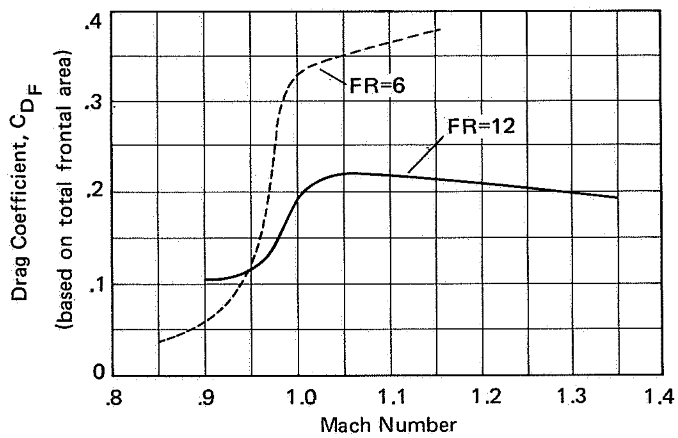


FIGURE 39. Graph of data from freely falling body tests showing effect of fineness ratio on drag of bodies.

The wing drag results are shown in figure 40, which compares 0-degree and 45-degree sweptback wings of 65-009 sections. Also shown is a calculated curve labeled "Jones' Theory." Although a large part of the drag reduction shown was the result of reduced thickness in the streamwise direction for the swept wing, reduction of the wing drag by a factor of almost 4 was certainly a verification of Jones' theory. (In this period, wing sections were normally given at right angles to the leading edge of the wing.)

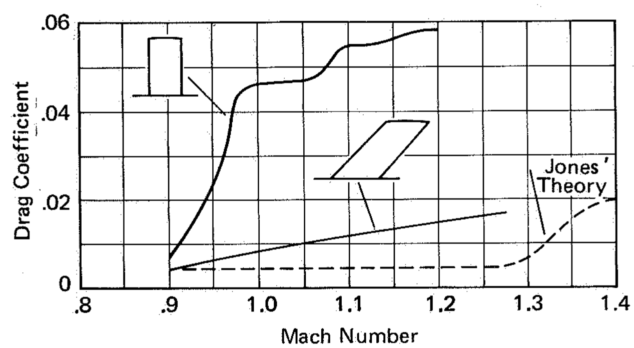


FIGURE 40. Wing drag results from tests using freely falling body technique: Comparison of drag of 0-degree sweepback with that of 45-degree sweepback.

The finding resulted in adoption of sweepback for almost all of the new high-speed airplane designs.

The usually conservative NACA report on the results concluded, "The appreciable magnitude of the drag reduction effected by the sweptback planform indicates that continued research is desirable to improve further the aerodynamic characteristics of such configurations." Dr. Lewis was impressed by the success of the technique and commented, "I want to congratulate the Flight Research Division and the Instrument Division on the excellent reporting of the flight test data. It is quite remarkable that so much information is obtained within a period of 52 seconds."[14]

The sweepback theory of Jones as outlined in his memorandum of March 5, 1945, was prepared as a technical paper and was transmitted to the military services in June 1945 (ref. 33). By this time, experimental verification of the theory had been obtained by both the wing-flow and freely falling body techniques, but the report was not held up to incorporate the experimental results. The first combined presentation of the theory and experimental confirmation was made at an Army-Navy-NACA-Industry Seminar on High-Speed Aerodynamics at Wright Field, Ohio, on September 6, 1945. A paper

14. NACA letter written by G. W. Lewis, Director of Aeronautical Research, to Langley on July 28, 1945, with regard to MR L5G23a.

by Jones gave the practical significance of the new theory and contained the comparison of theory with the freely falling body results shown herein in figure 40 (ref. 34). The curve labeled "Jones' Theory" in figure 40 was derived from the pressure drag measured for the unswept wing by reducing the pressure drag increments by a factor of $\cos^3\Lambda$ (where Λ is the sweepback angle) and plotting the resulting values at Mach numbers increased by $1/\cos\Lambda$. This derives from the consideration that the pressure drag is related only to the component of flow at right angles to the leading edge for a constant chord infinite wing. The somewhat higher values measured in flight for the swept wing were the result of fuselage interference and wing-tip effects. This finding of Jones was the immediate result of an extension of his earlier theoretical treatment of triangular wings, which he was asked to examine in connection with the Griswold triangular-wing version of the Tiamat guided missile (ref. 35).

By the time of the seminar at Wright Field, the war was over and the vast amount of research conducted by the Germans had been uncovered. At the seminar, Russell G. Robinson, NACA Headquarters, who had replaced H. J. E. Reid of Langley with the Alsos mission to Europe, presented a paper outlining the German contribution to high-speed aerodynamics (ref. 36). Robinson pointed out that the Germans had followed up Busemann's "hint" of 1935 and by 1940 had confirmed the advantages of sweep at high speed. "Wing sweep, either back or forward, is the most thoroughly developed new idea to come out of Germany and the one that leads to a great deal of 'Why didn't I think of it earlier?' Sweep was a characteristic employed in almost all high-speed aircraft being planned in Germany in the closing days of the war."

The Army Air Forces criticized the NACA in October 1945 for not releasing Jones' sweepback theory earlier. General A. R. Crawford, Chief of the Production Division, wrote Dr. Hunsaker that when ATSC personnel visited Langley in March 1945 to discuss the design of the XS-1 airplane (MX-653), no mention of the new theory was made, and the airplane "was laid out with a straight wing, while it now appears that the design can be greatly improved by use of a sweptback wing. Such a change at this time must, however, delay the project and increase the cost to the Government. Likewise, the XP-86, the XB-47, and other projects have been retarded by the delay in making this same information available." Later, the research airplane program was expanded by the addition of sweptback-wing designs by both the Army Air Forces and the Navy.

Floyd L. Thompson, Assistant Chief of Research at Langley, prepared an answer to General Crawford on the position of the NACA. Jones' theory was considered so radical that its general release in March 1945 without experimental verification was not felt to be justified. To have recommended changing airplane configurations from straight to swept wings without verification could have been a "blunder of the greatest magnitude. . . . Not only was experimental evidence lacking but our best theoretical minds[15] were divided as to the validity of the theory" (ref. 37).

In 1946, Jones was presented the Sylvanus Albert Reed award for "his contribution to the understanding of flow phenomena around wings and bodies at speeds below and above the speed of sound."

The first freely falling body test which verified Jones' sweep theory was the beginning of a continuing program on wing and body combinations. Wings of different aspect ratio and sweepback were investigated for NACA 65-009, 65-006, and circular-arc sections (refs. 38 and 39). Later, a test was made with a 45-degree sweptback wing mounted in a forward location on a streamlined body of fineness ratio 12.0, which was selected as being more representative of a supersonic airplane than the earlier cylindrical body. Although interference effects were greater than those with the cylindrical body, the considerable benefits of sweepback were still evident (ref. 40).

A few flights were made to determine the effects of sweepforward on the drag of wings. The Army Air Forces were interested in such information in connection with the Consolidated-Vultee XA-44 airplane under development. Sweptforward wings were to be tested on the Langley drop body, and a complete model of the airplane was to be dropped later, according to a request of the Army made on January 7, 1946. The complete model with 30-degree sweepforward was tested in August 1946. By this

15. In the letter transmitting Jones' report to NACA Headquarters, it was stated that "Dr. Theodore Theodorsen does not agree with the arguments presented and the conclusions reached and accordingly declined to participate in editing the paper." Theodorsen was Langley's foremost theoretical physicist at that time.

time, the XA-44 had become the XB-53 airplane. No formal report was prepared, but the test results were given to the interested parties. In the general program, the sweptforward wing mounted on the Langley body of fineness ratio 12.0 showed some drag reductions over a straight wing, but they were not as great as those of the sweptback wing (ref. 41). The interest in sweepforward, which stemmed from the more favorable low-speed stall characteristics, was short-lived because sweptforward wings present a greater structural divergence problem.

LIVING CONDITIONS

When Langley personnel established the launch base on the southern end of Wallops Island, it was a barren wilderness of sand and scrub growth populated by wild ponies, flies, and mosquitoes. Everything had to be moved in. Living accommodations had to be provided for two groups of personnel: the permanent complement on the island and the transient personnel from Langley.

Except for a few guards, who lived on the island and doubled as cooks and "hotel staff," the permanent crew had to be transported to and from the island daily. For them, "portal-to-portal" pay was the rule; that is, their day began at the Mainland Dock and ended at the same dock in the afternoon. During the day, the needs of these people were the same as those of the transients. After working hours, however, the permanent crew were on their own. They had to furnish their own homes or rooms.

On the Eastern Shore, living conditions were poor for nonresidents. There were few homes for sale there and practically none were available for rent. When the NACA moved in, the people from Chincoteague NAAS had been there for some time and had already taken over practically all available accommodations. Because of this, most of the NACA employees were recruited from among the people who lived up and down the Shore from Wallops a distance as great as 20 miles. It was difficult to entice professional people, either engineers or electronics technicians, to move there. The area was mostly a farming and fishing community. Chincoteague was the largest town, and it had a population of only 2,500 people, approximately. Attempts were made without success to get approval for construction of a Government housing project. In the summer of 1946, some houses became available from the Government wartime housing project of Copeland Park in Hampton. The Federal Housing Authority agreed to make these available to communities on the Eastern Shore, provided the communities furnished the land and utilities. As an NACA representative, G. S. Brown discussed this possibility with the towns of Parksley and Onancock, and both expressed an interest. The houses were not the answer, however, and the nonresident employees eventually established themselves in one of the communities by purchasing or building homes of their own. Some of the professionals selected the somewhat larger town of Pocomoke, Maryland, despite its distance of 20 miles from Wallops.

For transient personnel required during launch operations at Wallops, the first plan was to find accommodations on the mainland and transport them to Wallops Island and the tracking station as needed. But a survey made by Ray Hooker showed that very few rooms were available. There were three small hotels in the town of Chincoteague and some tourist cabins at Whispering Pines on U.S. Highway 13. These were sized to accommodate the normal transient fishermen, crop buyers, and salesmen, with no room for an influx of NACA personnel. In addition, the local people were reluctant to take in boarders or roomers. To make it even more difficult, no public transporation was available; this meant that the NACA would have to provide a large number of automobiles or station wagons. Hooker summed it up thus: "a survey of the eating and housing accommodations available, distances involved, and types of transportation available make it appear advisable to provide a minimum of sleeping and eating accommodations for NACA personnel involved in launching operations in the Chincoteague area. Failure to provide these facilities will result in considerable loss of time and inefficient operation" (ref. 42).

A plan proposed by Langley to NACA Headquarters on June 29, 1945, was adopted. The NACA Exchange, which operated the cafeteria at Langley, would establish a branch at Wallops Island and would employ a cook and provide food and lodging services on a cost basis. The lodging quarters were set up at first in tents, and then in Quonset huts. One of these huts is shown in figure 41. Figure 42 is a photograph of the interior of the hut, showing the sleeping cots. The cooking and eating facilities are shown in figures 43 and 44. The group shown in figure 45 in front of the Quonset hut consists of

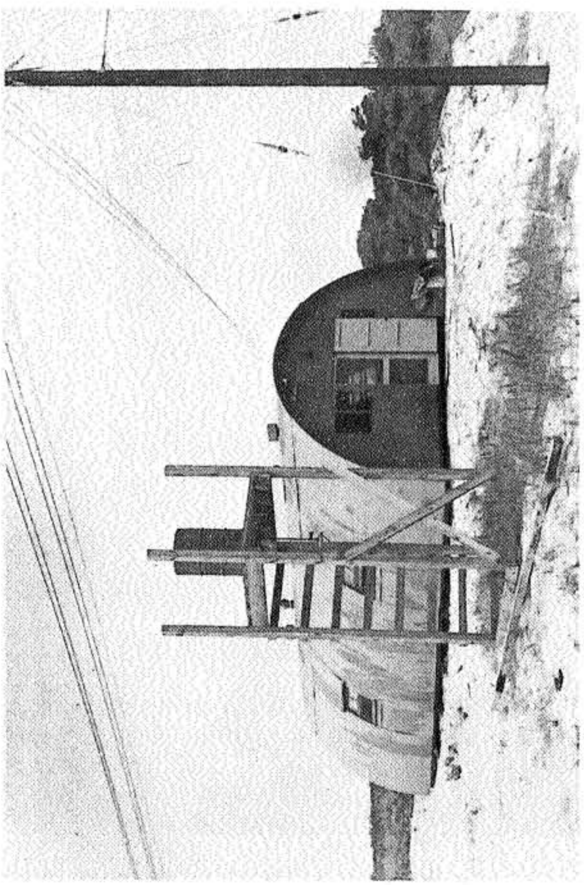


FIGURE 41. Quonset hut hotel at Wallops, August 20, 1945.

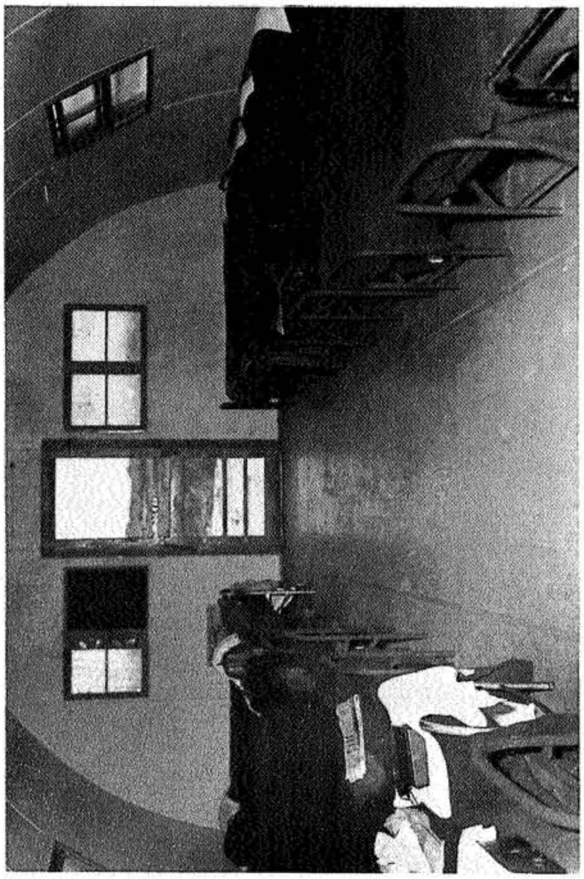


FIGURE 42. Bedroom wing of Wallops hotel, August 20, 1945.

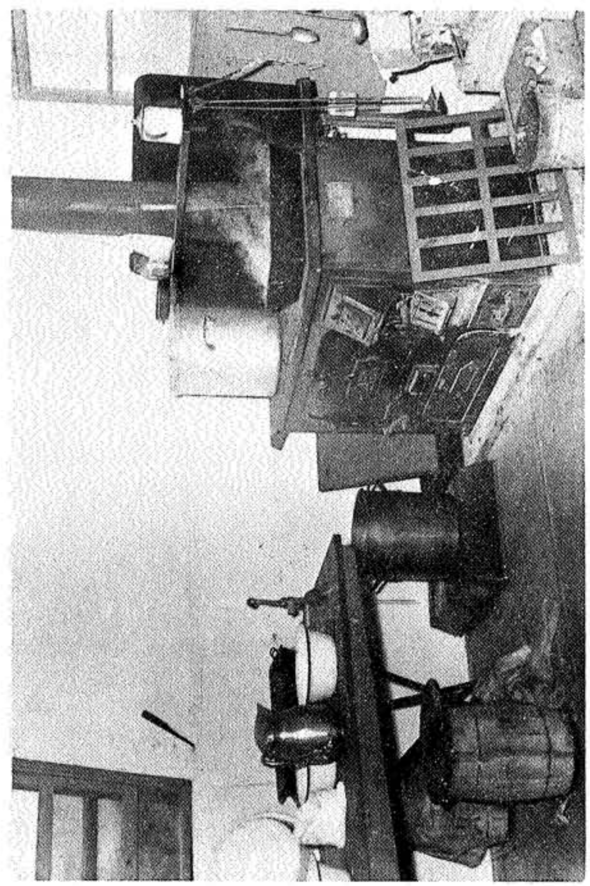


FIGURE 43. Kitchen wing of Wallops hotel, August 20, 1945.

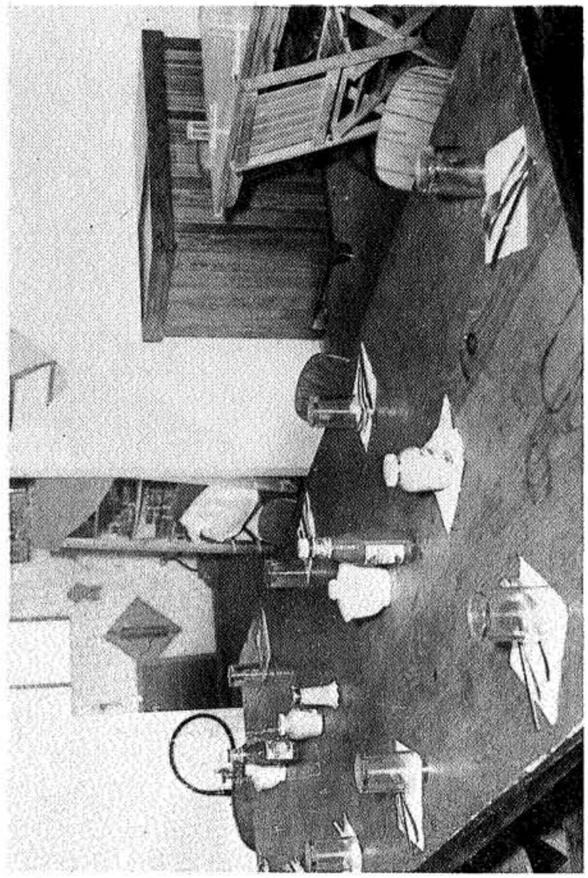


FIGURE 44. Dining area of Wallops hotel, August 20, 1945.

FIGURE 45. Staff members from Langley at Wallops for a flight operation, October 1945. Group is shown in front of the Wallops hotel. Back row: J. Stack, I. H. Abbott, H. J. E. Reid, R. R. Gilruth, R. W. Hooker, P. F. Fuhrmeister, C. A. Taylor, T. Haynes, unidentified staff member, R. A. Gardiner, and W. E. Norfolk. Front row: F. W. Baynes, C. L. Seacord, M. J. Stoller, S. Alexander, F. L. Plotz, W. Tracy, R. A. Everett, R. R. Lundstrom, M. Pitkin, H. D. Garner, and S. C. Cavallo.

personnel from Langley on hand for a flight operation. From left to right, standing in the back row, are Stack, Abbott, Reid, Gilruth, and Hooker, representing management. The name "Club 75" was given the hotel because a bed or any meal cost 75 cents each. To begin the service, G. S. Brown was placed in charge of the Exchange Branch. In submitting the plan to Washington, H. J. E. Reid stated: "For operations requiring personnel to remain on Wallops Island for several days in succession, the practice of sending in box lunches is considered to be unsatisfactory."

By the end of August 1945, a third Quonset hut was needed for sleeping. Personnel using the facilities complained of (1) crowded sleeping conditions, (2) inadequate washing facilities, (3) poorly prepared food, (4) high cost of food, and (5) high cost of lodging. Little improvement was made until the permanent facilities were completed late in 1946.

A good water supply was a necessity. The early system of water barrels and hauled-in water was replaced as soon as possible by shallow wells with a pitcher pump. Representatives of the Layne-Atlantic Corporation were of the opinion that the shallow wells would soon become contaminated by salt water, and that a deep well driven to 1,400 feet would be required to get fresh water in quantity. Such a well was estimated to cost between $50,000 and $75,000. Because of this high estimated cost, Langley considered installing a salt water distillation system. The shallow wells, however, held up until July 1946, when, as a part of the permanent construction, a trial deep well struck a good supply of fresh water at 147 feet. This well is still providing good water for the island.

Power was supplied by a 15-kw diesel-powered generator located in one of the temporary sheds. As the operations at Wallops expanded, an additional 15-kw generator and two 30-kw generators were added. Attempts to get a powerline installed to connect with the Eastern Shore Public Service Company were frustrated by the compay's inability to supply the required amount of power without extensive expansion of its equipment at a cost estimated at $100,000. Wallops generated its own power until the Public Service Company enlarged its facilities at its own expense; arrangements were finally made and Wallops began using power from this source on December 15, 1948.

For the men from Langley who were sent to Wallops on travel, living conditions in 1945 were practically the same as "camping out." From their $6 per diem travel allowance, they had to pay for use of the cots that served as beds, and for their food, which sometimes was not very good. In connection with the per diem rate, Elton W. Miller, Chief of Langley's Administrative Department, felt that "because of the hardships and difficulties of getting accommodations, the per diem should be made as generous as could be lawfully, so $6.00 per diem is recommended." (ref. 43).

Aside from the desolation, primitive living conditions, and isolation from civilization, the men could have enjoyed their trips to Wallops Island if it had not been for the insects. As pointed out by Ray Hooker in his request of July 20, 1945, for aerial spraying with DDT, "it has been noted in the course of our operations there that insects, particularly mosquitoes, sand flies, and horse flies, are prevalent in enormous quantities. These insects are so numerous as to cause great loss of working time. The nuisance is so great that it is difficult to obtain personnel and we have already had resignations as a result of this condition."

It was believed that the herd of 200 wild ponies on the island would not be harmed by the DDT spray. An Associated Press story, dated August 20, 1945, expressed concern that DDT was harmful to birds, fish, oysters, and beneficial insects. "If used in excess," the account said, "it will be like scalping to cure dandruff."

The summer of 1945 was over before approval for spraying was obtained. The following spring, the effort was resumed with success. A jeep was equipped with a nozzle for local spraying, and the Navy started aerial spraying with DDT. The wild ponies were moved to Assateague Island, but the flies remained behind. The insects were reduced in number, but they remained a problem despite the spraying.

RELATIONS WITH THE NAVY AT CHINCOTEAGUE

During the year and a half of operations with temporary facilities at Wallops Island, relations with the Navy at Chincoteague NAAS continued to be cordial and helpful. The Naval Aviation Ordnance Test Station (NAOTS) was established on the air station and BuOrd and BuAer used the station jointly. The commanding officer was Captain W. V. R. Vieweg, from BuOrd. The Navy took no action regarding acquisition of Wallops Island until late in this period, so there was no interference.

An attempt to have a BuAer project number assigned to Chincoteague to cover its support of NACA activities at Wallops was unsuccessful, although BuAer had issued a project number to the Patuxent NAS earlier for similar assistance. On May 13, 1946, Rear Admiral H. B. Sallada, BuAer, wrote Dr. Hunsaker, "NACA can call on the Bureau for anything available to us in the way of helpful service." And on August 16, 1946, Rear Admiral L. C. Stevens, Chief of BuAer, authorized the commanding officer at NAAS Chincoteague to continue giving the NACA services at Wallops as before. He left the subject of a project number up to the commanding officer. Captain Vieweg did not think a number was necessary, but did ask the NACA for its specific needs.

Langley took this opportunity to put on record the various services required of NAAS: (1) forty 3.25-inch rockets per month, (2) twelve 5-inch HVAR rockets immediately, (3) emergency repair parts for equipment, (4) special transportation, and (5) use of NAAS special facilities. It was pointed out that assistance in the storage of rocket motors or the services of ordnance men in firing rockets would not be required in the future (ref. 44).

Although the establishment of NAOTS at Chincoteague caused no interference with the NACA, NAOTS had trouble with local citizens over the plan to launch any kind of missile or to fire guns from the mainland base out over Wallops Island and the ocean. Captain Vieweg telephoned G. S. Brown and asked him to help calm the citizens of Chincoteague. The citizens had sent a group to Washington to see Senator Harry F. Byrd on May 31, 1946, to try to stop this part of the NAOTS project. As noted in Brown's diary, he attended a town hall meeting on June 3, 1946. It seemed from articles in the local paper that the citizens were aroused by a letter to the editor from C. C. Bye, President of Wallops Island Association, who objected to the Navy's taking Wallops Island away from them. Employees of the NACA cooperated with the Navy by trying to assure the people of Chincoteague that they would not be in danger from NAOTS, but, in fact, would benefit from the expansion.

In a letter to Congressman S. Otis Bland, in which Vice Admiral G. F. Hussey discussed the whole situation, it is interesting to note that Admiral Hussey stated, "all employees can use Wallops for recreation when not in use for tests." Members of NACA management did not have the same opinion; they objected to any unofficial use of Wallops Island.[16]

Although the actions of the Wallops Island Association did not prevent the Navy from condemning and taking over the northern part of Wallops Island by lease in 1946, the opposition did force NAOTS to move their firing point from a spot adjacent to NAAS to Wallops Island proper, to eliminate any threat to the town of Chincoteague.

Pending the condemnation of the Wallops Island area for NAOTS, Captain Vieweg asked permission of H. J. E. Reid, Langley, for use of a 100-yard strip of land on the area leased by the NACA, to test a "rocket loading machine for use in aircraft." Reid gave his permission and sent Ray Hooker to see Vieweg to discuss arrangements in detail. At this visit, Hooker learned that NAOTS still planned extensive construction on Wallops Island, such as a 3-mile-long railroad for carrying a glide-bomb target, and a 16-inch gun for launching guided missiles (ref. 45). This was the beginning of a period of potential interference between the NACA and NAOTS.

16. All letters regarding this incident were published in the July 26, 1946, edition of *The Eastern Shore News,* Onancock, Virginia.

References

1. Whitelaw, Ralph T.: *Virginia's Eastern Shore, A History of Northampton and Accomack Counties.* Virginia Historical Society, Richmond, Va., 1951, p. 1242.
2. "Program for Research on High-Speed Pilotless Aircraft," material prepared for use of J. W. Crowley at Apr. 18, 1945, meeting of NACA Special Committee on Self-Propelled Guided Missiles.
3. Hooker, Ray W., Memorandum for Files, "Initial Operations on Wallops Island Launching Site," June 29, 1945.
4. Shortal, Joseph A.; and O'Sullivan, William J., Jr.: *Instrumented Models in Free Flight.* Section M, Vol. VIII, *High Speed Problems of Aircraft and Experimental Methods.* Princeton University Press, 1961.
5. Hagginbothom, W. K., and Templeton, H. C., Memorandum of June 28, 1945, to Ray W. Hooker, "Suggestions for Operations at Auxiliary Flight Station."
6. Seacord, Charles L., Jr.: *Results of First Flight Test of MX–570 Tiamat.* NACA MR L5H29a for Army Air Forces.

7. Seacord, Charles L., Jr.: *Launching Technique for Two-Stage Missiles as Developed in Tests of MX–570.* NACA MR L6C25 for Army Air Forces.
8. Seacord, Charles L., Jr.: *Results of Flight Tests of MX–570 (Model B—Four Wing Tiamat).* NACA MR L6B13a for Army Air Forces.
9. Pitkin, Marvin; and Seacord, Charles L., Jr.: *Correlation of the Computed Rolling Motion of the MX–570 (Tiamat Model B) Guided Missile With That Obtained in Flight.* NACA MR L6C09 for Army Air Forces.
10. Seacord, Charles L., Jr.; and Teitelbaum, J. M.: *Results of Flight Tests of an Automatically Stabilized Model C (Sweptback) Four-Wing Tiamat.* NACA MR L7B03 for Army Air Forces.
11. Teitelbaum, Jerome M.; and Seaberg, Ernest C.: *An Experimental Investigation of a Gyro-Actuated Roll Control System Installed in a Subsonic Test Vehicle.* NACA RN L9B24a.
12. Pitkin, Marvin; Gardner, William N.; and Curfman, Howard J., Jr.: *Results of Preliminary Flight Investigation of Aerodynamic Characteristics of the NACA Two-Stage Supersonic Research Model RM–1 Stabilized in Roll at Transonic and Supersonic Velocities.* NACA RM L6J23.
13. Pitkin, Marvin; Gardner, William N.; and Curfman, Howard J., Jr.: *Observations on an Aileron-Flutter Instability Encountered on a 45° Sweptback Wing in Transonic and Supersonic Flight.* NACA RM L6L09.
14. Gardner, William N.; and Curfman, Howard J., Jr.: *Flight Investigation to Determine the Hinge Moments of a Beveled-Edge Aileron on a 45° Sweptback Wing at Transonic and Low Supersonic Speeds.* NACA RM L7H26.
15. Stone, David G.; and Mitcham, Grady L.: *Flight Test Evaluation of the Longitudinal Stability and Control Characteristics of 0.5-Scale Models of the Fairchild Lark P/A Configuration.* NACA MR L6H22.
16. Stone, David G.: *Flight Test Evaluation of the Longitudinal Stability and Control Characteristics of 0.5-Scale Models of the Fairchild Lark Pilotless Aircraft Configuration. Model With Wing Flaps Deflected 15°.* NACA RM L6J28a.
17. Stone, David G.: *Flight Test Evaluation of the Longitudinal Stability and Control Characteristics of 0.5-Scale Models of the Fairchild Lark P/A Configuration. Static Longitudinal Stability of Models With Wing Flap Deflections of 0° and 15°.* NACA RM L6L17a.
18. Stone, D. G.: *Flight Test Evaluation of the Longitudinal Stability and Control Characteristics of 0.5-Scale Models of the Fairchild Lark P/A Configuration. Standard Configuration With Wing Flaps Deflected 60° and Modem Having Tail in Line With Wings.* NACA RM L7F17.
19. Stone, David G.: *Flight-Test Evaluation of the Longitudinal Stability and Control Characteristics of 0.5-Scale Models of the Lark Pilotless-Aircraft Configuration.* NACA RM L7I26.
20. Alexander, Sidney R.; and Katz, Ellis: *Drag Characteristics of Rectangular and Sweptback NACA 65–009 Airfoils Having Aspect Ratios of 1.5 and 2.7 as Determined By Flight Tests at Supersonic Speeds.* NACA RM L6J16.
21. Alexander, Sidney R.: *Drag Measurement of a 34° Sweptforward and Sweptback NACA 65–009 Airfoil of AR 2.7 as Determined By Flight Tests at Supersonic Speeds.* NACA RM L6I11.
22. Alexander, Sidney R.: *Drag Measurements of Symmetrical Circular Arc And NACA 65–009 Airfoils of AR 2.7 as Determined By Flight Tests at Supersonic Speeds.* NACA RM L6J14.
23. Alexander, Sidney R.; and Katz, Ellis: *Flight Tests to Determine the Effect of Length of a Conical Windshield on the Drag of a Bluff Body at Supersonic Speeds.* NACA RM L6J16a.
24. Alexander, Sidney R.: *Results of Tests to Determine the Effect of a Conical Windshield on the Drag of a Bluff Body at Supersonic Speeds.* NACA RM L6K08a.
25. Alexander, Sidney R.: *Drag Measurements of a Sweptback Wing Having Inverse Taper as Determined By Flight Tests at Supersonic Speeds.* NACA RM L6L30.
26. Seacord, Charles L., Jr.: "Experiences With Wing Torsional Requirements." Paper presented at NACA Conference on Supersonic Aerodynamics, Langley Field, June 19–20, 1947.
27. Budiansky, Bernard; Kotanchik, Joseph N.; and Chiarito, Patrick T.: *A Torsional Stiffness Criterion for Preventing Flutter of Wings of Supersonic Missiles.* NACA RM L7G02.
28. Stack, John, Memorandum to Chief of Research, Feb. 18, 1944, regarding bodies for high-speed drop tests.
29. Bailey, F. J., Jr.; Mathews, Charles W.; and Thompson, Jim Rogers: *Drag Measurements at Transonic Speeds on a Freely Falling Body.* NACA ACR L5E03.
30. Thompson, Jim Rogers; and Mathews, Charles W.: *Drag Measurements at Transonic Speeds on a Freely Falling Body of Fineness Ratio 12.* NACA MR L5L14.
31. Jones, Robert T., Memorandum to Chief of Research, Mar. 5, 1945, "Proposed Tests of Wing Shapes Designed to Minimize Compressibility Effects."
32. Mathews, Charles W.; and Thompson, Jim Rogers; *Comparative Drag Measurements at Transonic Speeds of Straight and Sweptback NACA 65–009 Airfoils Mounted on a Freely Falling Body.* NACA MR L5G23a. Also released as NACA TR 988.
33. Jones, Robert T.: *Wing Plan Forms For High-Speed Flight.* NACA CMR L5F21. Reissued as NACA ACR L5G07; NACA TN 1033, Mar. 1946; and NACA TR 863, 1947.
34. Jones, Robert T.: "Sweepback." Paper presented at Seminar on High-Speed Aerodynamics, Wright Field, Sept. 6, 1945.
35. Jones, Robert T.: *Properties of Low-Aspect-Ratio Pointed Wings at Speeds Below and Above the Speed of Sound.* NACA ACR L5F13. Reissued as NACA TN 1032, Mar. 1946; and NACA TR 835, 1946.
36. Robinson, Russell G.: "The German Contribution." Paper presented at Seminar on High-Speed Aerodynamics, Wright Field, Sept. 6, 1945.
37. Thompson, Floyd L., Asst. Chief of Research, Memorandum of Oct. 31, 1945, regarding sweptback wings.
38. Mathews, Charles W.; and Thompson, Jim Rogers: *Drag Measurements at Transonic Speeds of NACA 65–009 Airfoils Mounted on a Freely Falling Body to Determine the Effects of Sweepback and Aspect Ratio.* NACA MR L6A31. Reissued as NACA RM L6K08c.

39. Thompson, Jim Rogers; and Marschner, Bernard W.: *Comparative Drag Measurements at Transonic Speeds of an NACA 65−006 Airfoil and a Symmetrical Circular-Arc Airfoil.* NACA RM L6J30.
40. Mathews, Charles W.; and Thompson, Jim Rogers: *Free-Fall Measurements at Transonic Velocities of the Drag of a Wing-Body Configuration Consisting of a 45° Sweptback Wing Mounted Forward of the Maximum Diameter on a Body of Fineness Ratio 12.* NACA RM L6L26.
41. Thompson, Jim Rogers; and Mathews, Charles W.: *Drag of a Wing-Body Configuration Consisting of a Sweptforward Tapered Wing Mounted on a Body of Fineness Ratio 12 Measured During Free Fall at Transonic Speeds.* NACA RM L6L24.
42. Hooker, Ray W., Memorandum to Engineer-in-Charge, June 22, 1945, regarding housing and eating facilities in the Chincoteague area.
43. Miller, Elton W., Memorandum for Files, June 7, 1945, regarding conference on administrative problems of the AFRS.
44. Hooker, Ray W., Memorandum to Chief of Research, Sept. 4, 1946, regarding materials and services needed by Wallops from Chincoteague NAAS.
45. Hooker, Ray W., Memorandum to Engineer-in-Charge, Nov. 19, 1946, regarding visit to Captain W. V. R. Vieweg, NAOTS, Chincoteague.

CHAPTER 4

FIRST YEAR WITH PERMANENT FACILITIES: 1947

The completion of the first permanent facilities on Wallops Island was impatiently awaited by all personnel. As soon as each unit was completed, it was immediately occupied. The construction took so long, however, that before it was completed the need for additional facilities was evident.

The funds for the first construction, appropriated while World War II was in full swing, had been obtained without difficulty. When the war ended in August 1945, Congress eliminated all requests for new construction from the 1946 appropriation, and no funds were requested by the NACA for Wallops construction in the 1947 budget. As a result, many of the temporary facilities continued to be used even after the permanent structures were completed.

DESCRIPTION OF PERMANENT FACILITIES

On August 14, 1945, the day the Japanese surrendered, bids were opened at Langley for the construction of permanent facilities on Wallops Island. A group composed of S. L. Butler, Procurement Officer, J. C. Messick, Contracting Officer for new construction, and E. H. Chamberlin of NACA Headquarters were on hand at the bid opening, which went ahead as scheduled even though the Government had declared a holiday to celebrate the surrender.[1] Doyle and Russell of Norfolk, Virginia, were the low bidders and were awarded a contract shortly thereafter. This contract covered most of the items under Project 371-B, -C, and -D, discussed earlier.

A summary listing of the original breakdown of funds from the 1945 First Deficiency Appropriation, as compared with the actual expenditures, is given in table II. It will be noted that the original plan for buildings was followed rather closely, with cost overruns being financed from funds planned for the purchase of missiles as well as from the contingency fund. By the end of 1947, it was concluded that construction costs on Wallops Island were approximately 45 percent higher than those at Langley because of the island's isolation and transportation difficulties.

Of the $4,100,000 appropriated for Langley, $884,627 was expended on the 4-foot Supersonic Tunnel (Project 363); $1,361,996 was expended at Langley Field for the PARD laboratory and supporting shops; $1,850,006 was expended at Wallops; and $3,371 was unexpended and returned to the Treasury. The funds mentioned covered equipment for the facilities, as well as construction.

The expenditures at Langley for PARD (Project 371 A) covered extension of the Model Shop and construction of a Missile Construction Shop, modified to include the Pilotless Aircraft Research Laboratory as an extension to the new shop building. This was the only appreciable change in the original plans at Langley.

1. The author's interview with S. L. Butler, Langley Procurement Officer, April 28, 1966.

TABLE II. DISPOSITION OF 1945 FIRST DEFICIENCY APPROPRIATION

Number on Figure 46	*Project Number*	*Item*	*May 1945 Estimate*	*Final Expenditure*
	371	Auxiliary Flight Research Station	3,060,000	3,212,002
	A.	Langley Field Station	1,087,300	1,361,996
	1.	Model Shop Extension	(151,000)	(152,581)
	2.	Missile Construction Shop	(485,000)	(781,033)
	3.	Equipment	(451,300)	(428,382)
	B.	Receiving Station	(105,000)	(22,318)
	C.	Launching Site	892,200	1,622,484
3	1.	Launching Ramp	(15,000)	(39,003)
5	2.	Launching Platform	(10,000)	(1)
15	3.	Final Assembly Building	(232,500)	(195,267)
19	4.	Office and Radio Building	(28,000)	(61,018)
18	5.	Living Quarters	(44,000)	(97,050)
16	6.	Oil Tanks	(20,000)	(29,104)
2	7.	Powder and Chemical Storage	(25,000)	(11,742)
8	8.	Loading Room	(7,500)	(1)
4	9.	Bombproof Shelter	(9,000)	(3,550)
1, 7, 11	10.	Site Purchase or Lease	(20,000)	(401)
14, 20	11.	Utilities	(338,800)	(653,397)
13	12.	Preflight Blower	(142,400)	(400,505)
9	—	Observation Tower	0	(30,000)
12	—	Quonset Hut (Fire Station)	0	(5,500)
6, 10, 17	—	Temporary Facilities	0	(51,999)
	—	Equipment	0	(43,948)
	D.	Observation Stations	(9,000)	(1)
	E.	Airplanes	0	0
	F.	Ground Transportation	(6,750)	(2)
	G.	Water Transportation	0	0
	H.	Missiles	(601,200)	0
	I.	Instrumentation	(358,470)	(205,204)
	363	Supersonic Tunnel (Langley)	630,000	884,627
	414	Contingency Fund	410,000	3,371
		Total	4,100,000	4,100,000

Notes: (1) Part of temporary facilities.
(2) Motor vehicles purchased from separate appropriation.

The breakdown of the costs of the different facilities at Wallops, as given in table II, was based on requests sent to NACA Headquarters by Langley, for reallocation of funds, and upon estimates made by Langley engineering personnel. Inasmuch as the Doyle and Russell contract covered practically all the permanent facilities in a lump sum, it was difficult to obtain an accurate breakdown. Most of the facilities were completed and in use by the end of 1946.

Experience at Wallops had shown that under severe storm conditions the ocean came ashore in unprotected areas. Pending construction of a seawall, concern was felt over the possibility of storm damage to the new buildings under construction on the island. For this reason an insurance policy was taken out with Lloyds of London by the contractor to cover up to $300,000 in damages for the duration of the construction period; the cost was $15,000.[2]

Construction at the Mainland Dock is listed in table II under Project 371 B, Receiving Station. In addition to the dock which has been described previously, a 40-foot by 40-foot Quonset hut was erected to serve as a garage and receiving station. A wooden building 31 feet by 17 feet was also constructed to serve as a dock office and waiting room. In addition, a greasing rack, fuel tanks, and a fence were constructed.

The Island Dock, which also has been described earlier, consisted of an LCM ramp and berths for personnel boats. A small wooden shack to serve as an office for boat crews was also constructed.

A concrete road was constructed from the Island Dock to the main area on Wallops. This road, as well as all other concrete facilities on the island, was constructed of a mixture of beach sand, cement, and water—a sharp departure from normal practice but one that was successful. The road consisted of a single lane from the dock to the launch area, and two lanes on to the Utility Building (hotel). Just south of the Utility Building, a curved turnout section was poured at the location of the proposed causeway. It remained a constant reminder until the causeway was finally constructed by NASA.

The main area at Wallops is shown in figure 46. This is a view looking northeastward up the beach on June 2, 1947. The road from the Island Dock enters the picture in the lower left corner. The occupied area is that owned by the Government. The numbers identifying the facilities on this figure are also listed beside the corresponding project item in table II. The facilities are discussed in the order given in the table. The names given on the figure were those approved by NACA Headquarters.

The Launching Ramp is first on the list (table II) under the Launching Site and it stands out prominently in figure 46. This wooden structure with steel rails was 400 feet long and had a slope of 4 degrees. It was based on the original German V-1 launching ramp and was intended to be used in the launching of such subsonic missiles as Tiamat and Gorgon. Because of the success of zero-length launchers for such missiles, the ramp was never used, and was later dismantled.

The Launching Platform was the original concrete slab constructed as part of the temporary facilities contract. It is shown in figure 46 with the Split-House (in a closed position) mounted on it. A circular concrete driveway was constructed from the road to the launching slab, encircling the Observation Shelter and returning to the road. In later years, additional concrete was added around this slab to make a larger launching area.

The Final Assembly Building or shop was the largest building constructed at this time. With dimensions of 104 feet by 158 feet, it served as a combination woodshop, sheetmetal shop, machine shop, stockroom, and vehicle maintenance shop. In addition, an area was set aside for missile assembly including, at times, live rocket-motor installation. An air-conditioned storage room for the TPS-5 radar was also provided in this building.

The Office and Radio Building or Administrative Building was constructed of cinder blocks and was 32 feet by 122 feet. It was the island headquarters and contained offices for department heads, staff personnel and purchase records, and miscellaneous files. The photo laboratory and communications center were also located in this building.

The Living Quarters, or Utility Building, as it was officially named, was a cinder block building 50 feet by 118 feet, on a concrete slab. It contained a kitchen, cafeteria, lounge, dispensary, two rooms for guard's quarters, and seven rooms for transients. Most of the rooms for transients contained four bunk beds, two to a stack, altogether providing sleeping space for 26 men. This building was a great improvement over the Quonset huts and served as a hotel until some time after NASA was established. Three meals a day were served; lunch had the largest patronage because all island and contractor personnel were served, as well as transients. The sleeping accommodations were adequate for all but the larger operations. Travel to Wallops was limited to the spaces available, although in special cases transients found space at the motels on the mainland and commuted along with the permanent Wallops employees.

2. Interview with J. C. Messick, Langley Assistant Chief of Engineering and Technical Services, November 23, 1965.

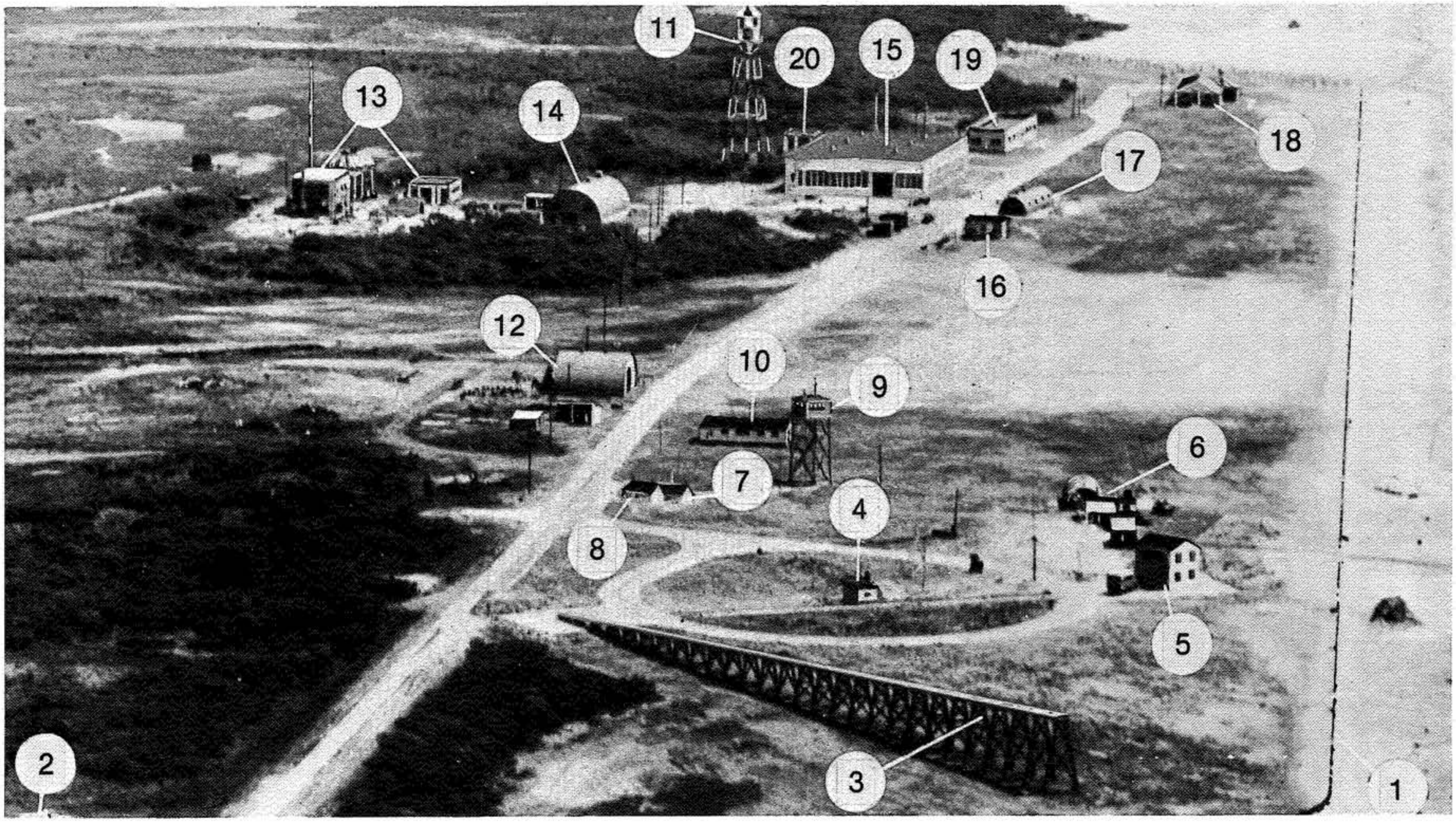


FIGURE 46. Pilotless Aircraft Research Station, Wallops Island, June 2, 1947. Numbers identify the following buildings or locations:

1 Sea Wall
2 Solid Fuel Storage
3 Launching Ramp
4 Observation Shelter
5 Launching Slab (with split-house)
6 Instrumentation Buildings (temporary)
7 High-Pressure Air Station
8 Final Loading Building
9 Observation Tower (Control Tower)
10 Temporary Buildings
11 Water Tower
12 Fire Station
13 Preflight Test Unit
14 Generating Plant
15 Final Assembly Shop
16 Liquid Fuel Storage
17 Temporary Buildings
18 Utility Building
19 Administration Building
20 Heating Plant

The Oil Tanks, officially called Liquid Fuel Storage, contained storage and servicing facilities for fuel oil and gasoline.

Powder and Chemical Storage was renamed Solid Fuel Storage when plans for using liquid-rocket motors were abandoned. The Solid Fuel Storage consisted of steel igloos. At first, some small igloos obtained from the Navy were erected as a part of the temporary construction and were covered with sand. The igloos shown in figure 46 were larger and were erected as a part of the permanent construction.

The Loading Room, renamed Final Loading Building, was erected near the Launching Site and was used for installation of igniters in the rocket motors, and for other work on loaded missiles. This building was too small to handle all its duties, so part of the Final Assembly Shop was used for similar purposes.

The Bombproof Shelter, called Observation Shelter in figure 46, was a small concrete building 10 feet by 20 feet, with narrow observation ports. It was the operations center for all launchings. While some improvement over the temporary sandbagged shelter, it was quickly found to be too small and was one of the first permanent buildings to be replaced. The original shelter was converted into an electrical junction room when a much larger control center was added to it.

The item of Utilities in table II covers the largest expenditure at Wallops: the seawall, roads, docks, power, and heat.

The seawall was erected along the ocean front, following the Wallops Grid north and south line which made it run nearly along a northeast-southwest line. It was made of interlocked sheet-steel piling 18 feet long, driven approximately 12 feet into the ground. So little of the piling was exposed that Hooker became worried and asked Messick to consider raising the piling a foot or so. In his response of January 1946, Messick replied that the original plan was a sound one that placed the top of the piling 9 feet above mean sea level. A concrete cap could be added later if desired.

In April 1946, NACA Headquarters asked the Army Engineers to study the adequacy of the seawall and to make recommendations. The job was turned over to the Engineers' Shore Protection Board, which made its recommendations on May 17, 1946.[3] The study showed that the shoreline had receded 500 feet since 1851, and protection was needed to prevent further erosion. The Board recommended that the NACA continue with its plan. The seawall, as planned, would protect the shoreline from erosion but would not keep water off the area under extreme storm conditions. Groins would be required eventually to protect the seawall; and it was recommended that their construction take place when the high water line came within 50 feet of the seawall. Eventually, through wind action, the seawall was completely covered by a high wall of sand and grass, so little damage was ever sustained by the wall itself, even in bad storms. Groins were required, as predicted, by 1958.

A High-Pressure Air Station was constructed near the Final Loading Building to provide storage area for the high-pressure air bottles used to load the air tanks in the missiles having air servosystems. The Water Tower, shown in figure 46, was supplied with water from the 147-foot-deep well discussed earlier. Water was piped to most of the buildings in this area. The Generating Plant shown in figure 46 was also called a Standby Powerplant. It was a large 40-foot by 80-foot Quonset hut containing diesel-powered generators for normal use and, in addition, two 800-kw generators to provide power for the Preflight Jet until connection was made with the Eastern Shore Public Service Company in 1948. These large generators were obtained from military surplus and were designed for submarine use. They were high-speed diesels and more maintenance was expected than would be normal for stationary engines. It was expected that, with two systems, at least one would be available at all times.

The Heating Plant was a 27-foot by 70-foot cinder block building, which contained a boiler room, an air compressor room for service air, and a battery-charging room. Heat to the buildings in the shop and living areas was supplied by this boiler through overhead steam lines hung from poles. The buildings at other locations had individual heating systems.

The general appearance of the island, as indicated in figure 46, was a great improvement over the appearance in 1945. The area between the seawall and the road and around the buildings had been

3. Letter from Colonel W. J. Ely, Corps of Engineers, to J. C. Messick, May 17, 1946, enclosing shore protection plan for Auxiliary Flight Test Station, Wallops Island.

cleared of underbrush and sand dunes and then graded. In addition, the entire area was covered with sod taken from the marsh area to the west. This was necessary to hold the land and to reduce the amount of sand blowing through the air. The sodding and grading work was done under a separate contract with general operating funds. Despite this effort, however, the combination of sand and salt spray from the ocean presented an almost endless problem in the maintenance of exposed metal parts. The solution finally reached was to cover all exposed steelwork with an asphalt compound similar to the "Fendex" used to undercoat automobiles.

Construction of the Preflight Blower—also called Preflight Test Unit and, later, Preflight Jet—was begun at the same time as the other permanent facilities, but its many unique features delayed completion until 1948. It will be described later and is mentioned here because initial funding came from the 1945 appropriation. The main housing and concrete work was made a part of the Doyle and Russell contract. The air-storage sphere and heater, as well as the jet itself, were obtained by contract with the Pittsburgh-Des Moines Company.

The Observation Tower was not a part of the original plan but was made a part of the permanent facilities contract. It was 15 feet square and 36 feet high from the floor level. Its main use was for surveillance of the launch and sea areas for safety purposes. An interior view of the tower is shown in figure 47. In addition to the binoculars used for sea search, a radar was installed to cover the 25-mile sea range in use at that time. The tower also contained the island telephone system and was equipped with an outside air temperature station. The status of impending launchings and the countdown were broadcast over the launch area from the tower.

The Quonset hut listed in table II was one obtained from the Navy and assembled by Doyle and Russell. In 1947, it was used as a fire station. One of the Quonset huts used for living quarters was moved behind the Final Assembly Shop and used as a temporary paint shop; the second hut was moved to the launch area to house instrumentation.

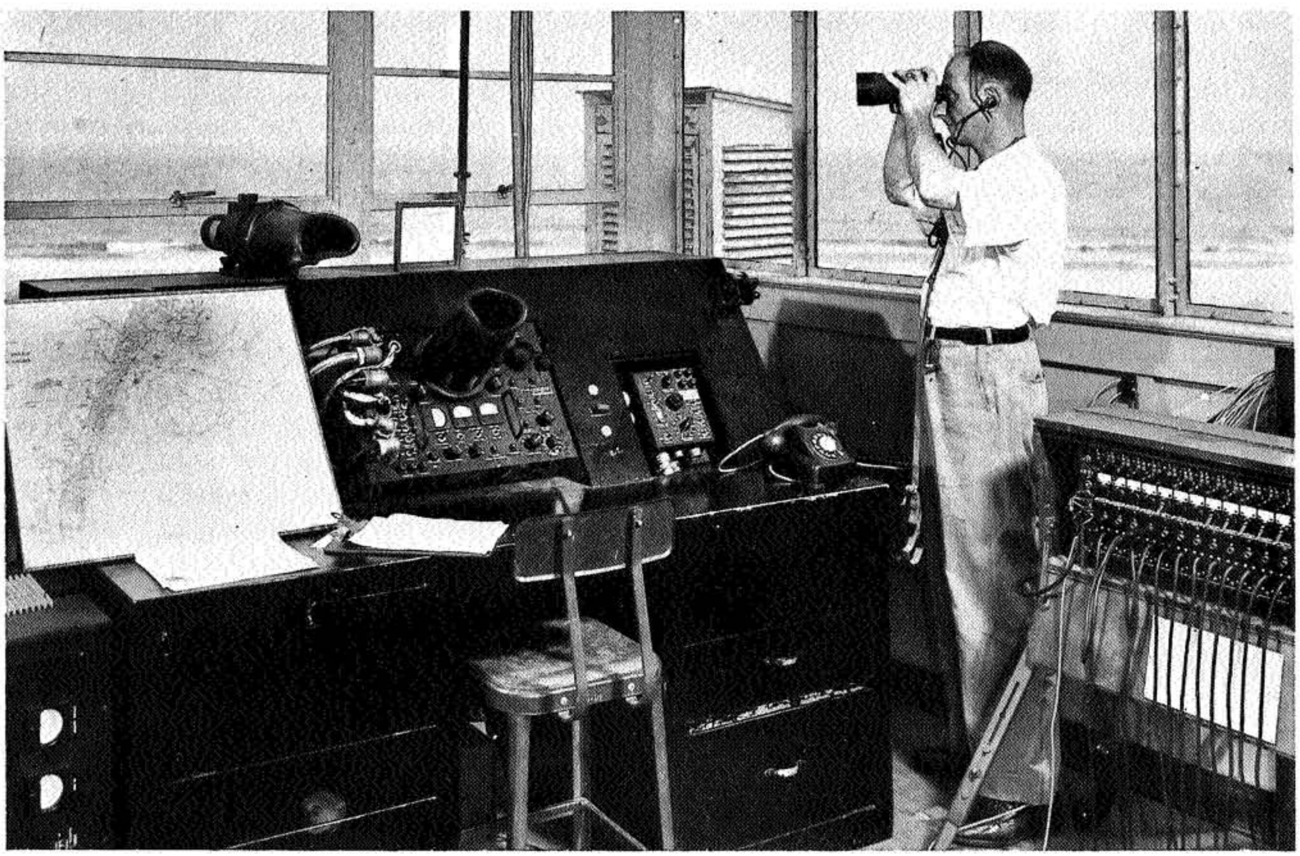


FIGURE 47. Wallops Observation (Control) Tower, July 30, 1948. First Aid and Safety Officer W. C. Carey looks for ship in rocket impact area.

The Observations Stations listed in table II were all temporary. The Instrumentation listed in table II, Project 371-I, was the special instrumentation purchased for Wallops in addition to that received at no charge from the military services.

In September 1945, Langley made plans to construct a landing strip 3,500 feet long on Wallops between the launching area and the dock. Funds were to be diverted from parts of Project 371. The savings in time that had been realized with the small amphibian, compared with the longer route by land plane and boat via Chincoteague Air Station, made the construction of a landing strip on the island very attractive. The use of the larger land planes would make it possible to carry out a flight operation at Wallops in a single day, with people from Langley. The plan, however, was not approved. In later years, the project was proposed several times without success. The eventual construction of a causeway in 1959 eliminated the need for a landing strip on the island itself.

TRANSPORTATION BETWEEN NACA LANGLEY AND CAPE CHARLES

Transportation between Langley and Wallops was a continual source of frustration. Travel by C-47 airplane from Langley to Chincoteague NAAS and thence to Wallops by truck and boat required 2 hours and could be made only in good weather. Many times plans had to be canceled because of bad weather. The amphibian was faster, but was very limited in payload and was affected by weather. Trips by the Pennsylvania Railroad boat from Fort Monroe to Cape Charles and thence by truck and boat to Wallops required 4 hours and the Cape Charles boat ran only twice a day. The Norfolk Little Creek ferry to Cape Charles ran every 2 hours, but its total travel time was from 6 to 8 hours.

It was proposed to obtain a boat to carry personnel and freight from Langley Field to Cape Charles. With such a boat, the overall time to Wallops would be 3 hours, trips could be made in all but the roughest weather, and the schedule would be governed solely by Langley needs. Another factor to be considered was that explosives could not be carried on the ferry but had to be flown to Chincoteague or taken by truck around the northern end of Chesapeake Bay, a distance of 462 miles each way. In March 1947, attempts were made to obtain a boat either from the Navy or from the Army. As a result, a 104-foot aircraft rescue boat was obtained on loan from the Navy Bureau of Ships on July 11, 1947. On that date, the boat was turned over to a crew from Langley, overhaul having been completed by the Norfolk Navy Yard. The boat is shown in figure 48.

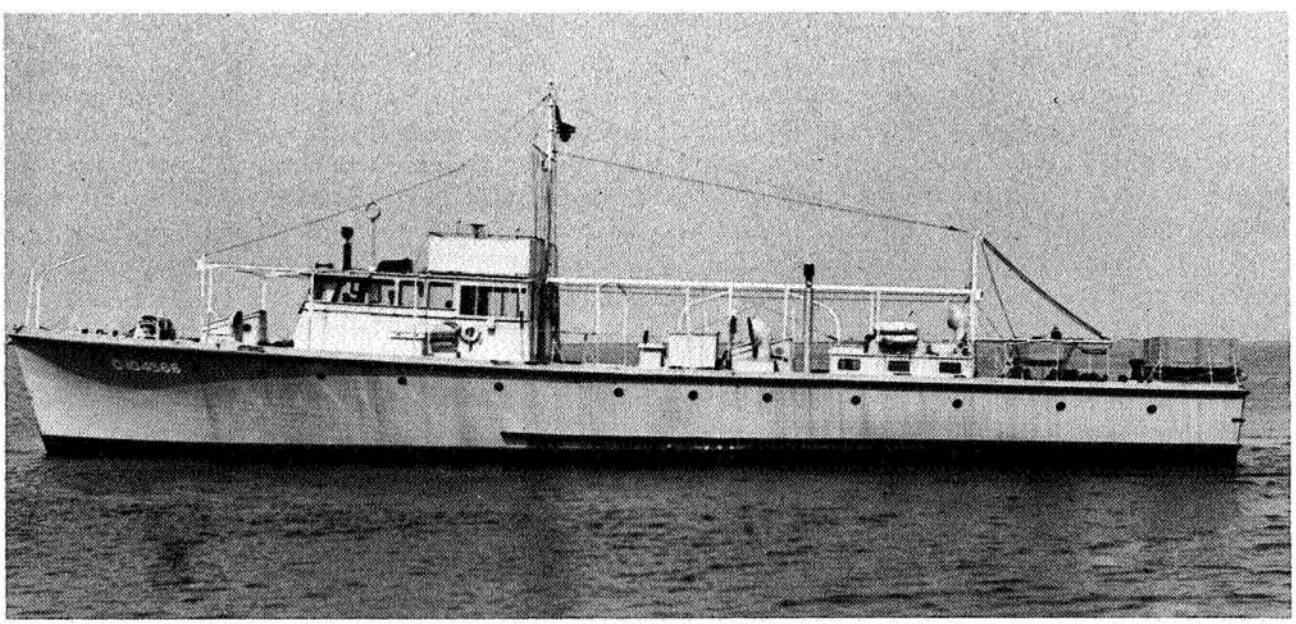


FIGURE 48. Navy 104-foot aircraft rescue boat used by Langley for transportation between Langley Field and Cape Charles, Virginia, from July 1947 to August 1955.

Docking privileges were obtained from the Army Air Forces at Langley Field for use of the Langley dock, and from the Army Harbor Defense Command at Ft. Story, Virginia, for use of their dock at Cape Charles. The dock at Cape Charles was built on land owned by the Pennsylvania Railroad, and eventually ownership of the dock was transferred to the railroad. Dock space, however, was still made available to the NACA for the Langley/Cape Charles boat.

A permanent crew was assigned from the Langley Maintenance Division, and dispatching was handled by the Operations Section of PARD. The boat was used continually until the need was practically eliminated in 1955 by increased use of airplanes and longer range planning of rocket flight missions. The boat was returned to the Navy on August 15, 1955.

With the boat, it was possible to leave Langley at the beginning of regular working hours, go to Wallops for a flight operation, and return to Langley in late afternoon of the same day. Although the boat could be used in weather too bad for the C-47 airplane, there were times when the boat had to turn back because of rough water in Chesapeake Bay. At other times, it was a rough experience that many PARD people wanted to avoid. On clear days, however, it was a delightful experience to cross the bay at 20 knots. The foamy wake astern was a beautiful sight.

PROCUREMENT OF HIGH-PERFORMANCE ROCKET MOTORS

The type of program and the maximum speeds attained in the rocket-propelled model flight tests at Wallops were strongly influenced by the rocket motors available. A continual search was under way for motors with greater efficiency and higher performance. Although every attempt was made to adapt standard military rockets to the needs of PARD, there were times when the NACA contracted for the development of special motors.

The success of the RM-2 drag model programs using the high-thrust, short-burning, 3.25-inch motor led to examination of a larger motor of the same type, for use as a booster. The 5-inch HVAR (High-Velocity Aircraft Rocket), developed by the California Institute of Technology under NDRC sponsorship, provided an average thrust of 5,570 pounds for 0.88 second and weighed 79 pounds. This rocket had the same efficiency as the 3.25-inch motor, and, being larger, made a good booster to use with it. It was available from the military in quantities and was used at Wallops for many years. The HVAR was also used by Cal Tech personnel in preliminary firings connected with development of the Army Ordnance's "Private" missile. The HVAR was nicknamed "Holy Moses" and was the one most used in combat by U.S. armed forces in World War II.

The Applied Physics Laboratory established by the Navy's BuOrd at Johns Hopkins University, also was interested in this rocket motor in connection with preliminary flight experiments, and was instrumental in having Cal Tech improve the performance by reducing the thickness of the motor case to save weight. This change reduced total weight to 63 pounds, increasing the propellant-mass fraction from 0.30 to 0.40. The motor was called the "White Whizzer" by the Navy, but at the NACA was known as HVAR, lightweight. Twenty of these rockets were received in April 1946 for preliminary trials. In a later order, the NACA offered to pay BuOrd for a supply of the motors, but 150 rockets were transferred at no charge, on the basis that the Navy expected to benefit from the research results of any tests conducted with them.[4] The lightweight HVAR replaced the standard HVAR as a booster rocket.

The survey made by K. F. Rubert in 1944 revealed the availability of Aerojet jato units of 1,000-pound thrust. In June 1946, such rockets seemed to have application in flutter research and other programs. Consequently, 25 of the model jato 12AS1000 motors were requested from Navy BuAer. These were 9.6 inches in diameter, and 35 inches in length, and weighed 202 pounds. The propellant-mass fraction was a favorable value of 0.50, but the stubby shape and low thrust offset this feature for use as a supersonic booster. A number of jato 14AS1000 motors also were requested for use as boosters in an air-launched ramjet program under the direction of the NACA Lewis Laboratory, Cleveland, Ohio.

Very early in the program, a need was seen for booster rocket motors to accelerate the Langley-proposed ground-launched ramjet missile and supersonic airplane models to supersonic speeds.

4. Letter from the Chief, BuOrd, to the NACA on December 5, 1946, regarding lightweight 5-inch HVAR rockets.

Contacts were made with both the Army Air Forces and the Navy regarding the requirements, which greatly exceeded the capabilities of available motors. As a continuation of the effort to obtain a usable motor, a specification for a motor having 7,000 pounds of thrust for 8 seconds, a maximum diameter of 10 inches, and a maximum gross weight of 900 pounds was sent to the Army Air Forces in March 1946. Such a motor was not available, but Aerojet was given a contract by Army Ordnance to develop a motor to meet these specifications. The motor was designated jato 7KS-6000, T27.

A prototype of the T27 motor was received at Langley in April 1948 and was flight tested as a separate unit on November 18, 1948. (See figure 49.) The motor performed well in the flight test (ref. 1), but was not put into production because its stubby shape had been outmoded by the Deacon rocket motor, which was developed in a parallel program.

FIGURE 49. Technician Phil Mears adjusts Aerojet T27 jato rocket motor for flight test at Wallops, November 18, 1948.

An attempt was made to convert the Tiamat booster into an "All-Purpose Booster" for airplane models. As mentioned earlier, this booster used the Monsanto ACL-1 rocket motor. A new fin arrangement was used, as shown in figure 50, in conjunction with an airplane model of a general research type. The system was launched in the summer of 1947 but was unsuccessful because of structural failure of the booster fins.

In August 1945, Langley first learned about the possibility of obtaining a solid-rocket motor of small diameter and high performance, when Dr. J. B. Rosser of the NDRC solid-rocket section visited Langley. He mentioned a Vicar rocket which could attain a Mach number between 2 and 2.5. As a followup on this, O'Sullivan called Dr. Rosser in December 1945 and talked with him and Dr. F. T.

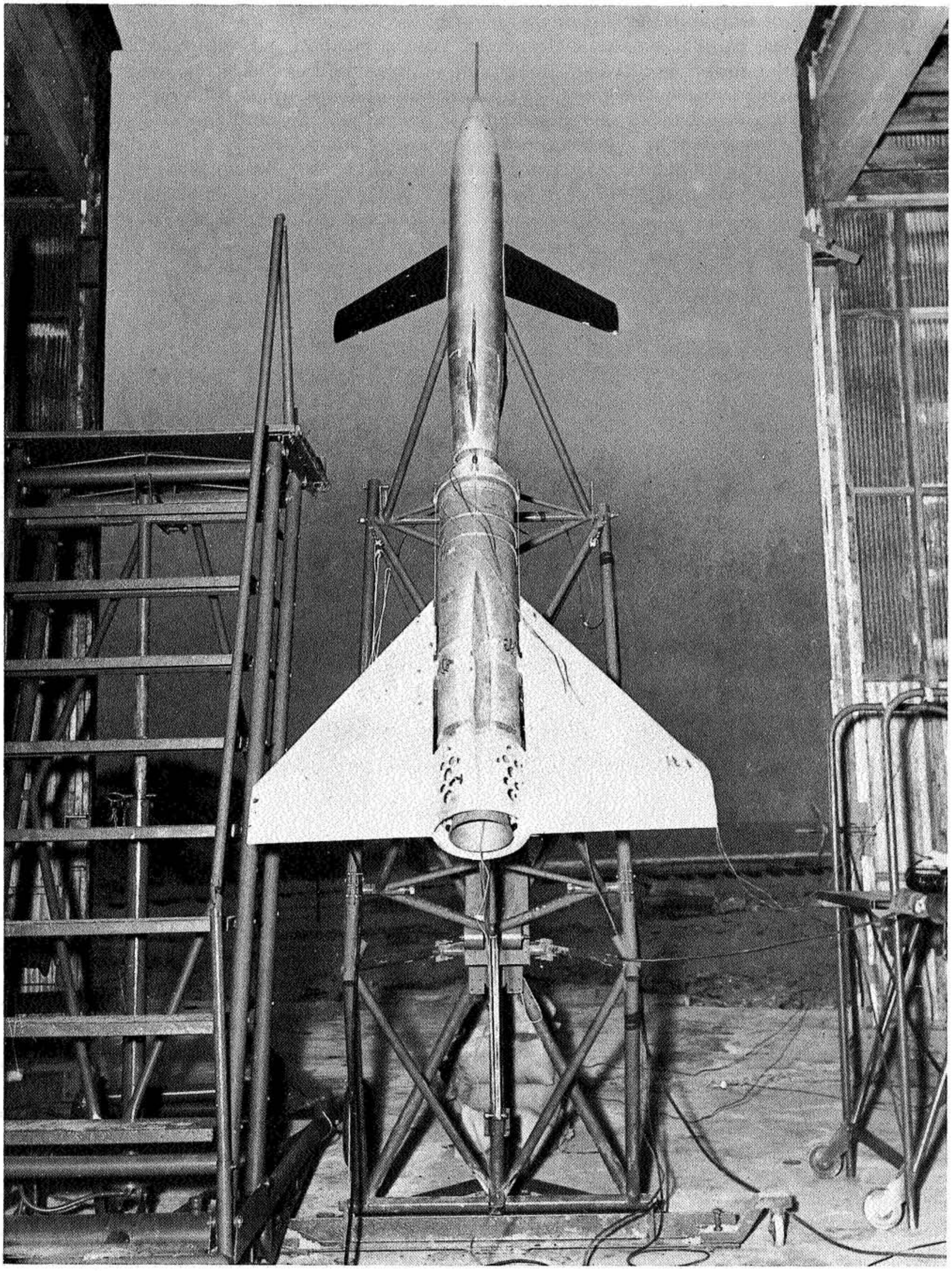


FIGURE 50. Development test of all-purpose booster, March 25, 1947.

McClure about high-performance rockets. The Vicar rocket was a development of the Allegany Ballistics Laboratory (ABL), whose Director of Research was Dr. R. E. Gibson. This rocket had been carried only as far as preliminary trials with heavy-walled cases. Unfortunately, on V-J day all development work on NDRC rockets was automatically stopped.

NACA Headquarters had learned of Dr. Gibson's activities in February 1945, when he visited the headquarters to discuss aerodynamic problems of rockets at transonic and supersonic speeds. At that time, Dr. Gibson stated that rockets could be developed for special applications. In recording the discussions during this visit, R. E. Littell of NACA Headquarters stated, "The writer feels that it may be to the Committee's advantage to utilize the facilities of the Allegany Ballistics Laboratory in view of the large amount of application of rockets that appears to be coming into the Committee's research program at Langley Field" (ref. 2).

Dr. McClure told O'Sullivan that "the Allegany Ballistics Laboratory was undoubtedly the only laboratory in existence in the United States which was able to both design and construct small quantities of rockets to the specifications set by the NACA." He stated, however, that any further contact with ABL should be made through the Navy BuOrd inasmuch as operation of the laboratory was being transferred from NDRC to BuOrd.

Following the contact with Dr. McClure, O'Sullivan began a relentless campaign to get a rocket of the Vicar type developed by ABL. He was convinced that the design was a real breakthrough in solid-rocket motor development, and such a motor was sorely needed for Wallops operations.

In October 1946, O'Sullivan visited Dr. L. G. Bonner, Director of ABL, and learned firsthand about the Vicar series of motors. The first design shown him was quite similar to what eventually became the Deacon motor. It had a 6.25-inch diameter and a 110-inch length, weighed 150 pounds with 98 pounds of propellant, and produced 8,000 pounds of thrust for 2.5 seconds. The motor had a computed capability of achieving a vacuum velocity in excess of 4,000 feet per second with a 50-pound payload (ref. 3).

After many conferences with BuOrd officials, an arrangement was eventually worked out whereby development of this 6.25-inch rocket was completed and the NACA was supplied with 100 units. Inasmuch as ABL was a research laboratory, BuOrd was reluctant to assign them a production project, yet they were the only people capable of producing the rockets at that time. Under the agreement, the NACA provided all the metal parts, BuOrd supplied the extruded propellant grain, and ABL did the assembly, including the protection of the aluminum case from the hot rocket gases. These motors cost the NACA approximately $600 each and were the first the NACA had to pay for.

The rocket achieved its high propellant-mass fraction of 0.67 through the use of an internal burning grain design that allowed the use of a lightweight aluminum case. Under NACA guidance, a 2024-T6 aluminum alloy case was developed for the motor (ref. 4). To obtain a constant burning area inside the motor, the cross section of the internal cavity was constructed to resemble an eight-pointed star with blunt tips. The aluminum case was protected from the propellant by an insulating shield and special end gaskets.

The 6.25-inch rocket of the Vicar family was named the Deacon by the NACA. BuOrd requested the NACA to conduct flight trials of the motor at different initial motor temperatures and with payloads of varying weight. In addition, they requested flight tests of a 9-inch motor of a different design. The NACA issued RA 1463 on May 19, 1947, to cover the requested test program. Ten Deacons and eight of the 9-inch motors were flown at Wallops Island between April and August, 1947. The flight tests were an unqualified success and showed the Deacon to be an outstanding rocket motor. The highest velocity achieved was 4,180 feet per second, with a 41-pound payload added to the motor in the nose cone, and with tail fins (ref. 5).

The Deacon became the major rocket used in Wallops launchings, and was used singly and in clusters of two, three, and four rockets. An additional supply of 200 Deacons was ordered in January 1948. In April 1947, during the flight-test program on the Deacon, it was learned that the motor was under consideration for possible use as a primary rocket for the MX-800 guided missile, and in a meteorological project involving altitudes up to 90,000 feet. Later, the extruded propellant grains were replaced by a cast grain that had a longer shelf life but approximately 10 percent less performance (ref. 4).

RANGE SAFETY

In January 1947, a new system to promote range safety at Wallops was put into effect (ref. 6). Firing and range officers were appointed and given responsibility for certain specific activities connected with rocket firing. Harry C. Shoaf and William Craig were the first such officers appointed. Their activities in the assignment were supervised by Julian Stainback of PARD at Langley, in his position as Special Range Officer.

The Firing Officer was responsible for the safe handling and storage of all rocket motors at Wallops Island. His position entailed personal responsibility for installing motors in the missiles and making electrical connections to firing leads. He was empowered to stop or delay any launching when, in his opinion, an unsafe condition existed.

The Range Officer was responsible for maintaining safe working conditions within the launch area, raising the "Baker" warning flag, and clearing the area before firing. This duty included scanning the horizon with fieldglasses for ships. He was empowered to order any person to a place of safety.

In a continuation of range safety improvement, a special safety committee was appointed in August 1947 by Elton W. Miller, Chairman, Langley Executive Safety Committee. The committee consisted of William N. Gardner of PARD and Paul F. Fuhrmeister of IRD. Many of their recommendations were adopted, among them the following: (1) fence off a restricted area and prohibit smoking, (2) provide protection shields for radar operators, (3) give one man the responsibility for correlation of all groups involved in a firing, (4) enlarge the launching slab, and (5) provide a second launching area.

FLUTTER PROGRAM

The lack of a method for calculating wing flutter characteristics in the transonic range and the lack of wind tunnel facilities in this range made free-flight testing imperative. Langley instituted a freely falling body flutter program and a program with rocket-propelled models. The programs were designed to study flutter phenomena directly in order to supplement flutter data obtained inadvertently in other flight projects. The tests were closely watched by the Army Air Forces and the Navy BuAer for whom the results would be of direct benefit.[5] [6] Testing was conducted under the direction of the Physical Research Division (PRD) at Langley, which had cognizance over the general subject of flutter. In the actual tests, the PRD research engineers were assisted by personnel from the Flight Research Division (FRD) or PARD, depending upon the particular program.

The initial flutter program with freely falling bodies followed the same technique that had been developed for drag measurements. In most of the flutter tests, the wings were designed to flutter in the speed range obtainable; the general practice was to compare the flutter speed in flight with that calculated by two-dimensional incompressible theory. The aim of the program was to establish empirical correction factors in order to extend the theory to finite wings of various sweep angles, and to transonic speeds.

In the case of a particular full-scale airplane or missile wing, the expected full-scale behavior could be obtained by testing a scaled model whose structural characteristics conformed to recognized scaling laws. In such cases, the margin of safety from flutter could be ascertained.

The first flutter test with a freely falling body was made in the summer of 1946. Four rectangular wing panels of different aspect ratios without sweep were mounted on a cylindrical body with ogival nose and rear sections. The body had four stabilizing fins. The use of wings with different aspect ratios allowed the determination of aspect ratio effects with a single test. Two of the wings failed at speeds up to 20 percent greater than the calculated speed. The other two wings failed at 90 percent of the calculated speed, but there was some question about the actual cause of failure (ref. 7).

A second series of flutter tests of wings on freely falling bodies involved six separate wings mounted on three different bodies. A four-channel telemeter was used to transmit longitudinal

5. NACA letter, written by J. W. Crowley to Chief, Navy BuAer, on May 27, 1946, regarding a coordinated research program for flutter.
6. Letter from AMC Engineering Liaison Officer to Commanding General, AMC, on June 20, 1946, regarding vibration and flutter testing by means of rocket-propelled models.

acceleration and, for the first time, strain gauge readings of bending and torsional stresses on the wings. Four of the wings duplicated the earlier questionable test, and the other two wings had 45-degree sweepback. The tests all gave flutter speeds up to 20 percent higher than two-dimensional theory. Sweepback had no effect in this test (ref. 8).

These meager results in a previously unexplored area of wing flutter were encouraging to airplane and missile designers in that existing theory was conservative, but apprehension remained about possible unfavorable effects in the transonic and supersonic region. Flutter failure so far had occurred below Mach 1.

Exploration at higher speeds was planned with two phases of a rocket model program dealing with flutter. The first phase was called FR-1 and was based on the assumption that low acceleration was essential for accurate flutter speed measurement. The rocket motor used was the Aerojet 12AS1000, and the highest longitudinal acceleration reached was 3.5 g. The use of this motor required construction of a complete fuselage and vertical tail assembly, as well as the flutter wings, and limited the speed to Mach 1.

The second phase of the rocket flutter program, FR-2, was designed around the use of a standard 5-inch HVAR motor, to which the wings and tail assembly were attached directly. This model provided a much simpler system that could probe into the supersonic speed region, but a longitudinal acceleration of 52 g had to be accepted.

The first FR-1 flutter model is shown in figure 51, along with its propulsion motor, which was mounted internally before flight. The first test was made in March 1947. Because of the low thrust of the rocket, a break link held the model until the thrust reached 800 pounds. The acceleration at takeoff was only 2.5 g and gradually increased to 3.5 g in 5 seconds. A break wire routed through each of the test wings was made a part of a circuit of a simple radio transmitter (spinsonde) in the nose of the model. Failure of either wing stopped the transmission.

In the first flight with the FR-1 model, the wings were sweptback 45 degrees, had an aspect ratio of 3.7, and were made of spruce. They were calculated to flutter at 550 feet per second. One wing broke off at a speed of 967 feet per second, 76 percent greater than calculated. This test indicated a more favorable effect of sweepback than did the freely falling body test (ref. 9).

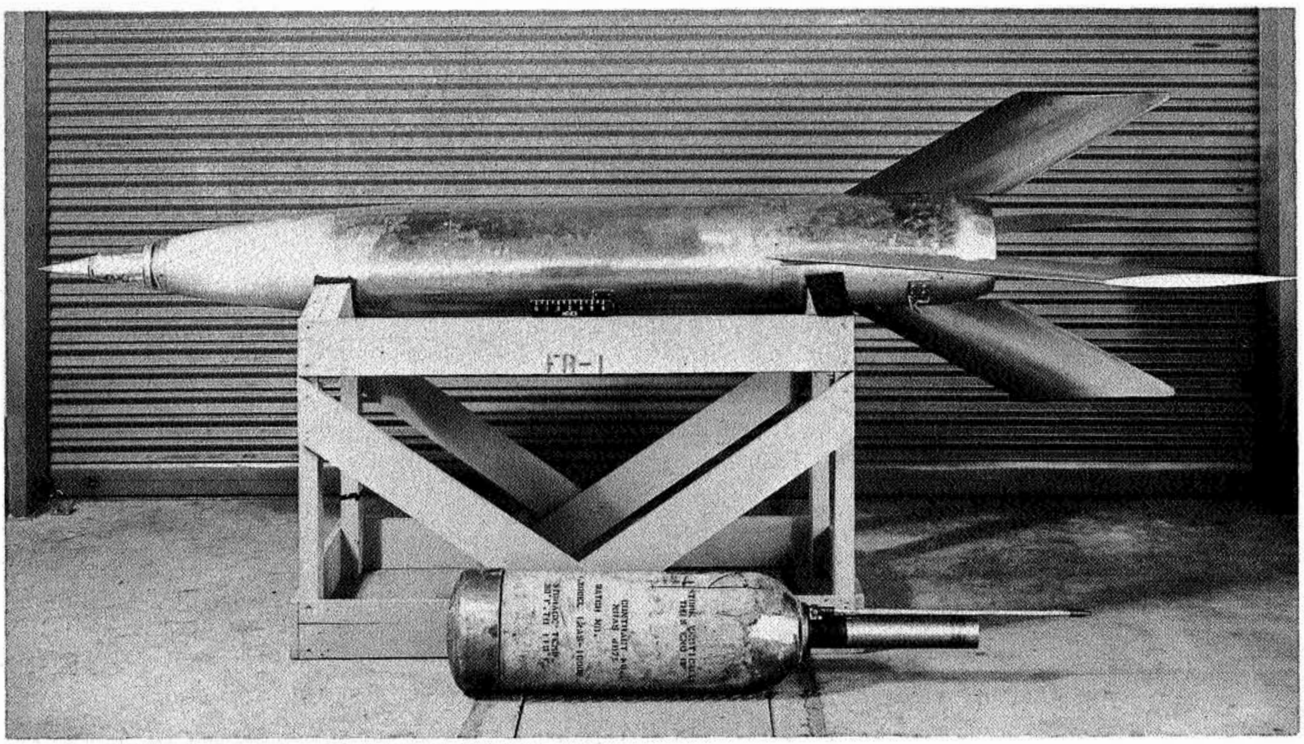


FIGURE 51. First low-acceleration rocket-propelled flutter model, FR−1, March 5, 1947.

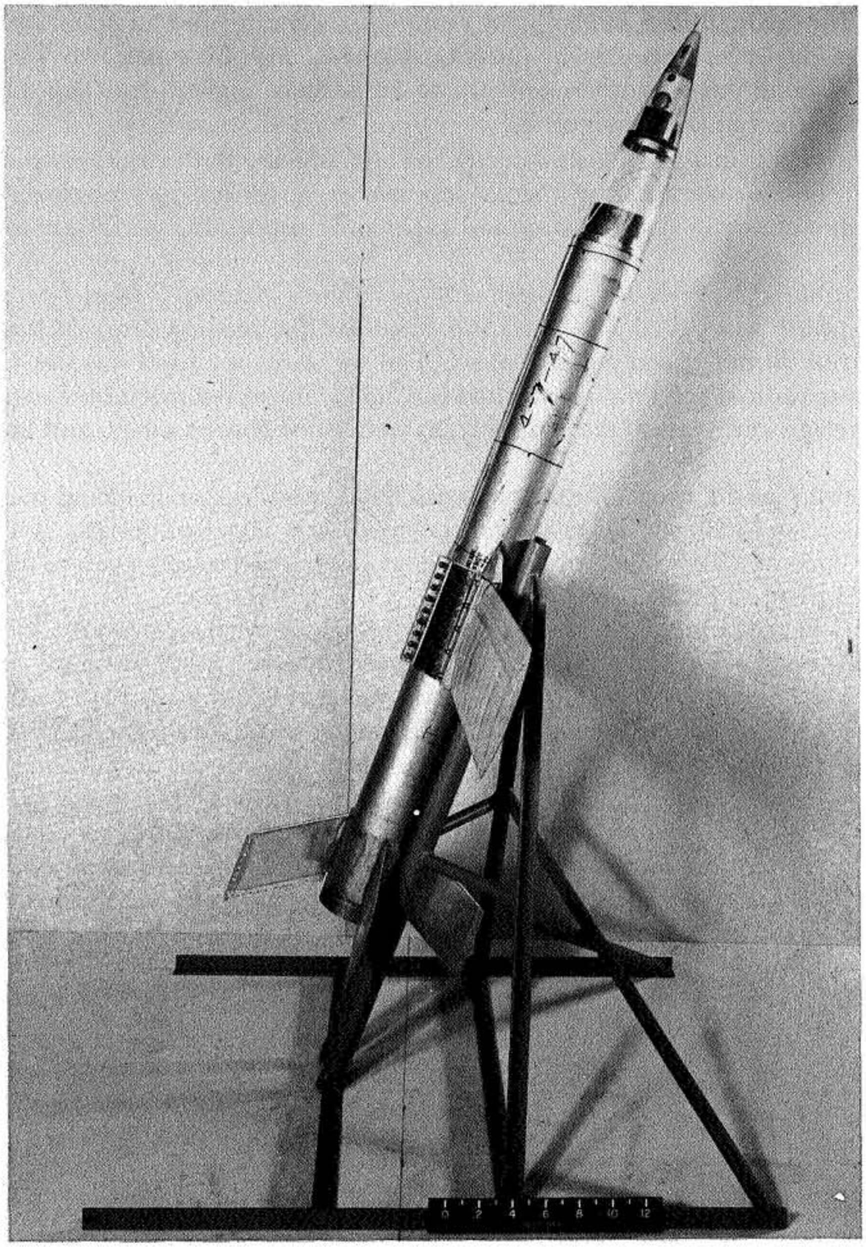


FIGURE 52. First high-velocity rocket-propelled flutter model, FR–2, April 23, 1947.

Figure 52 shows the first FR-2 flutter model mounted on its rail launcher. This model was launched in May 1947. The same break-wire system and spinsonde were used to indicate wing failure speed. The failure speed was 675 miles per hour for this straight wing of aspect ratio 6.8, compared with a calculated speed of 528 miles per hour for an infinite wing. The figures yielded a correction factor of 1.28 for this aspect ratio and speed. The result was in general agreement with the results obtained in the freely falling body program for straight wings, indicating that high longitudinal acceleration had little influence on flutter speed. This conclusion opened the way for continued use of the FR-2 technique at higher speeds (ref. 10).

AERODYNAMIC CONTROL PROGRAM

The difficulties reported earlier for the RM-1 missile regarding reversal of aileron control effectiveness at transonic speeds pointed up the need for an extensive aerodynamic control program in flight. The lack of transonic wind tunnels and the development of a simple technique using rocket-propelled models led to an extensive flight program. The program was first called "RM-5"; later, the name was changed to "E5." The number of such models flown at Wallops was large, reaching 135 for the year 1948.

The technique that made possible such a large number of launchings depended on use of a spinsonde to measure rolling velocity produced by any type of control device, and correlated with forward velocity obtained from the Doppler radar.

In the initial program, the only propulsion was provided by a 3.25-inch rocket motor mounted internally within the 5-in-diameter test body. The body was a standardized ogive-cylinder made of balsa except in the region where the wings were attached. In that section, spruce was used. The wings were usually made of spruce with metal stiffening plates glued to the outer surface. Initially, three equally spaced wing panels were used and were located near the rear of the fuselage for stability. Speeds up to Mach 1.4 could be obtained with this single-stage system.

The first launchings to test the spinsonde units began in May 1946. Launchings of complete models with controls began 2 months later, in July. In these early tests, the RM-2 launcher was used. The controls being tested were normally built into the wings in a deflected state, usually 5 degrees.

By April 1947, a second 3.25-inch rocket motor was added to the RM-5 as a booster. With this booster, the Mach number attainable was increased to 1.7. Boosted models were launched from an adjustable rail launcher as shown in figure 53. A simple cylindrical plug on the front end of the booster engaged a cylindrical socket in the rear of the model to transmit the booster thrust and to oppose any bending tendency.

The spinsonde, with which the rolling velocity was measured, is a radio transmitter that emits a polarized signal. When received on the ground, the transmission yields a fluctuating signal that reaches a maximum twice during each revolution. To increase the accuracy of the measurement, the receiving antenna is rotated at a known speed that increases the frequency of the fluctuating signal. The signal as received gives a measure of the relative angular positions of the model and the antenna; it is of sufficient accuracy that rolling velocity can be obtained by differentiation (ref. 11). For greater accuracy, the rolling effectiveness was evaluated only during coasting flight. The total drag of the model also was obtained as a bonus.

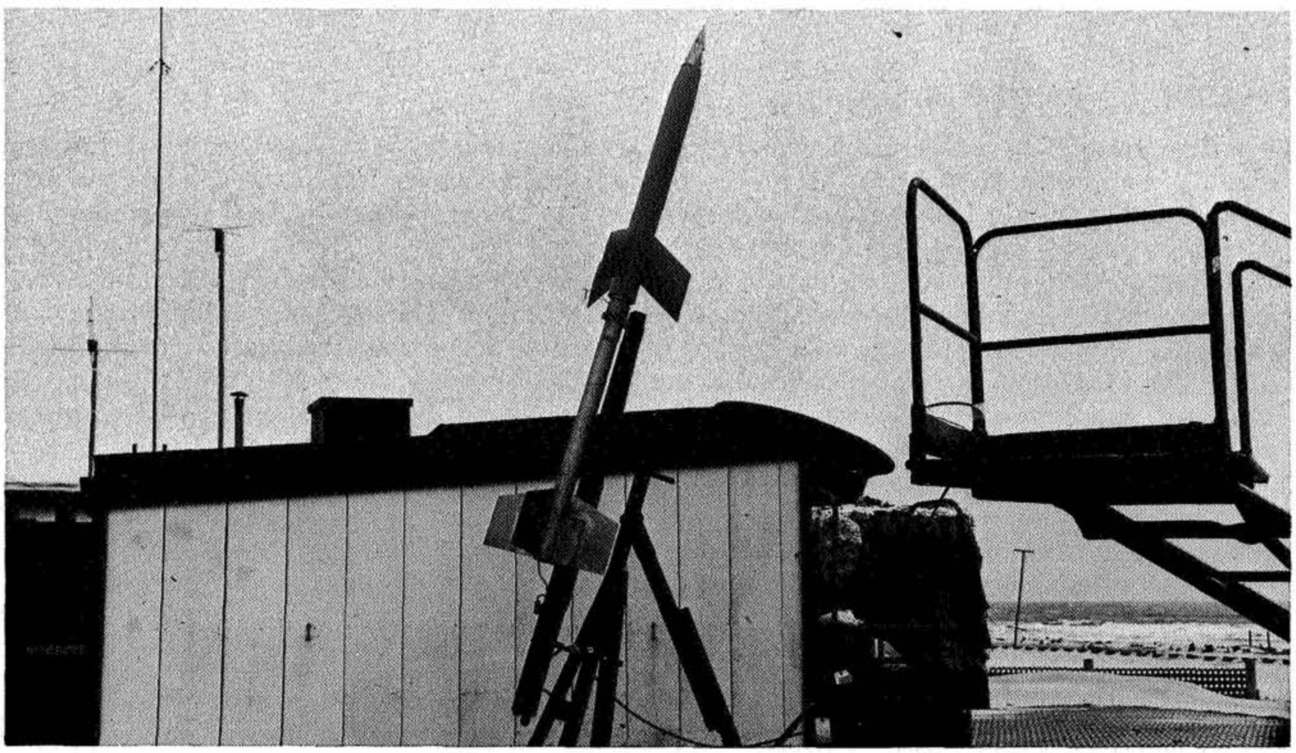


FIGURE 53. Two-stage rocket-propelled control effectiveness model, RM–5, mounted on adjustable rail launcher, April 28, 1947.

The spinsonde was developed by the Applied Physics Laboratory for measurement of spin rate of shells and other naval ordnance. Because of the extreme acceleration and shock experienced by the shells at firing, the components were "potted" or cast in plastic as a complete unit except for the batteries. The plastic case provided the "window" necessary for radio transmission. The NACA obtained the first supply of spinsondes from the Navy at no charge, but later had the units constructed on contract. They were "off-the-shelf" items which could be installed directly in the RM-5 models at Wallops, and required no calibration.

The RM-5 program did not yield a direct indication of rolling moments produced by controls. The rolling velocity, as measured, was the steady-state value which was reached when the rolling moment due to control deflection was balanced by the damping-in-roll of the wings. Thus, changes in either factor could influence the final result. In most cases, however, it was this steady-state value which was of interest.

The first three reports in the program were released in 1947 (refs. 12, 13, and 14). Figure 54 gives a typical set of data showing the abrupt loss of control effectiveness at transonic speeds, and the beneficial effect of sweepback in restoring this effectiveness. The roll rate is given in terms of the helix angle generated by the wing tip, $\frac{pb}{2V}$, where p is rolling velocity, b is wing span, and V is forward velocity. In either case, however, the effectiveness of these flap-type controls at supersonic speeds was found to be only one-fourth the value at high subsonic speeds.

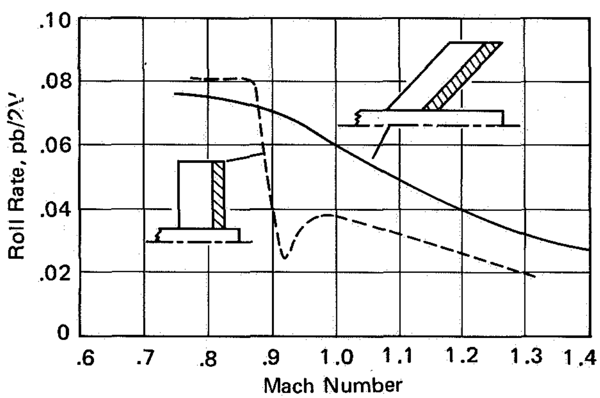


FIGURE 54. Graph showing effect of sweepback and Mach number on rate of roll for 5-degree aileron deflection on wing with aspect ratio of 3.0 (NACA 65–009 section perpendicular to leading edge).

REPUBLIC XF–91 AIRPLANE

The first model of a complete airplane to be tested at Wallops was that of the Republic XF-91. In a letter dated January 16, 1947, the Army Air Forces requested that the tests be conducted; and on February 7, 1947, the NACA issued RA 1450 to cover the program. The purpose of the tests was to determine transonic drag and stability characteristics.

The XF-91 was the Army Air Forces' first rocket-propelled airplane. As such, it had two unusual features: the wings had inverse taper, and a "vee" tail was used. The first phase of the program was conducted with 1/9-scale simple wood models propelled by 3.25-inch rocket motors mounted internally. The tests began in April 1947. One of the models is shown in figure 55. The RM-2 technique was used, supplemented by a two-channel telemeter arranged to measure normal and transverse accelerations.

The models in these flight tests achieved a Mach number of only 1.07, but good measurements of drag and stability were obtained, as reported by S. R. Alexander (ref. 15). The tests allowed the Army to evaluate the possible performance of the airplane, and indicated that it would be stable over the speed range tested, although a small abrupt change in longitudinal trim was noted near Mach 1.

CONTINUATION OF THE DRAG PROGRAM

The RM-2 rocket drag program was conducted on a continuing basis, with the models being constructed almost on a production line. There were many structural failures as the researchers attemped to fly a wide range of wing and body shapes into the unknown transonic range. As solutions were found to the difficulties, and repeat firings were made, a pattern of design data began to emerge,

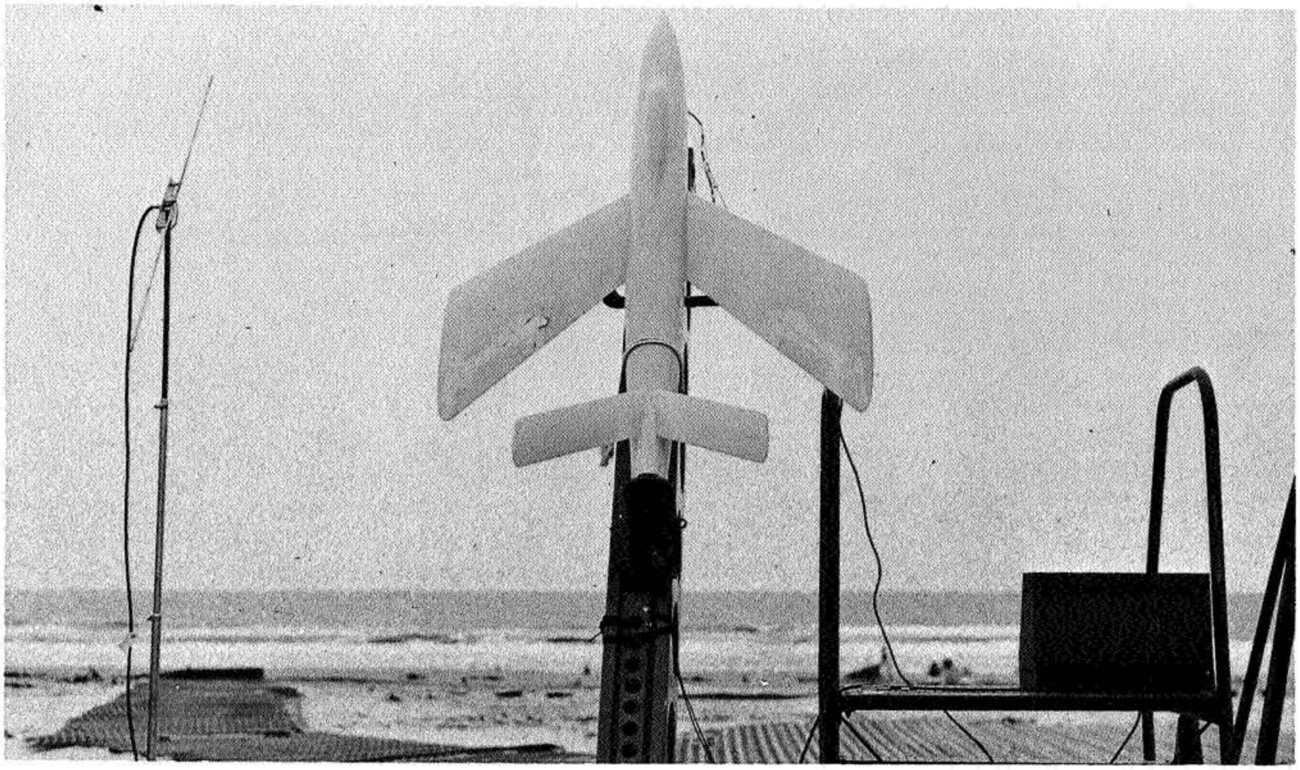


FIGURE 55. Republic XF–91 airplane: 1/9-scale rocket-propelled model, photographed on April 28, 1947.

which was very welcome in the supersonic missile and aircraft community. During 1947, six reports on new findings were released, as indicated by references 16 through 21.

Measurements of wing drag were extended to an aspect ratio of 5.0 for 45-degree sweepback. The effects of aspect ratio for this amount of sweepback was found to be small. In contrast, for a straight wing, the drag was found to increase as the aspect ratio was increased. The overall results were in general agreement with the results from the freely falling body program at a given Mach number. Results were obained on the effects of wing thickness ratios as low as 3 percent. The researchers departed from the earlier practice of expressing thickness in a plane at right angles to the leading edge of the wing and began comparing wings of the same streamwise thickness. This practice resulted in a smaller reduction in drag attributed to sweepback.

The RM-2 program concentrated principally on wing drag while maintaining a standard fuselage shape consisting of a cylinder with a short ogival nose. Early in 1947, a separate flight program on the drag of supersonic bodies was initiated. This program is referred to as F6 in Appendices C and E; but in the beginning the program had two phases—the RM-6 project and the so-called 65-inch RM-10 project. They are discussed together here because the drag results were reported in a single document (ref. 22).

The RM-6 was a brief program that used a parabolic body of revolution having a basic fineness ratio of 10. With the rear portion of the body cut off to make room for the rocket motor nozzle, the fineness ratio was reduced to 7.87. Three stablizing fins of 10-percent circular arc section were sweptback 60 degrees. These models were flown to Mach 1.2 from an RM-2 type of launcher, and were propelled by a 3.25-inch rocket motor.

The RM-10 missile was similar to the RM-6 except that it started with a body of fineness ratio of 15, which was reduced to 12 when the rear portion was removed. It had four sweptback stabilizing fins of longer span than those of the RM-6 model. The RM-10 was a standardized supersonic missile shape with enough internal space to accommodate the Deacon rocket motor. A long series of drag and heat transfer flight tests was made with the full-size RM-10. In addition, most of the supersonic facilities in the United States tested scaled models of the RM-10 to calibrate their equipment against the full-scale results. The complete RM-10 rocket program will be discussed in Chapter 8.

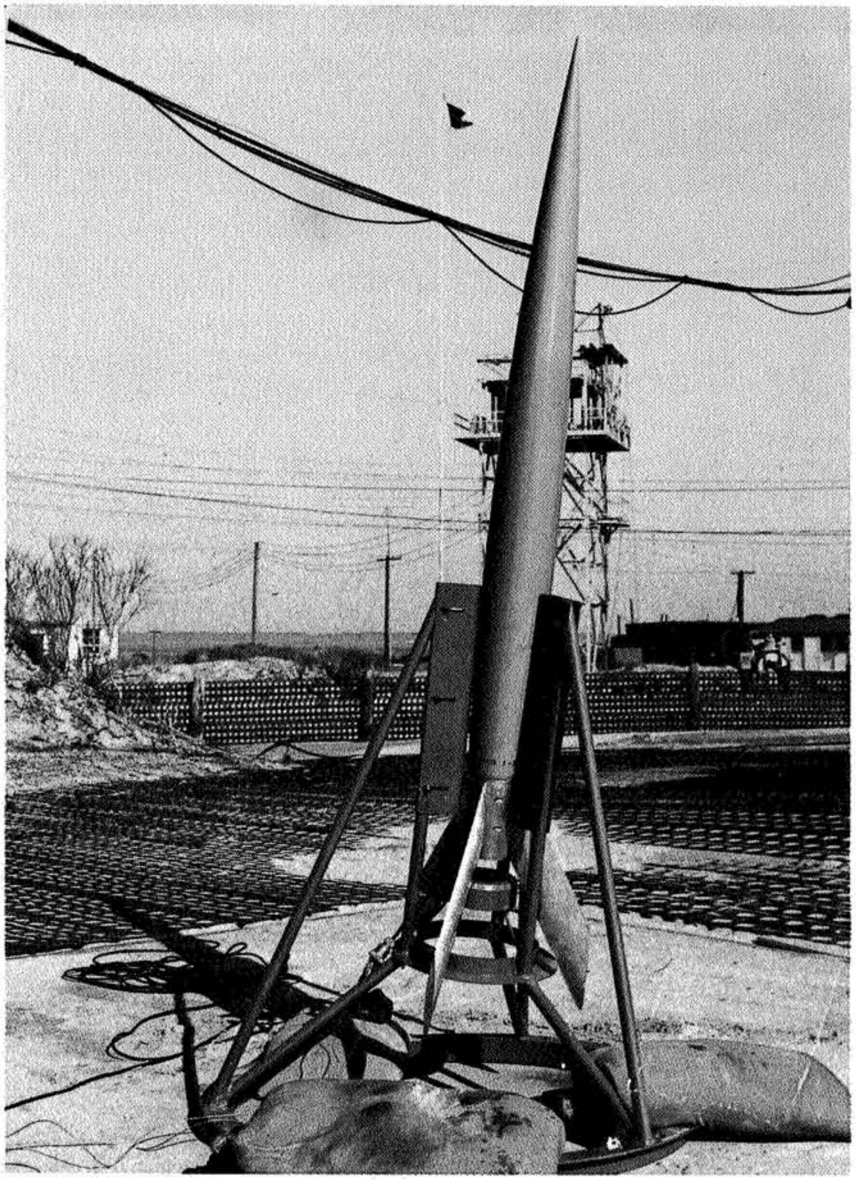


FIGURE 56. Single-stage 65-inch RM−10 model, shown on launcher February 11, 1947.

Pending initiation of the full-scale RM-10 program, a few 65-inch models were flown with only three fins, and the total drag was measured. One of the models was flown to 1,650 feet per second with only a 3.25-inch sustainer rocket motor from an RM-2 type of launcher, as shown in figure 56. Another model was flown to 3,050 feet per second by means of a new launch system consisting of a 3.25-inch sustainer motor and a 5-inch lightweight HVAR used as a booster. This model was flown on April 24, 1947, and achieved the highest speed of any research model flown to this time.

The lightweight HVAR booster was attached to the model with a new type of coupling, in which the rear of the model's body was pushed into a three-finger socket in the nose of the booster. The external fingers prevented bending, without any locking mechanism. At the cessation of thrust, the booster separated from the model as the result of its drag and the action of the sustainer rocket motor's thrust.

These early drag measurements of a body in flight at supersonic speeds over Mach 2 were fairly close to the values calculated, and gave aerodynamicists added confidence in supersonic theory.

The freely falling body program was continued through this period, and three reports were released relating to drag and airplane performance (refs. 23, 24, and 25).

An important finding at this time was that the interference drag of a sweptback wing located with its center section behind the maximum diameter of a supersonic body was much less than that of a wing whose center section was located ahead of the maximum diameter. The explanation for this favorable effect of an aft location was not understood at this time but it was explained later by the Whitcomb "Area Rule." In NACA RM L7I01, the authors stated, "The nature of these interference effects is not known at present, but possibly the presence of the sweptback wing in the aft location delays separation of the flow about the body."

References

1. Bond, Aleck C.; and Thibodaux, Joseph G.: *Flight Test of the Aerojet 7KS−6000 T27 Jato Rocket Motor.* NACA RM SL913a.
2. Littell, R. R., Memorandum for Dr. Lewis, February 5, 1945, regarding conference with Dr. F. L. Hovde and Dr. R. E. Gibson concerning rocket ordnance problems.
3. O'Sullivan, William J., Memorandum for Chief of Research, October 8, 1946, regarding visit to ABL to obtain information on rocket motors.
4. Newell, Homer E., Jr.: *Sounding Rockets.* Chapter 6, *Deacon and Cajun,* by W. J. O'Sullivan, Jr. New York, 1959.
5. Watson, R. S.: *Flight Investigation of 6.25-Inch-Diameter Deacon Rocket and 10-Inch-Scale Model Rocket.* NACA RM L8H26.
6. Gilruth, Robert R., Memorandum for All Concerned, January 17, 1947, regarding appointment of firing and range officers for Wallops.
7. Barmby, J. G.; and Clevenson, S. A.: *Initial Test in the Transonic Range of Four Flutter Airfoils Attached to a Freely Falling Body.* NACA RM L7B27.
8. Clevenson, S. A.; and Lauten, William T., Jr.; *Flutter Investigation in the Transonic Range of Six Airfoils Attached to Three Freely Falling Bodies.* NACA RM L7K17.
9. Angle, Ellwyn E.: *Initial Flight Test of the NACA FR−1−A, A Low-Acceleration Rocket-Propelled Vehicle for Transonic Flutter Research,* NACA RM L7J08.
10. Barmby, J. G.; and Teitelbaum, J. M.: *Initial Flight Tests of the NACA FR−2, A High-Velocity Rocket-Propelled Vehicle for Transonic Flutter Research.* NACA RM L7J20.
11. Harris, Orville R.: *Determination of the Rate of Roll of Pilotless Aircraft Research Models by Means of Polarized Radio Waves.* NACA TN 2023, 1950.
12. Sandahl, Carl A.; and Marino, Alfred A.: *Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Section Thickness and Wing Sweepback.* NACA RM L7D02.
13. Sandahl, Carl A.: *Free-Flight Investigation of Control Effectiveness of Full-Span, 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Wing Sweepback, Taper, Aspect Ratio, and Section-Thickness Ratio.* NACA RM L7F30.
14. Sandahl, C. A.; and Strass, H. Kurt: *Additional Results in a Free-Flight Investigation of Control Effectiveness of Full-Span, 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Wing Sweepback, Aspect Ratio, Taper, and Section Thickness Ratio.* NACA RM L7L01.
15. Alexander, Sidney R.: *Flight Investigation to Determine the Aerodynamic Characteristics of Rocket-Propelled Models Representative of a Fighter-Type Airplane Configuration Incorporating an Inverse-Taper Wing and a Vee Tail.* NACA RM L8G29.
16. Mastrocola, N.: *Effects of Number of Fins on the Drag of a Pointed Body of Revolution at Low Supersonic Velocities.* NACA RM L7A08.
17. Katz, Ellis R.: *Results of Flight Tests at Supersonic Speeds to Determine the Effect of Nose Fineness Ratio on Body and Wing Drag.* NACA RM L7B19.
18. Tucker, Warren A.; and Nelson, Robert L.: *Drag Characteristics of Rectangular and Sweptback NACA 65−009 Airfoils Having Various Aspect Ratios as Determined By Flight Tests at Supersonic Speeds.* NACA RM L7C05.
19. Alexander, S. R.; and Nelson, R. L.: *Flight Tests to Determine the Effect of Taper on the Zero Lift Drag of Wings at Low Supersonic Speeds.* NACA L7B26.
20. Katz, Ellis R.: *Flight Tests to Determine the Effect of Airfoil Section Profile and Thickness Ratio on the Zero Lift Drag of Low Aspect Ratio Wings at Supersonic Speeds.* NACA RM L7K14.
21. Purser, P. E.: *Effect of a Pilot's Canopy on the Drag of an RM−2 Drag Research Model in Flight at Transonic and Supersonic Speeds.* NACA RM L7L22.
22. Alexander, Sidney R.; Chauvin, Leo T.; and Rumsey, Charles B.: *Flight Tests to Determine the Drag of Fin-Stabilized Parabolic Bodies at Transonic and Supersonic Speeds.* NACA RM L8A05.
23. Mathews, C. W.; and Thompson, J. R.: *Measurements of Static and Total Pressure Throughout the Transonic Speed Range as Obtained From an Airspeed Head Mounted on a Freely Falling Body.* NACA RM L7C04a.
24. Thompson, Jim Rogers; and Mathews, Charles W.: *Measurements of the Effects of Thickness Ratio and Aspect Ratio on the Drag of Rectangular-Planform Airfoils at Transonic Speeds.* NACA RM L7E08.
25. Mathews, Charles W.; and Thompson, Jim Rogers: *Comparison of the Transonic Drag Characteristics of Two Wing-Body Combinations Differing Only in the Location of the 45° Sweptback Wing.* NACA RM L7I01.

CHAPTER 5

YEAR OF REORGANIZATION: 1948

CHANGES IN MANAGEMENT

During 1947 and 1948, changes in personnel and management affected the operation of the entire NACA, including Wallops. John W. Crowley, Jr., who as Chief of Research and, for a time, Acting Engineer-in-Charge at Langley, had participated directly in the establishment of Wallops Flight Center, was transferred to NACA Headquarters to assist the ailing Director of Aeronautical Research, Dr. George W. Lewis. Crowley was assigned on temporary duty at NACA Headquarters in March 1945 and, from the fall of 1945, served as Acting Director in Dr. Lewis' frequent absences. On July 18, 1947, Crowley was transferred permanently to Headquarters and was appointed Associate Director of Aeronautical Research, a position he held until NASA was established.

On September 1, 1947, ill health caused Dr. Lewis to resign as Director of Aeronautical Research, a position he had held since 1919. After his resignation, he served the NACA as a special consultant until his death on July 12, 1948. The NACA Flight Propulsion Research Laboratory in Cleveland, Ohio, was renamed the Lewis Flight Propulsion Laboratory in his memory.

Another death saddened the hearts of the aeronautical community during 1948. January 30, 1948, marked the passing of Dr. Orville Wright, who, with his brother Wilbur, had flown the world's first airplane at Kitty Hawk, North Carolina, on December 17, 1903. Dr. Wright had served continuously as a member of the NACA since 1920.

The NACA appointed Dr. Hugh L. Dryden to succeed Dr. Lewis as Director of Aeronautical Research, effective September 2, 1947 (ref. 1). Dryden came to the NACA from the Bureau of Standards where, during the war, he was responsible for guided missile development. Through his services on NACA committees—he was chairman of both the Special Committee on Self-Propelled Guided Missiles and the Subcommittee on High-Speed Aerodynamics—he was thoroughly familiar with NACA activity, and continued the policies of the NACA in the manner of his predecessor.

By the end of 1947, the NACA Special Committee on Self-Propelled Guided Missiles had reached the conclusion that it was no longer needed in the NACA committee complex. Whereas, at the formation of this committee, its scope of activities was expected to be broad and to encompass all phases of guided missile research, including guidance and automatic control research as well as aerodynamics, structures, and propulsion, the committee could not get much support from the NACA laboratories in these new fields. In particular, Langley did not feel competent in the field of guidance and preferred to leave this field to others such as the MIT Instrumentation Laboratory, Bell Telephone Laboratories, General Electric, and RCA. Without attacking the total missile problem, the NACA research was reduced to consideration of the individual disciplines, and the committee felt that the permanent NACA committees in these disciplines could adequately oversee the research. Consequently, at its meeting on November 20, 1947, the committee recommended that it be discharged, and the NACA Executive Committee, at its meeting on November 24, 1947, complied with these wishes.

Meanwhile, changes in management were taking place at Langley. During Crowley's absence from Langley, Floyd L. Thompson had been serving as Acting Chief of the Research Department, with Ira H. Abbott as his assistant. Thompson was appointed Chief of the Department on July 18, 1947. Later that year, Hartley A. Soulé joined Abbott as an assistant to Thompson. On October 7, 1947, the word "department" was removed from Langley organizational units. The head of the Langley Laboratory, Henry J. E. Reid, was now designated Director of the laboratory instead of Engineer-in-Charge; and on May 26, 1948, the word "Memorial" was removed from the name "Langley Memorial Aeronautical Laboratory." The abbreviation then became LAL instead of LMAL. Ernest Johnson continued as Chief of Administrative and Technical Services.

In February 1948, Abbott was transferred from Langley to NACA Headquarters as an assistant to Crowley, and John Stack succeeded Abbott as an assistant to Thompson. Gilruth reported directly to Thompson in connection with PARD activities.

On August 13, 1948, Soulé was given an additional assignment when NACA Headquarters named him Research Airplane Projects Leader. In this capacity, he was responsible to the NACA Associate Director for the entire NACA research airplane program, including supervision of the NACA High-Speed Research Station at Muroc Air Base, California. He had been in charge of the Langley aspects of this program from its beginning, including the NACA group at Muroc. As Research Airplane Projects Leader, Soulé was directly interested in projects at PARD relative to research airplanes, and was responsible for incorporating PARD findings into the new research airplanes. The breaching of the sonic barrier by a man-carrying airplane, the Bell XS-1, on October 17, 1947, was acclaimed throughout the aeronautical world. But the finding with this thick-wing airplane that there was a loss of roll control at transonic speeds was rather anticlimactic for PARD personnel, who by that time were deeply involved in finding solutions to the problem.

At PARD, even more extensive changes in organization were made. When Ray W. Hooker was asked to assist Gilruth in building up the Wallops test base in 1945, he was told by Ernest Johnson that he could leave this research unit whenever he wished. By early 1948, Hooker felt he had accomplished his original objective, and asked to be returned to the Engineering Services Division. The permanent facilities at Wallops had been completed, and operational procedures had been developed. No new construction projects at Wallops had been approved, and Hooker's hopes for a causeway and an airstrip seemed far from being fulfilled. On January 26, 1948, Hooker was transferred back to the Engineering Services Division as Assistant Chief, with continuing responsibility for new construction at Wallops.

Hooker was replaced as Assistant Chief of PARD by Edmond C. Buckley, who was relieved of his position as Chief of the Instrument Research Division on January 26, 1948. Morton J. Stoller was appointed Acting Chief of the IRD. The great dependence of the rocket-model technique upon instrumentation led Langley management to turn to Buckley as the logical man to take Hooker's place as Gilruth's assistant at this time. Buckley had had responsibility for Wallops instrumentation from the beginning, along with his other duties. Under the new organization, he could devote full time to this responsibility. There was need for an expansion of instrumentation capabilities and for a better approach to operational procedures.

Buckley had joined the Langley staff in June 1930 as a Junior Mechanical Engineer, after receiving his bachelor's degree from Rensselaer Polytechnic Institute in 1927 and working for 3 years for power and light companies. His first assignment was with the Langley Powerplants Division, where he demonstrated a high degree of competence in high-speed photography of internal combustion processes. A few years later, he was asked to organize an effective photo laboratory for the benefit of all Langley research personnel. Then he was given the job of organizing an instrument research laboratory, which he headed until the time of his transfer to PARD.

The operations at Wallops had, from the beginning, depended upon Langley personnel's traveling to Wallops for each rocket launching. This was true of electronic as well as rocket personnel. Buckley's first act as to rearrange and expand the Wallops organization toward self-sufficiency.

At the end of 1947, the only professional in the operations crew was Robert L. Hallett, who had taken over the maintenance and operation of the Doppler radars, and had made them a reliable scientific tool. Of the 65 men stationed at Wallops in 1947, only a half dozen were qualified to assist directly in a launching. The Superintendent, Clarence O. Green, was involved principally with maintenance and operation of the equipment connected with the island. The PARD engineers were left more or less to themselves to provide their own direct support.

When Green left the island assignment on September 1, 1947, his assistant, Harry Shoaf, took over the job as Acting Superintendent until November 26, 1947, when Junie A. Black was appointed Superintendent and Assistant Head of the Operations Section, PARD. At this same time, David G. Stone was appointed Head of the Stability and Control Section, PARD. Black attempted to operate the island from Langley and from a travel status until January 14, 1948, when he moved to Wallops. Shoaf was transferred back to Engineering Services Division at Langley on February 19, 1948. Black wasn't happy with living conditions on the Eastern Shore, and he, too, returned to Langley on April 5, 1948.

Buckley's approach to Wallops' operation was to transfer to Administrative and Technical Service personnel at Langley the responsibility for all administrative and technical service activities previously performed by PARD personnel. All men engaged in purely administrative functions at Wallops were transferred to a newly formed Wallops Island Administrative Unit with Joseph E. Robbins, Head, reporting to the Langley Administrative Officer. Robbins was transferred to Wallops from Langley. In making this assignment, according to W. K. Johnson, Administrative Officer, "Management was returning a competent native to his homeland, with the crafty intent of achieving better public relations on the Eastern Shore." All personnel engaged in technical service activity at Wallops were transferred to a newly formed Wallops Island Technical Service Unit with William E. Grant, Head, reporting to the Chief of the Langley Mechanical Services Division. This reorganization was in line with the Langley organization, but it had taken more than 2 years for PARD to see the wisdom of the arrangement. It was too much for the Operations Section of PARD to be concerned with all the administrative and technical service details as well as those connected directly with rocket launchings.

Robbins was transferred to Wallops on January 26, 1948, and Grant was transferred on April 19, 1948, but the official action establishing the two new units was not taken until June 15, 1948. Creation of these two new units at Wallops was followed by reassignment of the personnel who before this time had been on PARD rolls. Of the 65 people at Wallops, 10 were transferred to the Administrative Unit and 47 to the Technical Service Unit, leaving 8 on PARD rolls.

From the time Buckley was asked to improve operations at Wallops, he knew that he had to build a launch crew of both professional and technical personnel. In addition, he needed a man with instrumentation background and demonstrated ability to organize outdoor projects. Such a man was Robert L. Krieger, who had been involved with the radar-tracking phase of both the freely falling body program and the Wallops Island missile program from the beginning, although during 1947 he had had other assignments. In discussing the problems of Wallops operations, Buckley and Krieger reached a mutual agreement that Krieger should take the job as head of the Wallops base even though it meant moving to the Wallops area.

Krieger had worked at Langley as a messenger, a laboratory apprentice, and a photostat operator. He worked for Buckley in the Photo Lab in 1939, during which time Buckley convinced him of the value of obtaining an engineering degree. When Krieger returned for summer vacation following his first year at college, he again worked for Buckley, this time in the new Instrument Research Laboratory. Upon graduation from Georgia Institute of Technology with a B.S. degree in mechanical engineering, Krieger was reemployed at IRL on February 16, 1943, as a professional engineer. He first worked on instrumentation for the Impact Basin, but when radars came along he was assigned to them for various flight programs. In addition to his work with the freely falling body and rocket programs, Krieger was involved in measuring airplane speed in dives and with in-flight calibration of airspeed meters. He was engaged in developing special photo-optical instrumentation when he was selected for the Wallops assignment.[1]

1. Based on a conversation between the author and R. L. Krieger on September 21, 1966.

On June 30, 1948, Krieger was officially appointed as head of Wallops. The position of Station Superintendent was abolished and the position of Engineer-in-Charge of PARS at Wallops Island, reporting directly to the Chief of PARD, was created. Krieger was appointed to serve in this capacity.

Creation of this new title was in line with a recommendation made by T. M. Butler, Langley Personnel Officer, to the Langley Administrative Officer in March 1948. Butler visited the Chincoteague Naval Air Station to discuss personnel matters with officials there, including the possibility of obtaining housing for Wallops families on the Naval Station. Butler commented; "If Krieger goes to Wallops he should be introduced to the officials of the Air Station by someone from the NACA with considerable authority. . . . Mr. Krieger should be given a title that will impress the Navy officials as well as the people in the surrounding community."

On March 19, 1948, Krieger was introduced to Captain W. V. R. Vieweg, Commanding Officer of Chincoteague NAAS and NAOTS, by Dr. H. J. E. Reid, Director of Langley, as Engineer-in-Charge of the NACA Wallops Test Range. Whether this title impressed Captain Vieweg is not known, but it was not sufficiently impressive to obtain quarters for Krieger and his family on the station, nor did it forestall eventual conflict with NAOTS regarding operations on Wallops Island. Eventually, Krieger did occupy quarters on the station—those of the Commanding Officer—but not until the station was abandoned by the Navy and NASA took it over in 1959.

Under the new organization at Wallops, the PARD Operations Section, headed by Charles A. Hulcher, was no longer concerned with personnel problems at Wallops but devoted full time to the coordination of all activities at Langley leading to rocket operations at Wallops. This responsibility included transportation of personnel and equipment, scheduling of flight operations, and long-range planning for budget purposes. Although Krieger reported to Gilruth, operational planning and day-to-day operations were still coordinated through Hulcher and his Operations Section.

Upon moving to Wallops, Krieger quickly expanded the flight operations group to include professional personnel. By late 1948, this group maintained and operated all instrumentation at Wallops, and assembled and loaded, as well as launched, all rocket vehicles. Research engineers from PARD were now required at Wallops only to give general directions concerning their special needs on particular flight projects. By the end of 1948, Krieger had the following professional men on his staff: R. L. Hallett (Doppler radar), J. C. Palmer (electrical), J. J. Fenner (telemetry), I. Levy (SCR-584 radar), and E. H. Helton (Preflight Jet).

With the accomplishment of his mission at PARD, Buckley asked to be transferred back to the IRD. On November 1, 1948, he was relieved of his assignment at PARD and was reassigned as Chief of the IRD. On the same date, Joseph A. Shortal was appointed to succeed Buckley as Assistant Chief of PARD. Shortal had reported for duty at the NACA Langley Laboratory on June 26, 1929, after receiving a B.S. degree in mechanical engineering from Texas A. & M. University. Until assignment at PARD, he had been involved entirely with low-speed wind tunnel research except for a brief assignment as Project Manager for the NACA Quiet Airplane Project in 1947. His experience had been principally with stability and control of airplanes and missiles, and included development and operation of the unique Free-Flight Wind Tunnel. At the time of transfer to PARD, he was Assistant Chief of the Stability Research Division.

With the continued growth of PARD, the sections were changed to branches, and new sections were organized during 1949. The organization was then as shown in the following outline:

R. R. Gilruth, Chief
J. A. Shortal, Assistant Chief
W. J. O'Sullivan, Jr., Assistant to Chief

Operations Section	C. A. Hulcher, Head
General Aerodynamics Branch	P. E. Purser, Head
Aerodynamic Analysis Unit	W. A. Tucker, Head
Aircraft Configurations Section	C. L. Gillis, Head
Aircraft Components Section	P. E. Purser, Acting Head

Propulsion Aerodynamics Branch	P. R. Hill, Head
Preflight Jet Section	P. R. Hill, Acting Head
Model Propulsion Section	P. R. Hill, Acting Head
Performance Section	P. R. Hill, Acting Head
Stability and Control Branch	D. G. Stone, Head
Automatic Control Dynamics Section	R. A. Gardiner, Head
Aerodynamics Section	D. G. Stone, Acting Head
Wallops Island Branch (Pilotless Aircraft Research Station)	R. L. Krieger, Engineer-in-Charge

EXPANSION OF INSTRUMENTATION

The SCR-584 tracking radar continued to provide researchers with flight path data on test models. In 1945, this radar was located at Station 2 on the mainland as a compromise between tracking at launch, tracking of subsonic missiles, such as the Tiamat, as they flew a constant-altitude course parallel to the coast, and tracking of freely falling bodies dropped onto the target south of Wallops Island.

By the middle of 1946, Langley was unhappy with the use of Wallops as a test range for the freely falling body program. The radar and telemeter receiver operators had to be sent from Langley on travel status, and on each trip considerable time was spent getting the equipment back into operation. A large percentage of the time, the drop was called off because of weather, airplane troubles, or instrumentation difficulties in the test body. The resulting wasted effort prompted the decision to return the body-drop program to the Langley area.

A second SCR-584 radar was obtained and, when modified as before, was located at Fox Hill near Langley for a resumption of drop tests with Plum Tree Island as the target. In late 1947, a model of the XS-1 airplane was dropped on Plum Tree, but the model performed an erratic maneuver and "buzzed" a populated area before striking the ground. Fortunately no damage was done, but Langley management decreed that all further drops would be made at Wallops.

The model drops at Wallops were not without incident. Although the drop airplanes were equipped with modern bombsights, the bodies did not always fall within the special target area. On one occasion, a body fell into the ocean just off shore from the launch area. After that time, the airplanes were vectored into position and commanded to release the test body by controllers on the ground who were following the flight path of the airplane on the radar plotboard. The impact point was selected a safe distance off shore.

With the ending of constant speed flights of missiles down the coast and the shifting of the freely falling body target area to an offshore position, it was no longer necessary to keep the SCR-584 tracking radar at the mainland tracking station. Better tracking could be obtained for rocket firings from locations nearer the launchsite. In 1947, the radar was moved to a position in the launching area. After trials in several locations, it was finally moved to a location approximately 1,300 feet behind the launching area, where it was given a permanent home. Power and telephone lines were run to the site in 1948, but not until December 1949 was a paved road built to the radar site.

The range of the SCR-584 radar, as used in a modified condition, was 38 miles for a one-square-meter target. Some models were large enough to be equivalent to such a target. The power had been increased from 250 to 410 watts and the diameter of the tracking dish had been increased from 6 to 8 feet.

In anticipation of an increased range of flight models, IRD queried the electronics industry in July 1947 regarding a possible pulse radar with a 60-mile range and an an accuracy of 0.2 mil. The inquiry also asked for a Doppler radar with a range of 15 miles. The only favorable reply came from Reeves Instrument Corporation, which stated that it was developing an improved version of the SCR-584 radar that would have a range of 200 miles.

In May 1947, Paul F. Fuhrmeister of IRD was placed in charge of all radars at Langley. His specialty previously had been the TPS-5 Doppler radar. By this time, Langley had four SCR-584 radars, two TPS-5 Doppler radars, and one Sperry Model 10 Velocimeter Doppler radar.

The Doppler radar was a genuine asset to PARD; it made possible the direct determination of velocity, and allowed the measurement of drag for such simple models as the RM-2 and RM-5 types. Doppler radars were used in every launching from Wallops. The first radar of this type, the AN/TPS-5, was obtained from the Signal Corps in June 1945, just prior to the first Tiamet missile launchings at Wallops. The radar had been developed during the war for use in sentry duty—in particular, to detect movements across bridges. It came complete with a loudspeaker that "growled" at any movement.[2] This first radar had a range of approximately 1 mile and a power of 10 watts. A second TPS-5 was purchased from Sperry Corporation and received in 1946.

Drag determination with the TPS-5 radar did not start until the sustainer rocket ceased burning; and frequently the test model was beyond radar range before it had slowed to subsonic speeds. As higher speeds were obtained through use of larger booster rockets, the problem of obtaining data over the complete range became more acute.

In cooperation with the Army's Aberdeen Proving Ground, specifications for a more powerful Doppler radar were prepared. A 150-watt radar which its manufacturer, Sperry Gyroscope Corporation, called the Model 10 Velocimeter, was purchased. This radar was mounted on a SCR-547 trailer, which led Langley men to call it the TPS-547 radar for some time. The radar had a range of approximately 5 miles and was the first of a series of this type used at Wallops for many years.

The Model 10 Velocimeter is shown in figure 57. One operator directed the dishes toward the target in azimuth while the other controlled the elevation. (The fact that two operators with independent gunsights and earphones could coordinate their efforts in this fashion surprised many "experts.") The Doppler radars were always located near the launcher and the operators usually served in a dual capacity, acting also as rocket technicians. After the Velocimeter was placed in operation, the TPS-5 radars were no longer used.

An automatic firing sequencer or programmer was developed in 1947. The programmer, shown in figure 58, made it possible to start the various recording instruments and cameras at designated times prior to launch, and to fire the rockets at a desired time. This was a step forward in launch technique. The programmer was automatic after a nominal value of minus 30 seconds, yet it could be stopped by an operator at will.

Standard weather balloons and radiosondes were acquired from the U.S. Weather Bureau for use at Wallops as soon as the flight altitudes became high enough to warrant consideration of effects of altitude on air density. Radiosonde balloons or special balloons equipped with radar reflectors were also used to determine wind velocity. This equipment was improved as required to meet the needs of the flight program. In later years, density-measuring devices were necessary for altitudes as high as 100,000 feet. A typical launching of a radiosonde balloon is shown in figure 59.

Communication equipment at Wallops (fig. 60) consisted of telephone circuits between all island stations and both high- and low-frequency radio links. In May 1946, IRAC (Interdepartmental Radio Advisory Committee) approved NACA use of radio frequencies 3040 and 3480 kc and 34.38 mc for line-of-sight communication. In October 1946, temporary assignment of frequencies 77 and 80 mc also was made for trial purposes. In 1949, permission was obtained to use ship-to-shore radio frequencies (2638 and 2738 kc) to warn fishing boats of impending rocket launchings.

Allocation of two frequency bands for telemeter use was also obtained from IRAC in May 1946. These bands were near 217 and 219 mc. The frequencies were to replace the 118-mc equipment in use at the time. Use of the new frequencies began as soon as equipment was obtained, and provided the standard NACA telemeter frequencies for many years to come.

From the beginning at Wallops Island, two separate telemeter receiving stations were used to increase the chances of obtaining good data. Initially, one receiving station was located at the mainland tracking station and the other in a trailer near the launching site. Later, both receivers were located at the launchsite, in the Control Center, as shown in figure 61.

An improved telemeter receiving antenna, developed in 1948, provided a 12-decibel gain over the original antenna. It was a turnstile antenna that was mounted on a searchlight mount and could be

2. Based on conversations between the author and Paul F. Fuhrmeister, July 27, 1966.

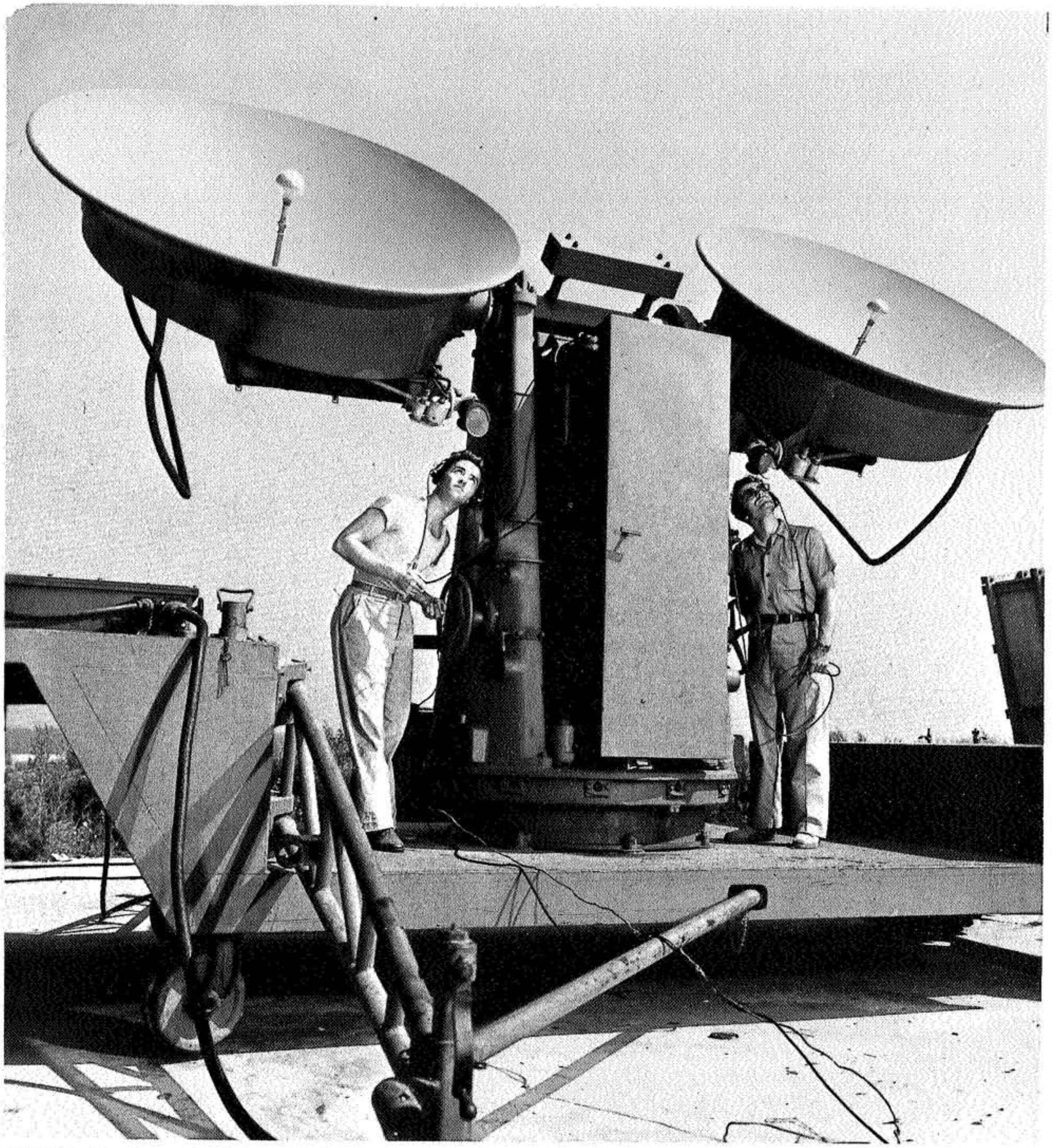


FIGURE 57. Sperry Model 10 Velocimeter, Wallops Island Doppler radar, shown with trackers P. R. Mears and J. Quillen, July 28, 1950.

pointed at a remote target by the SCR-584 equipment. This capability was made possible through adaptations of the M-9 computer, which provided parallax corrections. The antenna is shown in figure 62. With it, the effective range was increased by a factor of 3. During this period, the number of continuous telemeter channels was increased first to 6 and then to 8.

Discussions with the Eastern Shore Public Service Company carried on from the beginning of Wallops Flight Center finally yielded results during 1948. The Public Service Company agreed to supply 200 kw of electrical power in 1948 and 500 starting in January 1949, provided that the NACA would construct the powerline.

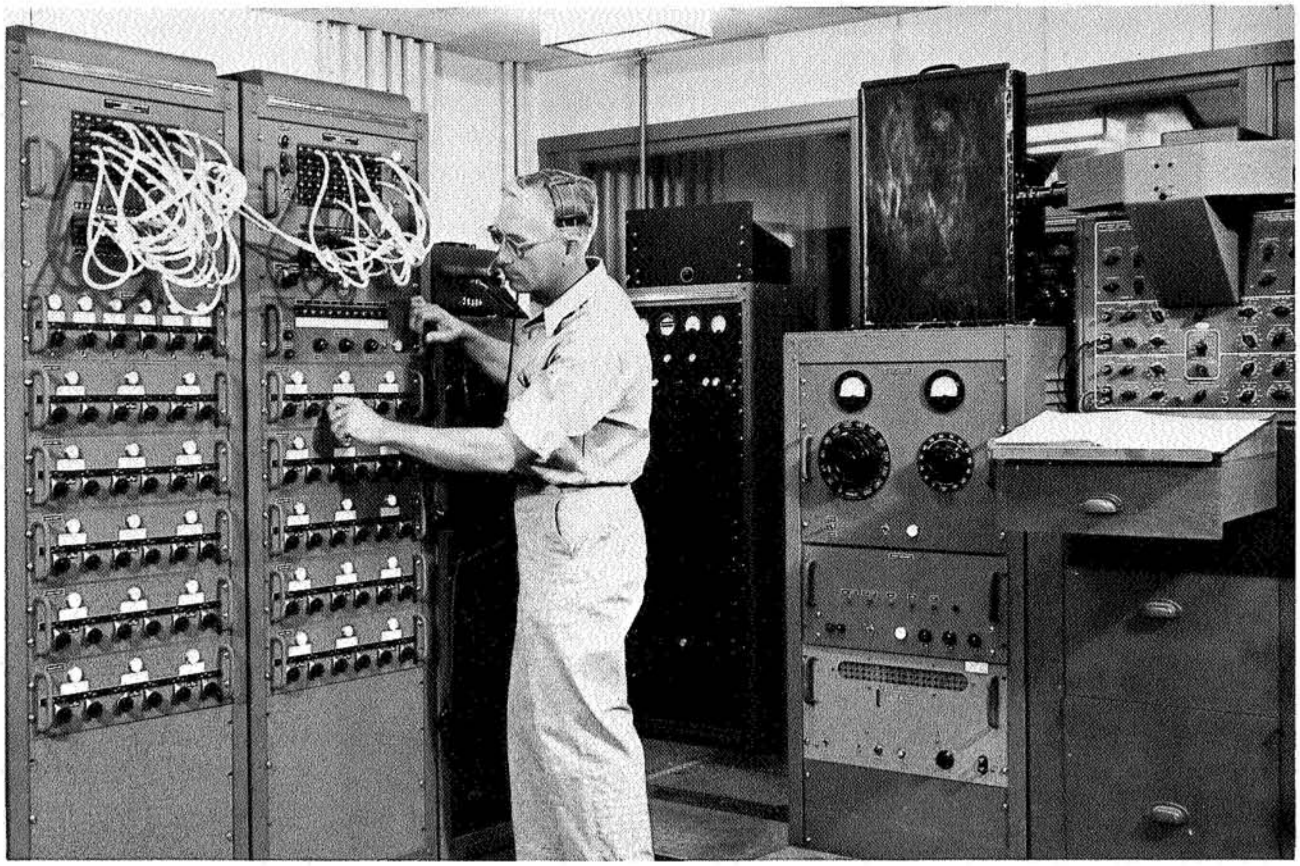


FIGURE 58. Wallops automatic programmer being monitored by F. H. Forbes, July 29, 1950. Doppler radar recorders are behind Forbes.

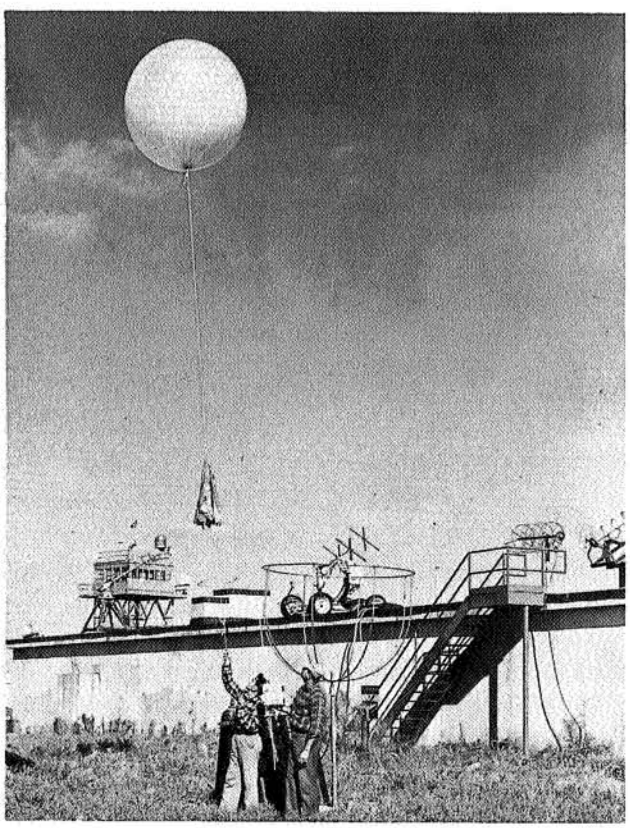


FIGURE 59. Technicians P. R. Mears and W. A. Roberson perform typical launching of a radiosonde balloon at Wallops Island.

FIGURE 60. Engineer R. L. Hallett, Jr., listens over portable EE88 telephone as he adjusts spinsonde receiver during rocket test flight at Wallops Island, July 28, 1950.

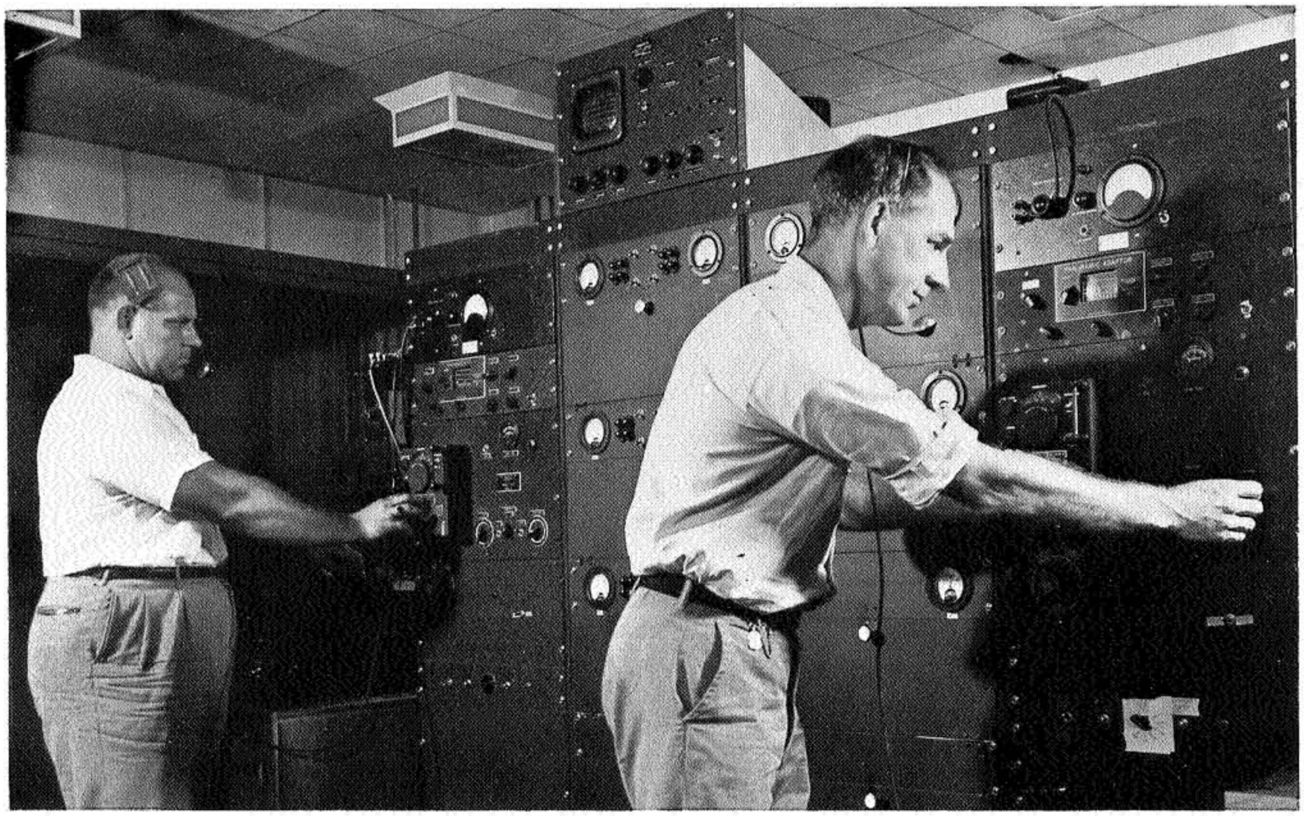


FIGURE 61. Dual telemeter receivers at Wallops Island being adjusted by J. J. Fenner and J. W. Smith.

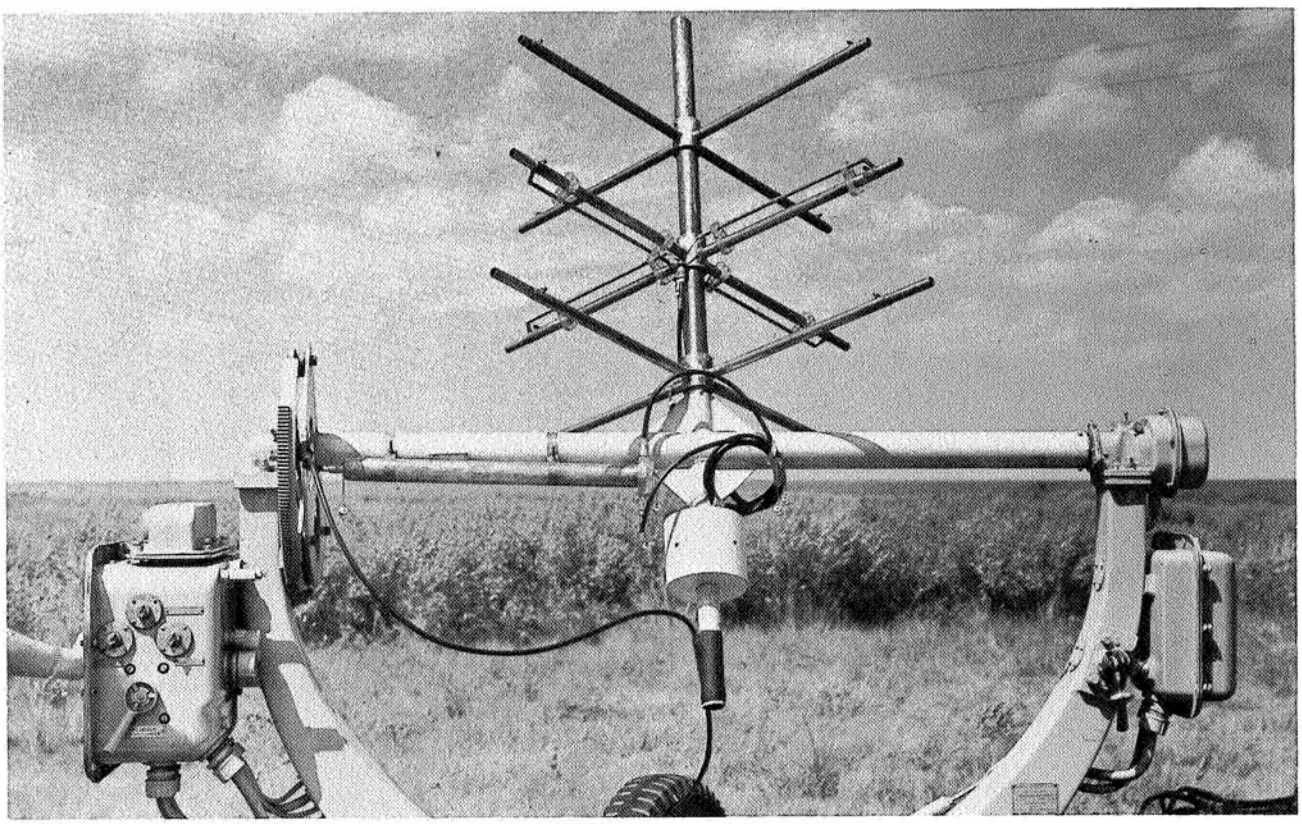


FIGURE 62. Turnstile telemeter receiving antenna on searchlight mount for automatic pointing, Wallops Island, photographed on July 30, 1948.

After obtaining leases on land across the marsh between the mainland and Wallops, and securing permission from the U.S. Army Engineers' office for an aerial crossing of the intercoastal waterway, the pole line was installed under a contract with Carpenter Construction Company of Norfolk, Virginia, for $50,801. The Chesapeake and Potomac Telephone Co. installed five telephone circuits on the same poles.

The location of the line, as shown earlier in figure 8, was the proposed location for a causeway; it started near the island cafeteria and ran in a northwesterly direction to the mainland. Power was turned on December 15, 1948.

DREDGING OF A BOAT CHANNEL

By April 1947, the channel used by boats between the mainland and island docks had filled with silt to a level where, at some low tides, damage was sustained by propellers and rudders. Transportation schedules had to be altered to suit the water conditions with resulting loss of time and delays in firing operations. It was clear that extensive dredging was required.

G. S. Brown recommended that the route be redesigned by cutting across some marshes to allow the use of Old Woman's Bay (Oyster Bay). The new route would reduce travel time by one-third. The proposed new channel is shown in figure 63 as Route 1; the existing channel, as Route 2. The estimated cost for the new route was $42,000, compared with $23,000 for the old one. Brown recommended dredging a channel 60 feet wide and 9 feet deep at low water.

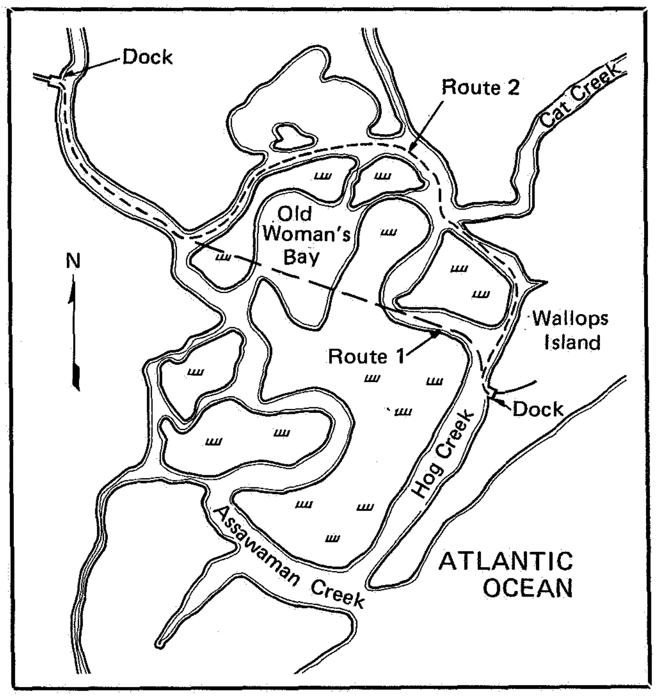


FIGURE 63. Proposed new boat channel from Mainland Dock to Island Dock.

On July 23, 1947, Langley asked NACA Headquarters to request the Corps of Engineers to handle all details connected with the dredging, at an estimated cost of $65,000 to be financed by funds that would be transferred from the NACA to the War Department. The Corps of Engineers would not provide this service because the work was considered a private convenience, and the NACA had to handle the contract. Approximately a year later, the Steen Contracting Company was awarded a dredging contract for Route 1, under Project 808, for $68,400. The channel was completed on June 8, 1949.

With extremely high tides, the marsh surrounding the channel was under water, and for safety it was necessary to install additional channel markers. In 1946, the NACA was successful in getting the Coast Guard to install daybeacons with reflectors to mark the original channel (Route 2). On completion of the dredging project, the NACA asked the Coast Guard to install three markers in the new channel. At this time, two LCM boats, two personnel boats, and two barges, converted to personnel carriers were using the channel, as were contractors' boats and other private craft. The Coast Guard first replied that funds were not available, but it had no objection to the NACA's installing private markers. The NACA attempted, without success, to get the Coast Guard to change its ruling. On the second request, the Coast Guard ruled that inasmuch as the Corps of Engineers had refused to handle the dredging for the NACA, the channel must be considered primarily a private channel and part of NACA facilities. The Coast Guard agreed, however, to install the markers for the NACA at cost. The estimated cost for the three daybeacons was $660, with a yearly maintenance expense of $50.

When the channel through Old Woman's Bay was dredged, several private oyster grounds were crossed, and damages had to be paid by the Government. Before dredging could be started, it had been necessary to obtain permission from the holders of the private lands as well as from the Commonwealth of Virginia for State-owned lands. Such permission carried a stipulation that any damages to oyster grounds would be settled in accordance with a postsurvey by a State-appointed Oyster Inspector.

As a result of such a survey and other claims for damage from dumping of dredged material, the following claims were paid by the NACA:

T. F. Mears	$ 50
Elihu Matthews	200
Pierce B. Taylor	1,000
Young and Ardis	800
N. P. Collins	500
Sewell Chesser	200

The payment of all claims was completed on August 3, 1949.

CONFLICT WITH NAOTS, CHINCOTEAGUE

When the NACA selected Wallops Island for its test site, it was aware of the Navy's intention to use the northern end of the island for a test range. The NACA envisioned a cooperative relationship similar to the one existing with the Army Air Forces at Langley Field. NACA relations with the Navy BuAer had always been excellent, but relations with BuOrd at Wallops were to be a different story.

When the Naval Aviation Ordnance Test Station (NAOTS) was established at the NAAS, Chincoteague, the command of the joint activity was given to an ordnance officer, Captain W. V. R. Vieweg. Official cooperation was given by NAOTS because of high-level directives, but at the working level, NAOTS personnel were continually submitting plans for expansion at Wallops, which, if approved, would practically have forced the NACA off the island.

In the beginning, Chincoteague officials posed no objection to the NACA's use of the lower end of Wallops, but they did point out that they were going to purchase the entire island and would allow the NACA to continue using the lower end provided there was no interference. The NACA personnel moved in with full knowledge of a potential interference problem; but they were so accustomed to working on a cooperative basis that they did not consider the problem a serious one.

Before the Navy leased the remaining portion of Wallops north of the NACA lease line, in March 1947, their operations people were planning activities on NACA property. In fact, as was noted in Chapter 3, Langley had agreed to a request from NAOTS in December 1946 for the use of a 100-yard strip of NACA beach for testing a rocket-loading machine. In February 1947, Captain Vieweg obtained an agreement from H. J. E. Reid, Engineer-in-Charge at Langley, for NAOTS to use the lower tip of Wallops for some special inert bomb drops.[3] The same agreement gave Vieweg authority to issue passes for naval and contractor personnel to enter NACA areas.

3. Letter from H. J. E. Reid, Langley, to Captain W. V. R. Vieweg, February 7, 1947, regarding use of southern tip of Wallops Island as a bombing target.

Hooker became concerned about this bombing activity within the NACA base, and was even more apprehensive about future plans for Wallops as outlined by Vieweg during several of Hooker's visits to NAOTS and at a meeting in Norfolk, Virginia, held to discuss danger areas.

At the meeting, Vieweg stated that his station would reqire ranges for the following types of tests:

(1) Tests of ground-launched and air-launched guided missiles

(2) Firing tests of antiaircraft guns

(3) Fire control tests

(4) Ground and air tests of aircraft rockets

(5) Aerial bombing

It appeared to Hooker that any ground launching of missiles from Wallops by NAOTS would certainly interfere with NACA activity. To protect the NACA's interest, Hooker recommended that the area at Wallops under lease be purchased as soon as possible. This recommendation was rejected by the Bureau of the Budget because of the Navy plan to purchase the entire island.

NAOTS operations began very slowly at Wallops, and little interference actually existed for some time. The Navy used its area more as a daily test range than as a base for operations requiring transient personnel overnight. Subsonic air-to-surface guided missiles were air launched, and some bombs were dropped. A gun-firing test range was constructed on the beach, and tracking radars, as well as a Hastings Raydist system, were installed. For many operations, the NACA was asked to assist the Navy by tracking with the NACA radar.

Through 1947, NAOTS operated with temporary facilities; but by March 1948 it was ready for the construction of permanent quarters. In March, NAOTS submitted a detailed plan for the expenditure of $1,500,000, which was under consideration by Congress.

In August 1948, the NACA was asked by NAOTS to confer about the need for offshore observation stations for use in NAOTS tests of Kingfisher missiles. Gilruth and Krieger attended the meeting on August 12, 1948, and raised the question of range interference. Vieweg expressed surprise that the NACA foresaw an interference problem. Gilruth pointed out that research conducted by the NACA at Wallops was the only source of large-scale transonic aerodynamic data in this country, and that the aircraft industry had requested the NACA to increase the productivity of Wallops Island by a factor of at least 3. Such an increase would mean 1,000 launchings per year. Gilruth stated that if NAOTS constructed observation stations in front of Wallops and entered into an extensive test program, there certainly would be interference. He stated, "If such is the case, a high-level decision is clearly called for as to whether it is in the national interest for two test ranges to be located on Wallops Island (ref. 2).

The possible interference problem was referred by NACA Headquarters to its dependable friend and ally, Captain W. S. Diehl of BuAer, who in turn conferred with Admiral M. J. Schoeffel, Chief of BuOrd. Commander O. C. McCracken, who represented BuOrd at the Kingfisher meeting, convinced Admiral Schoeffel that there would be no interference. The NACA countered with continued expressions of concern regarding serious interference problems. On November 12, 1948, BuOrd arranged a conference to be held at NAOTS on November 18 to discuss the interference. Commander McCracken was to represent BuOrd. Captain Vieweg invited H. J. E. Reid to send representatives to the November 18 meeting at NAOTS. Instead, at Reid's invitation, the BuOrd and NAOTS representatives met at Langley with NACA representatives on December 6, 1948.

At the December 6 meeting, Gilruth fully discussed PARD facilities at Wallops Island, its missile and airplane flight research program, and the range interference probability. Gilruth again pointed out the need for even greater rocket-firing activity as recommended by a Joint Army-Navy-NACA-Industry Committee in a resolution calling for an increase in the rocket test technique by a factor of at least 3. Commander P. D. Buie, NAOTS, stated that even if there were no interference at the present time, but study showed that interference might develop in a few years, "then it would be much wiser to move, at this time, rather than later, one or the other range to another locality."

No conclusions were reached but three committees were appointed to study the interference problem and to report back to the larger group in January 1949. The three committees were titled according to their respective areas of study: (1) Facilities, (2) Electronics, and (3) Safety, Space, and Scheduling.[4]

The special committees met and reported back to the original group at a second meeting held at Langley on January 17, 1949. Captain G. K. Fraser, who had replaced Captain Vieweg as Commanding Officer, NAOTS, also attended this meeting. The meeting produced general agreement that a serious interference problem would attend the use of Wallops Island by both the NACA and NAOTS, and the matter was referred to higher authority. Higher authority was represented by the RDB Guided Missiles Committee, which sent the matter on to its Ad Hoc Subcommittee on Range Planning. In its report of March 4, 1949, this subcommittee recognized that the NACA had a more extensive program at Wallops, as well as a more extensive investment there, and recommended that the interest of the NACA be given precedence over that of the Navy. Further study of electronic interference was recommended (ref. 3). At this point, BuOrd withdrew its request for funds for an expansion of activities at Wallops, and a mutually satisfactory agreement was reached.

On March 11, 1949, an agreement was signed by Captain S. E. Burroughs, USN, and Hugh L. Dryden, NACA, which recognized the primary interest of the NACA in Wallops Island and effectively ended the problem of interference.

The agreement (ref. 4) stated the following:

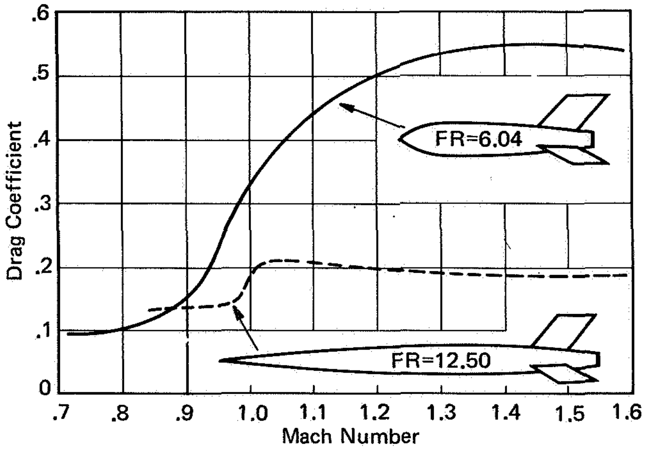
1. NACA agrees to cooperate fully with Navy in launching Kingfisher missiles in Wallops Island area without objection unless interference to NACA becomes intolerable.
2. NACA agrees to permit the use of land now occupied by it on the south end of Wallops Island on a temporary basis for Navy use during the Kingfisher experimental program for such observation and tracking as is necessary.
3. Navy agrees that Wallops Island will not be set up as a permanent Bureau of Ordnance guided-missile range and its use for such purposes will terminate with the end of the Kingfisher experimental project.
4. Navy agrees that NACA activities have a primary interest in the Wallops Island area.

CONTINUATION OF ROCKET-MODEL DRAG PROGRAM

The RM-2 rocket-model drag program continued through 1948 with the accumulation of basic aerodynamic drag information on such items as external wing tanks, the pilot's canopy, and the drag-reducing effects of small cones or wedges mounted on a strut in front of a blunt-nosed missile-type body (refs. 5, 6, and 7). Most of the RM-2 models were now propelled by the two-stage system first used on the 65-inch RM-10 model described in Chapter 4. This was a 5-inch HVAR booster with a 3.25-inch sustainer rocket motor. Mach numbers of 1.6 to 1.8 were obtained with the two-stage system.

One of the outstanding programs used to obtain aerodynamic drag characteristics of parabolic bodies of revolution was a special series of RM-2 models launched during this period. All of the bodies were 7.5 inches in diameter and were stabilized by identical three-fin systems. The bodies had their maximum diameters located at points representing 20, 40, 60, and 80 percent of the length, respectively, and had fineness ratios of 6.04, 8.91, and 12.50. The significant effect of fineness ratio and location of maximum diameter is clearly shown in figure 64, which compares a body of fineness ratio 6.04 and maximum thickness at 20 percent, with a body of fineness ratio 12.50 and maximum thickness at 60 percent. The comparative values of drag coefficients (based on cross-sectional area of the body) are given in the following table for a series of parabolic bodies at a Mach number of 1.4. The drag varied between the highest and lowest values by a factor of almost 3 (ref. 8). Such data as these were influential in dictating fuselage shapes for supersonic airplanes and missiles.

4. Langley letter to the NACA on December 8, 1948, enclosing minutes of conference held December 6, 1948, between NACA, BuOrd, and NAOTS personnel regarding interference problems.



DRAG CHARACTERISTICS OF A SERIES OF PARABOLIC BODIES AT MACH 1.4 AS DETERMINED FROM ROCKET-MODEL TESTS

Fineness Ratio	Location of Maximum Diameter			
	0.20	*0.40*	*0.60*	*0.80*
6.04	0.54	0.31	0.28	0.34
8.91	.39	.23	.19	.25
12.50	.28	.19	.18	.21

FIGURE 64. Graph showing effect of fuselage shape on drag of E2 rocket models.

CONTINUATION OF FREELY FALLING BODY PROGRAM

The freely falling body program to determine drag characteristics was also continued in 1948. In June 1948, the use of bombers for this program was discontinued and a North American XP-82 fighter plane was substituted. This change became possible after launch control was shifted from a bombardier to the radar controller on the ground. The airplane was generally similar to the P-82 used in the Lewis ramjet free flight program at Wallops (see figure 65).

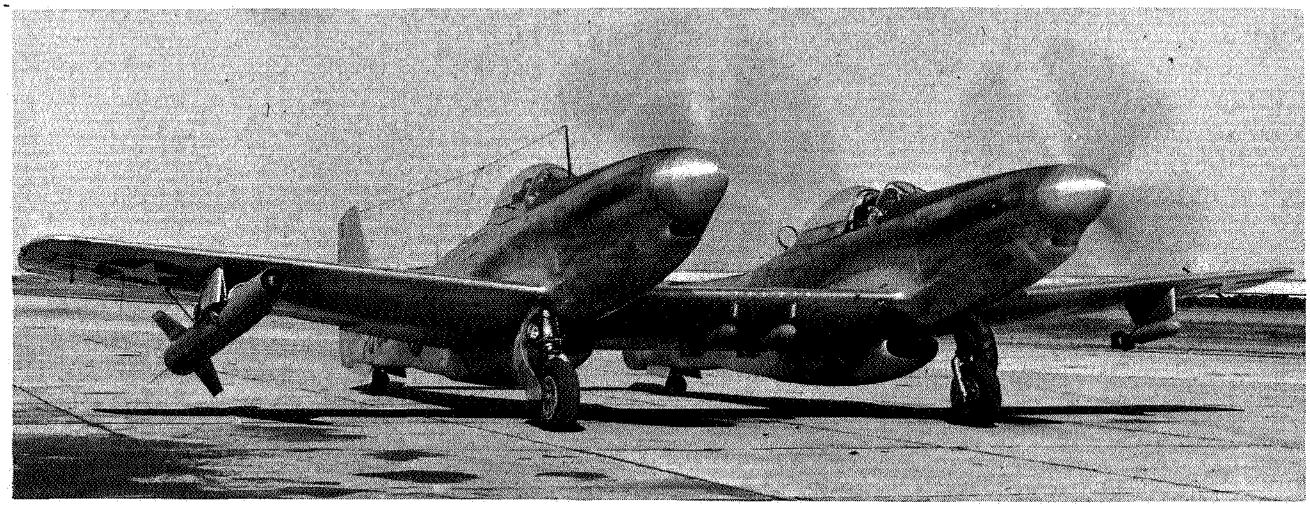


FIGURE 65. North American P–82 airplane used in Lewis ramjet program at Wallops. Photograph taken on March 31, 1948.

In an attempt to explain the large decrease in drag obtained earlier in the freely falling body program when the fineness ratio of the basic body was increased from 6.0 to 12.0, two additional bodies were dropped. One had its front half replaced by the front half of a body of fineness ratio 12.0, and the other had its rear half replaced by the rear half of a body of fineness ratio 12.0. The effect was to create two new bodies of finess ratio 9.0, but with the maximum diameter located in different fore and aft positions. In fact, the effect was to approximate two of the bodies of the rocket-model program, fineness ratio 8.91, maximum diameter located at 40 and 60 percent of the body's length. The difference between the two bodies' drag was small, indicating that the entire body had to be lengthened to achieve the large drag reduction (ref. 9).

In an earlier freely falling body test, locating the wing of a wing-body combination aft of the maximum diameter resulted in a remarkable reduction in drag over that obtained with the wing located ahead of the maximum diameter (refs. 23, 24, and 25, Chapter 4). In an effort to obtain even lower drag, a second body was tested with a large wing-root fillet added ahead of the leading edge of the wing. The hope was that "sweeping the line of maximum thickness progressively forward as the wing root was approached might be an effective means for further reducing the drag. . . ." Adding this area ahead of the wing, of course, violates the Whitcomb Area Rule referred to earlier and should increase the drag. This is exactly what happened (ref. 10).

There was much to be learned in these days about the mysterious transonic region. To obtain a better understanding of basic flows over a body in this region, one test was made wherein local pressures were measured over the body in flight (ref. 11).

Additional wing-body combinations were tested with 35-degree sweepback of wings with 9-percent and 12-percent thickness, for correlation with the earlier 45-degree sweptback wings. While these results were of general interest to aerodynamicists, they were of little practical value because, by this time, much thinner wings were being considered for both airplanes and missiles (ref. 12).

Stability and drag at an angle of attack were determined for the body of fineness ratio 12 in another test by setting the tail surface for trim at 27-degree angle of attack (ref. 13).

CONTINUATION OF E5 AERODYNAMIC CONTROL PROGRAM

During the period 1947–1949, the RM-5 or E5 aerodynamic control program with simple rocket-propelled models was being conducted at a remarkable rate. As shown in Appendix C, 386 such models were launched at Wallops in this 3-year period. This high rate was justified by the fact that Wallops was the only facility in the nation for obtaining rolling effectiveness information in the transonic range. By early 1948, a booster rocket containing either a 3.25-inch or a 5-inch HVAR rocket motor had been added to the system to extend the Mach number to 1.8 or 1.9.

Twelve reports released in 1948–1949 are discussed in this chapter. Improvement in technique to yield more accurate data involved accurate measurements of aileron deflection and wing incidence and correction to a nominal setting, and measurements of torsional rigidity to allow correcting the results to rigid wing conditions. It was also found necessary to measure the profile of the wings to be sure just what section was being tested. In one case, it was detected that the model finishers filled in the cusp near the trailing edge with the mistaken belief that the wing had been constructed in error.

Models simulating the wings of the Douglas D-558-II, the Douglas X-3, and the Bell X-2 research airplanes were among those tested early in this period. The results of the D-558-II with its NACA 63012 wing section normal to the 0.3-chord line and 35-degree sweptback planform were not much different from those of earlier tests of similar configurations. A reduction in control effectiveness was measured over the speed range, with the sharpest drop occurring near Mach 0.95 (ref. 14).

The Douglas X-3 was the first to have the thin-wing supersonic airplane design. Its low-aspect-ratio wing with its modified double-wedge section was only 4.6 percent thick. The wing tested in the RM-5 program was of higher aspect ratio than the final airplane, but the control results were indicative of what could be expected. Although the wing tested was made of solid aluminum alloy, there was a large reduction in control effectiveness at supersonic speeds because of aeroelastic effects. That is, the deflected aileron caused the wing to twist and partially nullify the rolling effect. When this result was translated into the full-scale airplane, the lower pressures associated with the high-altitude operation of the airplane had to be taken into account. At transonic speeds, there was a reduction in effectiveness, but without the sharp reversals previously encountered with thick wings (ref. 15).

The results with a model simulating the Bell X-2 airplane presented quite a different picture and revealed a phenomenon whose discovery and detailed exploration were among the major contributions of the RM-5 program.

This phenomenon was the complete reversal of aerodynamic rolling effectiveness at Mach 0.95 (ref. 16). The explanation lay in shock-induced separation of flow over the control surface, the severity of which was related to the slope of the rear portion of the wing surface, as measured by the trailing-edge angle.[5] This wing, which was tapered and sweptback 42.7 degrees, had a circular-arc airfoil section 10 percent thick, normal to the quarter-chord line, and a trailing-edge angle of 21 degrees.

With the aid of preliminary tests by the "transonic-bump" technique in the Langley 7-foot by 10-foot tunnel, it was found that reducing the trailing-edge angle, either by thickening the trailing edge or by extending the aileron rearward, would eliminate the reversal. The solution recommended for the actual airplane was to thicken the trailing edge to one-half the maximum thickness of the aileron. This amount of blunting of the control reduced the trailing-edge angle to approximately 8 degrees (ref. 17).

The flight results for the original aileron and this thickened trailing-edge aileron are given in figure 66. With this modification, the rolling effectiveness approximated the military requirement for piloted high-speed airplanes, shown in figure 67 for a typical case (ref. 18).

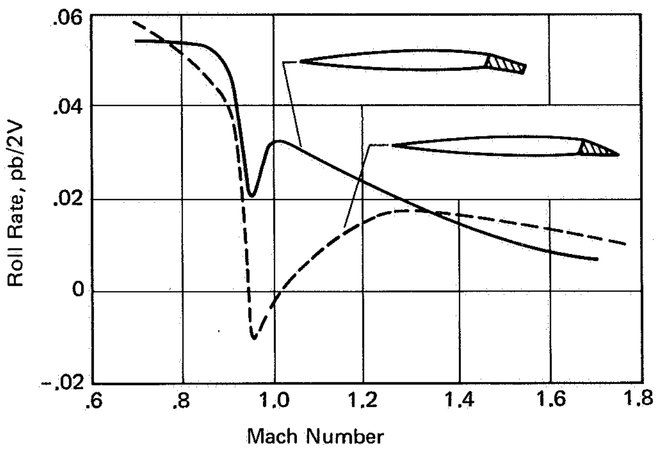


FIGURE 66. Graph showing effect of aileron trailing-edge bluntness on rolling effectiveness of circular-arc wing with 42.7-degree sweepback and 10-percent thickness.

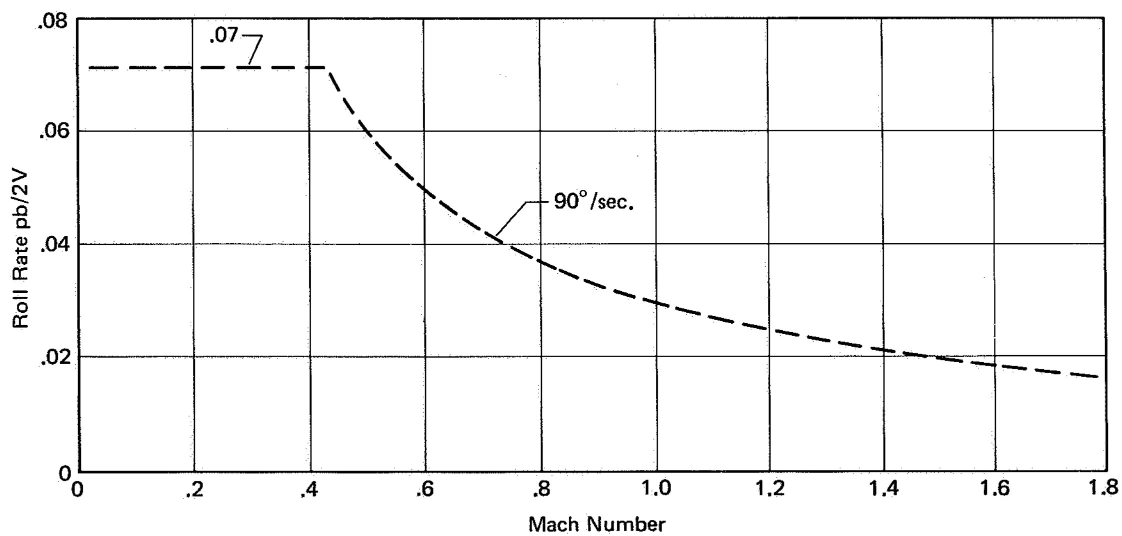


FIGURE 67. Military rolling requirements for a high-speed fighter.

Extensive investigation of this trailing-edge angle effect was made for a wide range of airfoil sections and wing planforms. The results all showed the harmful effect of a large trailing-edge angle (refs. 19, 20, and 21). This was but one of the phenomena that led airplane and missile designers to turn to thin airfoil sections. Other reasons will be discussed later.

The delta wing is a special case of a sweptback, low-aspect-ratio, tapered wing. Its extreme taper gives it certain structural advantages and makes possible the use of thin airfoils. It was of interest for use on either supersonic airplanes or missiles (e.g., the F-102 airplane and the Sparrow guided missile).

5. The trailing-edge angle is the included angle formed by the upper and lower surfaces of the wing at the trailing edge.

A program of control research for such wings was included in the RM-5 series. Conventional trailing-edge controls and all-moving tip controls were investigated. The tip control is aerodynamically self-balancing, and in the flight tests was found to be twice as effective at supersonic speeds as a trailing-edge control of the same area. Comparative results are shown in figure 68. The relative effectiveness of the two types of controls reversed at subsonic speeds (ref. 22). The tip controls found favor with missile designers while airplane designers, in general, favored the conventional trailing-edge type.

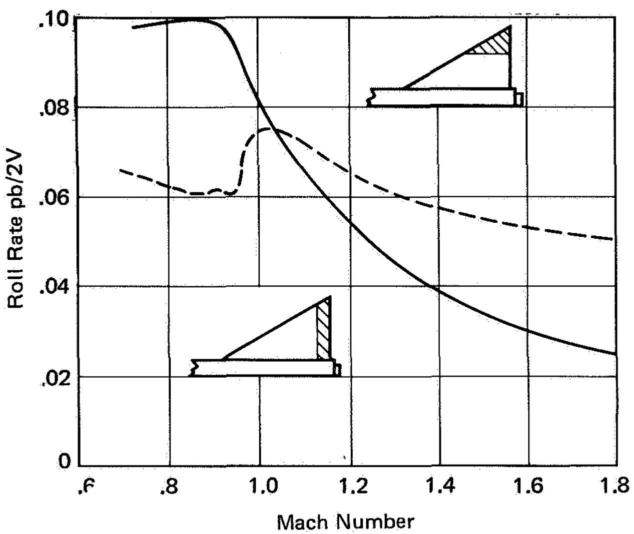


FIGURE 68. Comparison of rolling effectiveness of wing-tip ailerons with that of trailing-edge ailerons, as used on a 60-degree delta wing.

Other special types of controls investigated were spoilers and combinations of leading- and trailing-edge devices. The combination of a leading-edge and a trailing-edge flap was quite effective over the entire speed range on a highly tapered wing without sweep, but it was never used in practice, probably because of the structural problems involved (ref. 23). The spoilers were able to produce a high rate of roll at transonic speeds, but their effectiveness at supersonic speeds was low (refs. 24 and 25).

CONTINUATION OF FLUTTER PROGRAM

Because of concern on the part of Navy BuAer about the possibility of "aileron buzz" on the Douglas D-558-II research airplane, the NACA was asked to study the possibility of such behavior by wind tunnel and rocket flight tests on a 1/4-scale model of the outer 55 percent of the wings complete with ailerons. For the flight tests, the wing panels were mounted on a standard FR-1 flutter research body. In one test, up to a Mach number of 1.03 no flutter occurred, but in a second test a nondestructive flexure-aileron flutter was encountered between Mach 0.58 and 0.73, and aileron "buzz" was found at Mach numbers above 0.96. The buzz occurred with a frequency of 85 to 108 cycles per second. Wind-tunnel tests duplicated the lower speed flexure-aileron flutter, and more research was recommended (ref. 26).

The Navy also requested flight tests of 1/10-scale models of the D-558-II wings having structural characteristics scaled to represent the full-scale airplane. Wings were built with design flutter speeds lower than, equal to, or higher than, those of the true scaled conditions. This was the first series of tests made at Wallops to study the possibility of fluter for a particular full-scale airplane. The models were similar to a scaled-down version of the FR-1 series and a 5-inch Cordite motor provided the propulsion. This series of flutter models was designated FR-3. One of the models is shown in figure 69. Two-channel telemeters were used in the tests. In the "low speed" model and "true speed" model, wing frequencies were measured, whereas, in the "high speed" model, normal acceleration and angle of attack were measured. A maximum Mach number of 1.54 was reached, and no flutter was encountered (ref. 27).

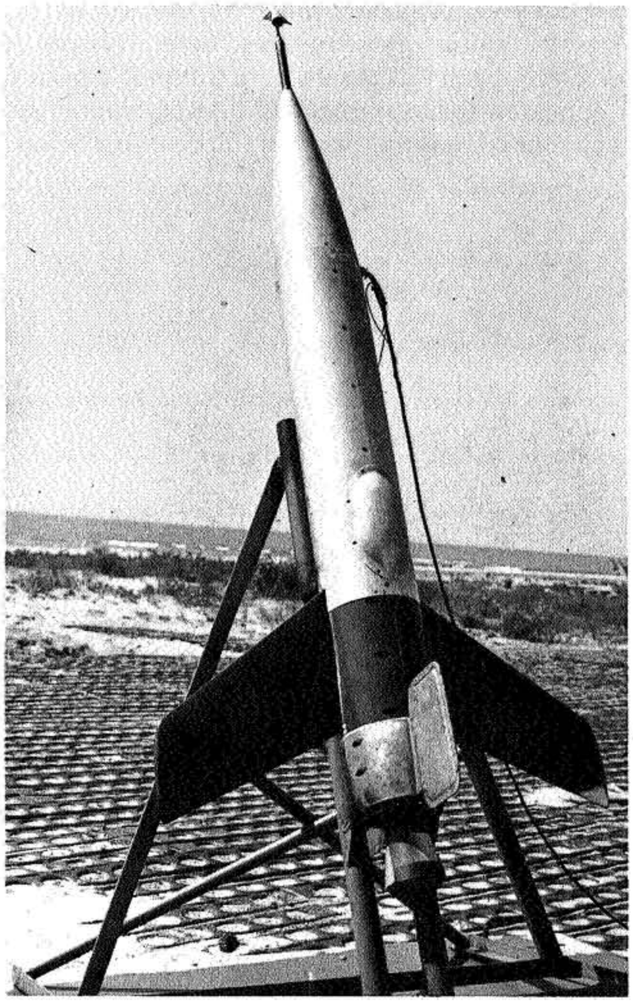


FIGURE 69. View of FR-3 flutter test vehicle with 1/10-scale wings of Douglas D-558-II research airplane. Photograph taken in January 1948.

In a continuation of the general research program on wing flutter, additional FR-1 models were flown. One was a repeat of the first FR-1 model (45-degree sweepback, aspect ratio 3.7), but this time strain gauges were installed in the wings to provide a measure of the wing frequency during any flutter encountered. Flutter showed up a short time (Mach 0.66) before wing failure (Mach 0.70). The flutter speed was again higher than the calculated two-dimensional flutter speed, this time by a factor of 1.35 (ref. 28). It was noted in the flight flutter tests that usually only one wing would fail; apparently the loads on the remaining wing were relieved by the failure of the first wing.

In an attempt to obtain torsion as well as bending frequencies on the next FR-1 model, one wing was instrumented and intentionally made weaker than the other so as to induce earlier flutter. This wing was designed without sweep, and had an aspect ratio of 4.1, with an NACA 65009 section. Flutter occurred at Mach 0.92, which was 26 percent higher than the figure calculated by two-dimensional theory. The final FR-1 model in this series likewise had no sweep but had an aspect ratio of 7.0 and an NACA 65006 section. This time, failure occurred at Mach 0.71 from a low-frequency oscillation which involved, instead of the normal bending-torsional motion of the wing, a bending of the wing coupled with a pitching oscillation of the entire model, a most unexpected occurrence (ref. 29). A repeat test was made in 1949 with a more extensively instrumented model, with similar results. One explanation of this unusual behavior was that the damping-in-pitch was effectively reduced or eliminated by the coupled wing motion (ref. 30).

An unswept flutter wing of aspect ratio 7.3 was mounted well forward on a standard ogive-cylinder for tests as a freely falling body. Although this wing was geometrically similar to one previously tested (ref. 8, Chapter 4), the fact that the body was dropped from a higher altitude exposed the wing to lower forces at a given speed and delayed flutter until a Mach number of 1.17 was reached, a speed 1.86 times the calculated flutter speed. This result combined with other experimental flutter results led W. T. Lauten and J. G. Barmby to conclude that Mach 0.9 was the critical speed for wing flutter. That is, a wing moving at a constant altitude at a continuously increasing speed will be safe from flutter if it passes Mach 0.9 without mishap (ref. 31). This conclusion appeared to be verified by PARD experience with rocket launchings at Wallops in that most failures attributed to flutter seemed to occur just below Mach 1.0.

References

1. Minutes, NACA Executive Committee, Nov. 24, 1947.
2. Gilruth, R. R., Chief of PARD, Memorandum to Director, August 17, 1948, regarding discussions with NAOTS of offshore observation stations and range interference.
3. Report, of the Ad Hoc Subcommittee on Range Planning, Committee on Guided Missiles, Research and Development Board, Mar. 4, 1949.
4. Agreement on Use of Wallops Island Range, Capt. S. E. Burroughs, Jr., BuOrd, and Hugh L. Dryden, NACA, Mar. 11, 1949.
5. Alexander, S. R.: *Effect of Windshield Shape of a Pilot's Canopy on the Drag of an RM−2 Drag Research Model in Flight at Transonic Speeds.* NACA RM L8E04.
6. Alexander, S. R.: *Flight Investigation at Low Supersonic Speeds to Determine the Effectiveness of Cones and a Wedge in Reducing the Drag of Round-Nosed Bodies and Air-foils.* NACA RM L8L07a.
7. Alexander, S. R.: *Effect of Strut-Mounted Wing Tanks on the Drag of NACA RM−2 Test Vehicles in Flight at Transonic Speeds.* NACA RM L8H31a.
8. Hart, Roger G.; and Katz, Ellis: *Flight Investigation at High-Subsonic, Transonic, and Supersonic Speeds to Determine Zero-Lift Drag of Fin-Stabilized Bodies of Revolution Having Fineness Ratios of 12.5, 8.91, and 6.04 and Varying Positions of Maximum Diameter.* NACA RM L9I30.
9. Thompson, Jim Rogers; and Kurbjun, Max C.: *Drag Measurements at Transonic Speeds of Two Bodies of Fineness Ratio 9 With Different Locations of Maximum Body Diameter.* NACA RM L8A28b.
10. Cheatham, Donald C.; and Kurbjun, Max C.: *Transonic Drag Characteristics of a Wing-Body Combination Showing the Effect of a Large Wing Fillet.* NACA RM L8F08.
11. Thompson, Jim Rogers: *Measurements of the Drag and Pressure Distribution on a Body of Revolution Throughout Transition From Subsonic to Supersonic Speeds.* NACA RM L9J27.
12. Thompson, Jim Rogers; and Mathews, Charles W.: *Effect of Wing Sweep, Taper, and Thickness Ratio on the Transonic Drag Characteristics of Wing-Body Combinations.* NACA RM L8K01.
13. Kurbjun, Max C.: *Longitudinal Stability and Drag Characteristics of a Fin-Stabilized Body of Revolution With a Fineness Ratio of 12 as Measured By the Free-Fall Method.* NACA RM L54E13.
14. Sandahl, Carl A.: *Free-Flight Investigation at Transonic and Supersonic Speeds of a Wing-Aileron Configuration Simulating the D558−2 Airplane.* NACA RM L8E28.
15. Sandahl, Carl A.: *Free-Flight Investigation at Transonic and Supersonic Speeds of the Rolling Effectiveness of a Thin, Unswept Wing Having Partial-Span Ailerons.* NACA RM L8G20a.
16. Sandahl, Carl A.: *Free-Flight Investigation at Transonic and Supersonic Speeds of the Rolling Effectiveness of a 42.7° Sweptback Wing Having Partial-Span Ailerons.* NACA RM L8E25.
17. Sandahl, Carl A.: *Free-Flight Investigation at Transonic and Supersonic Speeds of the Rolling Effectiveness of Several Aileron Configurations on a Tapered Wing Having 42.7° Sweepback.* NACA RM L8K23.
18. *Military Specification for the Flying Qualities of Piloted Airplanes (Fighters).* MIL−F−8785 (ASG), as amended Apr. 17, 1959.
19. Sandahl, Carl A.: *Preliminary Free-Flight Investigation of the Effect of Airfoil Section on Aileron Rolling Effectiveness at Transonic and Supersonic Speeds.* NACA RM L8B26.
20. Sandahl, Carl A.; Bland, William N., Jr.; and Strass, H. Kurt: *Effects of Some Airfoil-Section Variations on Wing-Aileron Rolling Effectiveness and Drag as Determined in Free Flight at Transonic and Supersonic Speeds.* NACA RM L9D12.
21. Strass, H. Kurt; and Fields, Edison M.: *Flight Investigation of the Effect of Thickening the Aileron Trailing Edge on Control Effectiveness for Sweptback Tapered Wings Having Sharp- and Round-Nose Sections.* NACA RM L9L19.
22. Sandahl, Carl A.; and Strass, H. Kurt: *Comparative Tests of the Rolling Effectiveness of Constant-Chord, Full-Delta, and Half-Delta Ailerons on Delta Wings at Transonic and Supersonic Speeds.* NACA RM L9J26.
23. Strass, H. Kurt: *Free-Flight Investigation of the Rolling Effectiveness at High Subsonic, Transonic, and Supersonic Speeds of Leading-Edge and Trailing-Edge Ailerons in Conjunction With Tapered and Untapered Planforms.* NACA RM L8E10.
24. Sandahl, Carl A.: *Free-Flight Investigation of the Rolling Effectiveness of a Wing-Spoiler Arrangement at High Subsonic, Transonic, and Supersonic Speeds.* NACA RM L8A07.
25. Strass, H. Kurt: *Additional Free-Flight Tests of the Rolling Effectiveness of Several Wing-Spoiler Arrangements at High Subsonic, Transonic, and Supersonic Speeds.* NACA RM L8I23.
26. Angle, Ellwyn E.; and Lundstrom, Reginald R.: *Flight and Wind-Tunnel Investigation to Determine the Aileron-Vibration Characteristics of a 1/4-Scale Wing Panels of The Douglas D558−2 Research Airplane.* NACA RM L8H09.
27. Teitelbaum, Jerome M.: *Flight Investigation of Flutter Models With 1/10-Scale Douglas D555−2 Wing Panels.* NACA RM L9A06.

28. Angle, Ellwyn E.; Clevenson, Sherman A.; and Lundstrom, Reginald R.: *Flight Test of NACA FR−1−B, a Low-Acceleration Rocket-Propelled Vehicle for Transonic Flutter Research.* NACA RM L8C24.
29. Lundstrom, Reginald R.; Lauten, William T., Jr.; and Angle, Ellwyn E.: *Transonic-Flutter Investigation of Wings Attached to Two Low-Acceleration Rocket-Propelled Vehicles.* NACA RM L8I30.
30. Cunningham, H. J.; and Lundstrom, R. R.: *Description and Analysis of a Rocket-Vehicle Experiment on Flutter Involving Wing Deformation and Body Motions.* NACA RM L50I29. Later reissued as NACA TN 3311.
31. Lauten, William T.; and Barmby, J. G.: *Continuation of Wing Fluter Investigation in the Transonic Range and Presentation of a Limited Summary of Flutter Data.* NACA RM L9B25b.

CHAPTER 6

YEAR OF PURCHASE OF THE ENTIRE ISLAND: 1949

PURCHASE OF THE ISLAND

With the signing of the agreement of March 11, 1949, between the Navy and the NACA, which recognized the NACA's primary interest in Wallops Island, the road was open for acquisition of the entire island by the NACA. Earlier requests by the NACA for authority to purchase the island had always been turned down by the Bureau of the Budget. Now a request for such authority was added to the 1950 appropriation bill under consideration by the Congress and was approved without delay.

The Wallops Island Association had paid $8,000 for a controlling interest in the island in 1889 and had built a clubhouse. Their total investment was $15,000, subscribed by their 30 members. In 1946, an appraiser appointed by the Navy placed a value of $10 per acre on solid land and $3 per acre on marshland. The Navy offered $30,000 to the Association for the approximately 3,000 acres.

The 1950 NACA appropriation bill was approved with the understanding that not more than $100,000 would be spent for the purchase of the island. The NACA considered $45,000 to be a fair price, and deposited this amount with the United States District Court for the Eastern District of Virginia on September 26, 1949. Legal proceedings then began. A Petition for Condemnation and a Notice of Condemnation were filed with this court on October 13, 1949. The case was entitled: "United States of America v. 3,000 acres of land, more or less, in Accomack County, Virginia, and Wallops Island Club, Inc., et al." The Order on Declaration of Taking was signed by Judge Albert V. Bryan on November 7, 1949, on which date the Government legally took possession of the island. The Attorney General officially notified the NACA of this action on December 5, 1949.[1]

The Court impaneled a jury on May 8, 1950, to try the case to determine just compensation. The jury visited Wallops on May 10, 1950, and heard evidence in court on May 15, 1950. The Government had the land appraised by three men who placed a valuation of $40,000 to $45,000 on the entire island. The Wallops Island Club presented evidence which placed the valuation on the property between $187,000 and $250,000. The jury agreed upon a value of $91,500 plus $1,758.71 interest, for a total of $93,238.71, and this amount was paid the defendants. The sum was close to the publicized available amount of $100,000.[2]

The NACA gave the Navy a use permit for the area of the island which it had been using, except that the boundary of the original lease line of 75°28′15″ west longitude was changed to 37°51′54″ north latitude. This gave the NACA a larger area of the island, but the Navy area still contained all of the

1. Letter from J. Howard McGrath, Attorney General, to Dr. Jerome C. Hunsaker, NACA Chairman, December 5, 1949.
2. Letter from A. C. Whitehead, Special Assistant to the U.S. Attorney, to the Attorney General, May 19, 1950, regarding Case No. 7343, United States versus 3,000 Acres of Land in Accomack County, Virginia, and Wallops Island Club, Inc., et al.

facilities in use by its activities. The permit carried a "revokable at will" clause which was disturbing but acceptable to NAOTS. The permit also stipulated that any major construction by the Navy would require prior approval of the NACA (ref. 1).

EXTENSION OF THE SEA RANGE

The first official range designated by the NACA for its rocket launchings was a 3-mile circle centered just off the lower tip of the island. With the higher performance rocket motors and the use of multistage systems, the higher speeds obtainable increased the range of some missiles to as much as ten miles. Plans for the future envisioned that some firings might impact as far as 20 miles from the launch base. The NACA did not apply at this time for an extension of the danger area but instead decided to support NAOTS in their requests for a large danger area. Such a danger area could be used jointly by the NACA and NAOTS.

The plans of NAOTS included air-launches of guided bombs and guided missiles carrying torpedoes. The station also planned air-to-air firings out over the ocean. For these reasons, NAOTS required a greater range than did the NACA. In December 1946, NAOTS initiated a request for establishment of a large danger area out from Wallops. The Commander of the Fifth Naval District forwarded this request to the Commander of the Eastern Sea Frontier.[3] A conference was held in Norfolk, Virginia, on February 4, 1947, at which all affected Government units had a change to raise objections. Ray W. Hooker represented the NACA at this conference. Hooker informed the group that the NACA needed a longer range and that the request of NAOTS was quite satisfactory to the NACA even though it overlapped the existing NACA danger area (ref. 2). Several days later, however, Hooker felt that the NACA danger area should be excluded from the new NAOTS area and asked NACA Headquarters to try to have it eliminated. Headquarters, however, after receiving assurances of cooperation from the Navy Department decided not to raise the issue (ref. 3).[4,5] The Army Air Forces had also requested a danger area off the coast of the Eastern Shore of Virginia for gunnery practice, and objected to sharing this area with NAOTS.

As a result of all of the objections raised at the conference of February 4, 1947, NAOTS revised its request and resubmitted it on February 17, 1947.[6] The New York Regional Air Space Committee considered the requests and objections at their meeting number 65 on March 20, 1947, and established a new danger area but did not give NAOTS control of all of it. The new danger area, shown in figure 70, was named the Great Machipongo Inlet Danger Area after the nearby inlet between Cobb and Hog islands.

The Great Machipongo Inlet Danger Area was divided into three areas identified in figure 70 as "A," "B," and "C." Control of Area A was assigned to NAOTS for daily use by NAOTS and the NACA. Note that this area overlaps the previous circle of 3-mile radius which enclosed the NACA Danger Area at Wallops, shown as an open circle with a dotted outline. Area A also overlaps the upper end of the area requested by the Army Air Forces.

Control of Area B was assigned to the Tactical Air Command, Langley Field, Virginia, for joint use by NAOTS, the NACA, and the Air Force. The Air Force was also given control of the remainder of the area it had requested.

Control of Area C was placed under the Chesapeake Bay Training Group, Fleet Training Command. Note that this area includes Fleet Training Areas 5 and 6 of the nine Fleet Training Areas east of Wallops Island. The decision concerning Area C, in effect, left this area under the control of the Fleet Training Group but did identify it as a danger area.

The danger areas were required to be rejustified at regular intervals. In early 1948, the Government decreed that there were to be no danger areas located outside the 3-mile limit. As a result, all such areas outside the 3-mile limit were changed to warning areas. In response to this decree and a

3. Com NAB 5 letter to Commander, Eastern Sea Frontier, January 6, 1947, regarding request for danger area.
4. Johnson, Ernest, Langley letter to the NACA, March 7, 1947.
5. Kelly, J. J., Jr., Legal Officer, NACA letter to Langley, March 25, 1947.
6. NAOTS letter by Captain W. V. R. Vieweg to Commander, Eastern Sea Frontier, Feb. 17, 1947, regarding establishment of aircraft danger area.

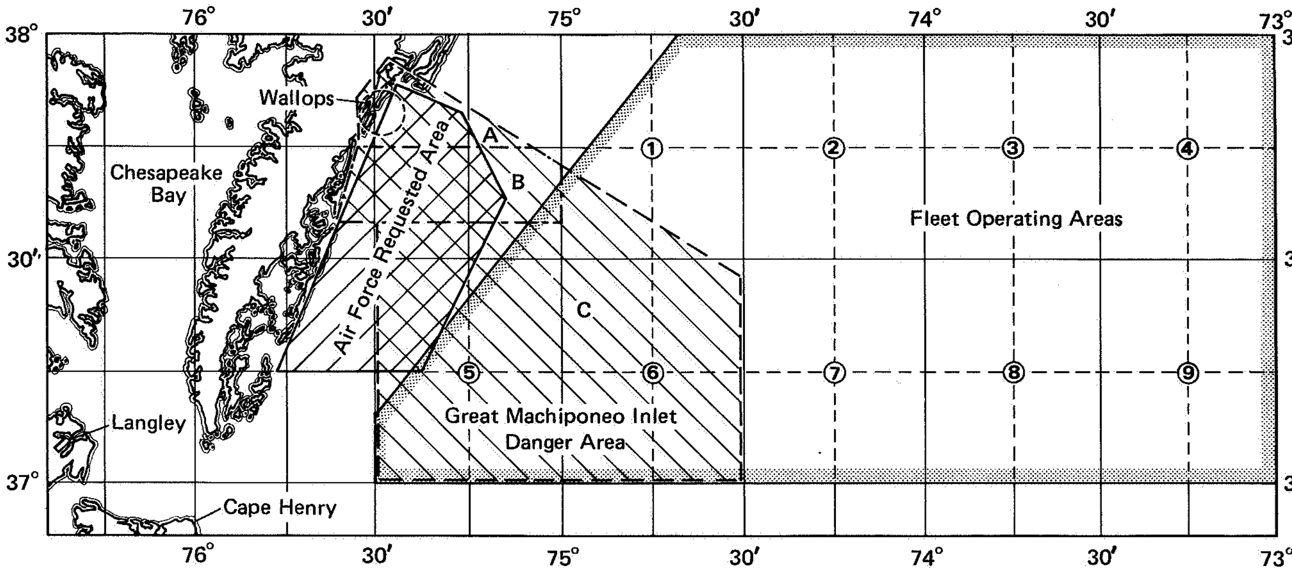


FIGURE 70. Great Machipongo Inlet Danger Area and Fleet Operating Areas, 1947.

request for rejustification of the danger area, NAOTS on February 19, 1948, requested that all of the Great Machipongo Inlet Danger Area inside the 3-mile limit be changed to a Wallops Island Danger Area and the remaining area be renamed the Great Machipongo Inlet Offshore Warning Area.[7] The Air Space Committee at their meeting number 114 followed this recommendation except that the danger area near Wallops was identified as the Chincoteague Inlet Danger Area. This area is identified in figure 71 as Danger Area. In later years, this area was also changed to a warning area and its western boundary was changed slightly to coincide with longitude 75°31.5′.

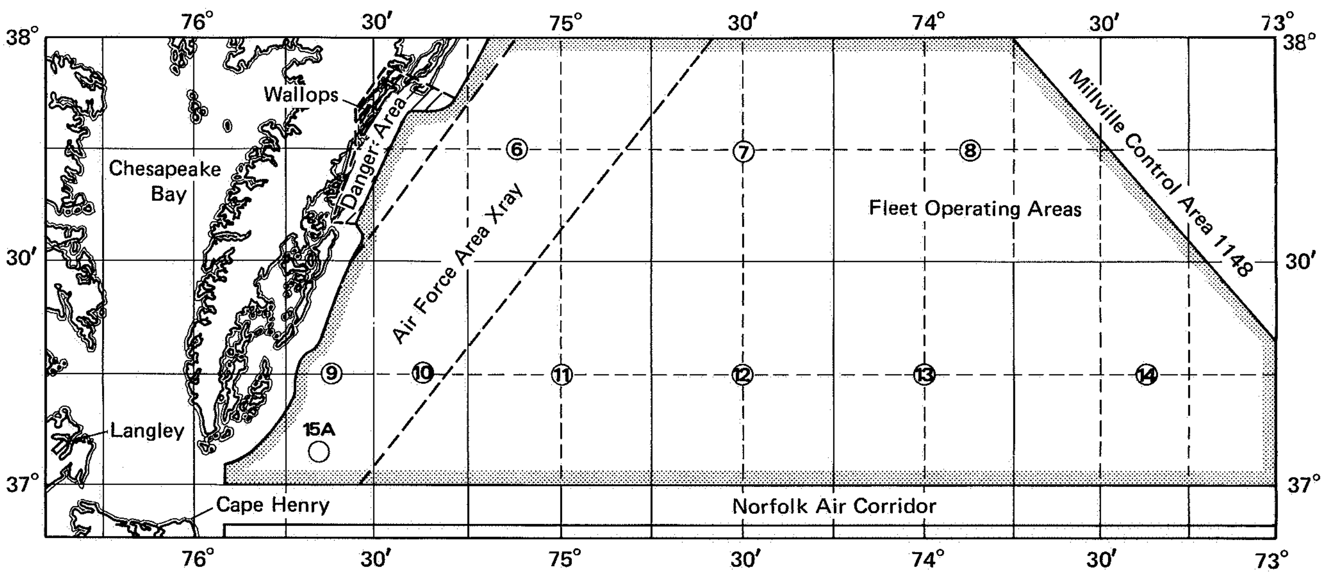


FIGURE 71. Air Force Area Xray and Fleet Operating Areas, 1949.

On January 18, 1949, at the Air Space Committee meeting number 138, all the earlier actions regarding danger or warning areas outside the 3-mile limit were revoked and all the area between the Millville Control Area and the Norfolk Air Corridor was designated the Chincoteague-Virginia Capes Airspace Warning Area. This action gave the Fleet Training Group, Chesapeake Bay, control of all the area outside the 3-mile limit from Cape May to Cape Henry. The portion of this area below the 38th parallel that was of interest for Wallops firings is shown in figure 71. The Chincoteague Inlet Danger

7. NAOTS letter to Commander, Eastern Sea Frontier, February 19, 1948, regarding establishment of offshore warning areas.

Area inside the 3-mile limit was unchanged. The Fleet Training Group rearranged the area into various Fleet Operating Areas. This action of the Air Space Committee now placed NAOTS, the NACA, and the Tactical Air Command under the Fleet Training Group for all clearances for operations beyond 3 miles.

This action had little effect upon the NACA and NAOTS operations because Chincoteague maintained good relations with the Training Group and had practically a permanent reservation for use of Area 6. In addition, Chincoteague provided target drones for the use of the fleet for training purposes. The Tactical Air Command, on the other hand, despite the unification act of July 26, 1947, was still treated as an element separate from the Navy. The command was not satisfied with the arrangement whereby it had to obtain clearance from the Navy for all training flights over the Atlantic Ocean. After an appeal had been made to the Department of Defense, a permanent assignment of part of this Navy training area was made to the Air Force. At a meeting at Langley Field, September 29, 1949, an area designated as Xray was agreed upon (ref. 4). This area is also shown in figure 71. W. J. O'Sullivan and J. A. Shortal represented the NACA at this meeting. At the request of the NACA representatives, the Xray area was located offshore from Wallops a distance of 10 miles (ref. 5).

The understandings reached at the September 29, 1949 meeting were formalized in a letter signed on March 15, 1950, by all affected military units.[8] Procedures were established for obtaining clearance for use of airspace in this entire area: (a) area inshore of Xray was to be under the control of NAOTS; (b) airspace below 10,000 feet, within area Xray—under control of Fifth Naval District or, later, NAOTS; (c) airspace above 10,000 feet, within area Xray—under control of Ninth Air Force, Langley Field; (d) airspace beyond area Xray—under control of Fleet Training Group, Norfolk Naval Base. This arrangement continued for several years.

As time went by, the Air Force found that the northern half of area Xray was of little use to it, and control was shifted to NAOTS. NACA operations were more numerous than those of NAOTS and in actual practice the NACA had control of the area and was contacted by NAOTS whenever the Navy desired to use it. In effect, then, the NACA was given control and use of Fleet Training Area 6 (figure 71), which provided a sea range of approximately 40 miles. This arrangement provided Wallops with a firing range which was adequate for most purposes during this period. The first attempt, however, in the summer of 1950, to obtain clearance from the Navy for launching a missile beyond area Xray into the Fleet Training Areas was bitterly opposed by the Atlantic Fleet despite the memorandum of understanding. This conflict and its solution will be discussed in a later chapter.

PREFLIGHT JET

Although NACA Headquarters approved construction of the Preflight Jet at Wallops Island in May 1945 and allotted funds for its construction from the 1945 First Deficiency Appropriation, it was 1948 before the facility went into operation. At that time, progress seemed very slow, but in retrospect this time for construction for a unique piece of equipment was not excessive. The situation simply illustrates one of the big advantages of the free-flight rocket-model technique for obtaining research data. The first rockets were fired from Wallops just 2 months after the appropriation bill was signed by the President. The quick reaction time of the rocket technique was to be demonstrated over and over as data at higher and higher speeds were needed, including data at missile reentry speeds and, eventually, data for the space program.

Despite the long time required for construction of the Preflight Jet, it was ready by the time the ramjet engines were ready for test. The original justification for the Preflight Jet was to provide preliminary testing of ramjet engines for missiles, and it was designed to meet the requirements for such engines. Later, many other types of tests were conducted there, as will be discussed later.

The first estimate of the cost of the Preflight Jet was $142,400, as shown in the Breakdown of Funds section of Chapter 2. The final expenditure was $400,505 from the 1945 Deficiency Appropriation, but this had to be supplemented by an additional $160,000 from general operating funds before

8. Letter from Ninth Air Force, Fifth Naval District, NAOTS, and Fleet Training Group to the NACA, March 15, 1950, regarding agreement on use of Chincoteague-Virginia Capes offshore Airspace Warning Areas.

the facility was ready for use. Doyle and Russell performed most of the housing and concrete construction work while Pittsburgh-Des Moines Steel Co. was the prime contractor for the steel work and the jet itself.

The Preflight Jet was the first true-temperature, sea-level-pressure, supersonic-speed facility known in this country. These features were necessary to provide the proper environment for preflight testing of the ramjet engines. The difficult part of this specification was the true-temperature aspect. Normally, the air in a supersonic wind tunnel is not heated and the air, upon expanding through the supersonic nozzle, suffers a large drop in temperature. At very high speeds, this drop in temperature can be sufficient to liquefy the air. In such cases, some heat is added to avoid liquefaction. Of course, dry air is used to avoid water drops or ice crystals in any case.

The Preflight Jet is a "blow-down" type of wind tunnel. Air is stored in large spheres and then exhausted through a supersonic nozzle to create a jet of air at supersonic velocities. The length of time available for a test depends upon the size of the jet and the size of the storage spheres. A quick-opening valve is used to increase the time at full-speed conditions. This type of facility was selected for Wallops and the ramjet program because of its basic simplicity and economy.

The need for a preflight jet for preliminary testing of ramjet engines in missiles prior to launching was not foreseen when the Request for Appropriation (RFA) for the construction of an Auxiliary Flight Research Station was prepared in January 1945. By May 1945, however, the need for such a facility was recognized; funds were requested by Langley for the construction of a "Preflight Blower Set-up" and were subsequently approved by NACA Headquarters. The facility envisioned at this time consisted of a continuous jet of air produced by two blowers driven by diesel or gasoline engines.[9] This type of blower setup was to be similar to those in the Induction Aerodynamics Laboratory at Langley for internal flow research. Gilruth was not satisfied with the capabilities of such a blower, and instituted a series of studies which culminated in a change to an intermittent blow-down type of jet.[10] Such a change was necessary to provide a jet of the required size, speed, and density, without unreasonable cost.

The first design for a blow-down jet made by Langley engineers consisted of nine cylindrical pressure tanks 11 feet by 73 feet, in which air would be heated to 650°F and stored at a pressure of 205 pounds per square inch. These tanks were to be interconnected and fitted with a quick-opening valve and a supersonic nozzle through which the air would be exhausted to form the supersonic test jet. The tanks were to be internally insulated to minimize heat losses. Langley was not completely satisfied that this was the best arrangement; when bids were asked from industry, alternate proposals were invited. The invitations to bid called for the "Design and Construction of Pre-Flight Test Unit for Auxiliary Flight Research."

Several proposals were received, but the low and successful bidder was the Pittsburgh-Des Moines Steel Company (PDM), whose chief engineer, J. O. Jackson, took a personal interest in all phases of this unique facility. PDM proposed that the air be stored under pressure in spherical tanks and be heated by a large heat exchanger as it flowed to the supersonic test nozzle. Two types of heat exchangers were considered: a bed of preheated steel balls and a large bundle of preheated tubes. The tube system was recommended by Paul R. Hill of PARD and was adopted. During the negotiations with the contractor, the volume of stored air was reduced from 50,000 cubic feet to 25,000 cubic feet to reduce costs. A contract with PDM was awarded June 10, 1946. The final adjusted cost of this portion of the Preflight Jet contract was $248,255.

The general arrangement of the Preflight Jet is shown in figure 72. A photograph of the facility is shown in figure 73. Air was compressed to approximately 205 pounds per square inch and was dried by being passed through a bed of activated alumina before it was stored in two spherical steel tanks 28 feet 10-3/4 inches in diameter. Two alumina dryers were in the line. While one was being used, the other was being reactivated. A large quick-opening valve called a "rotovalve" controlled the flow of air from the spheres to the heat exchanger. The heat exchanger consisted of 39,000 1/8-inch iron pipes 10 feet long. The nominal 1/8-inch pipe size actually had a 0.40-inch outside diameter and a 0.27-inch inside

9. Langley letter to NACA Headquarters, December 12, 1945, regarding request for reallocation of funds in First Deficiency Appropriation Act, 1945.
10. Based on the author's conversations with J. C. Messick and P. R. Hill, November 17, 1966.

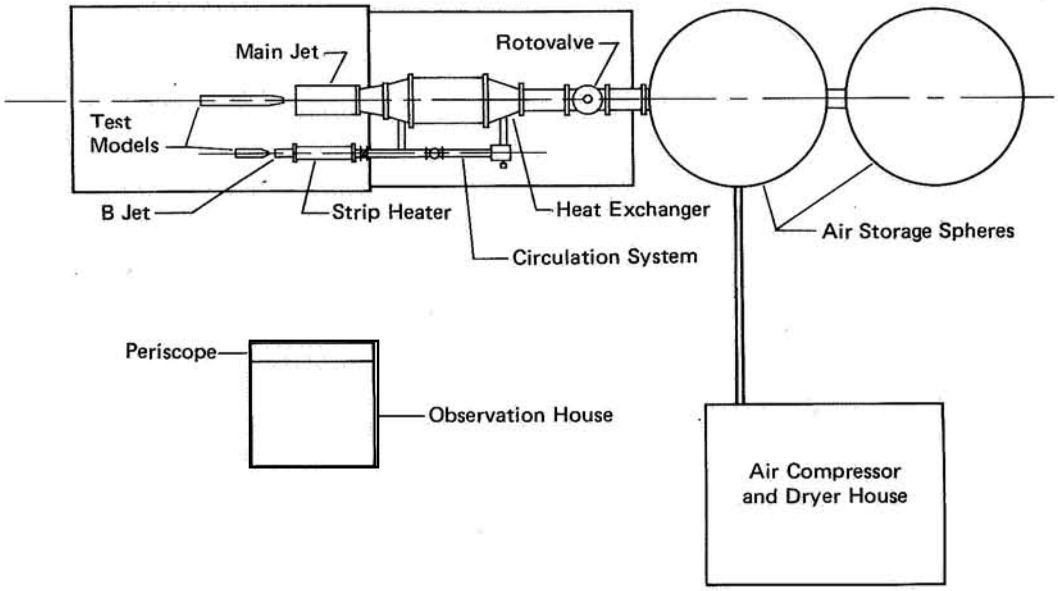


FIGURE 72. Schematic view of Wallops Preflight Jet test unit.

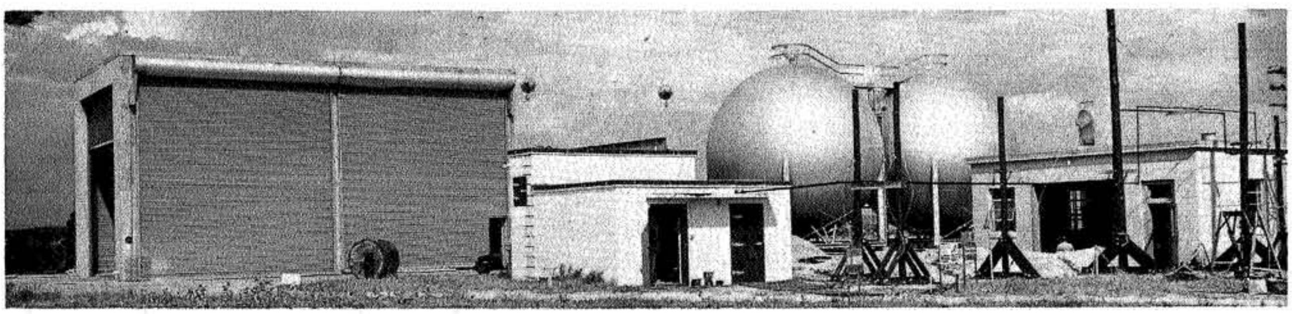


FIGURE 73. Exterior view of Wallops Island Preflight Jet test unit.

diameter. These pipes or tubes were arranged in bundles in the center of which was a long calrod electrical heating element. The temperature of the tubes was equalized during heating by circulating air through the exchanger by means of a bypass circulation system as shown in figure 72. When the proper pressure and temperature were reached, the rotovalve was opened and the stored air was exhausted through the heat exchanger and on to the supersonic nozzle and over the model under test in the open jet. One of the first tests was made on a full-scale Lewis 16-inch ramjet, shown in figure 74. The 800-kw

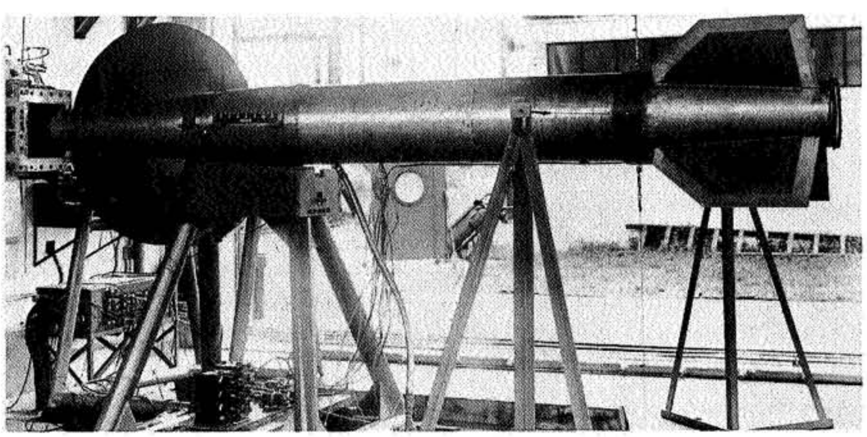


FIGURE 74. Lewis 16-inch ramjet flight test unit in 12-inch nozzle of Wallops Preflight Jet.

generator mentioned earlier was obtained to provide the electrical power for this facility as well as for the other needs of the island.

The size of the main jet, as well as the Mach number, could be varied by means of interchangeable nozzle sections bolted to a common plate. When not in use, the nozzle was sealed by bolting a cover over the nozzle exit face. The different test conditions available in the main jet are given in the following table.

OPERATING CHARACTERISTICS OF MAIN JET, WALLOPS PREFLIGHT JET FACILITY

Mach Number	Running Time (seconds)		Pressure	Temperature (degrees F)	Time (hours)		
	12-inch Nozzle	*27-inch Nozzle*			*Refill*	*Reheat*	*Circulate*
1.40	125	23	32	280	7	1.2	4
1.60	98	18	48	340	6	1.3	4
1.80	71	13	69	416	5	1.4	4
2.00	44	8	100	500	4	1.5	4
2.25	10		145	620	3	1.6	4

The main jet was square in cross section and was constructed in two sizes: 12 inches and 27 inches. Four 27-inch nozzles were available to provide Mach numbers of 1.4, 1.6, 1.8, and 2.0. Five 12-inch nozzles provided Mach numbers of 1.4, 1.6, 1.8, 2.0, and 2.25. Later, a subsonic 27-inch nozzle was added to the inventory.

The normal pressure in the storage spheres was 205 pounds per square inch and the initial pumping time was 11 hours. During a test run, the pressure at the heat exchanger was controlled at the value needed for the Mach number desired. The running time available was a function of the nozzle size and Mach number, as shown in the table. It varied from 8 seconds for the 27-inch nozzle at Mach 2 to 125 seconds for the 12-inch nozzle at Mach 1.4. The tanks could be repressurized in 3 hours after a full-length run at Mach 2.25, or in 7 hours after a full-length run at Mach 1.4.

The heat exchanger temperature was adjusted to the temperature required to yield room temperature in the jet after expansion through the nozzle. These temperatures varied from 620° F. for Mach 2.25 to 280° for Mach 1.4. The time to reheat the heat exchanger varied from 1.2 to 1.6 hours, as shown, but these times were increased to 4 hours by the recirclation cycle that was required to equalize the temperature. During a run, the temperature of the tubes started to drop at the upstream end and by the time a run was completed the drop in temperature had extended to the downstream end.

It can be seen that after a maximum-length run, the time to restore the pressure varied between 3 and 7 hours, while the time to restore the heat in the heat exchanger was 4 hours. In 1952, the compressor capacity was doubled to bring the pressurization capacity into line with the heating capacity.

An auxiliary jet, termed "B Jet," was installed by the side of the main jet, as shown in figure 72. This jet was circular in cross section and had interchangeable nozzles 5 inches to 8 inches in diameter. The B Jet was very useful for preliminary testing because a number of runs could be made before the system had to be recharged.

The main jet was ready for preliminary operation in April 1948. Initial calibration runs revealed two difficulties that had to be corrected. First, the impact-pressure load on the bundle of tubes in the heat exchanger exceeded the design load, and the entire mass shifted downstream somewhat. By the use of hydraulic jacks, the tubes were returned to their proper location and stronger supports were installed. The second difficulty was with the automatic control system that operated the rotovalve. The S. Morgan Smith Company furnished this special valve, but PDM was responsible for the control system. Large fluctuations in pressure were obtained when attempts were made to hold a constant pressure during a run. Many corrective measures were tried but not until early in 1949 was the problem solved and the main jet made ready for regular operation. In the interim, the B Jet was used almost exclusively.

A third difficulty was noted after the main jet had been operated for some time. Large quantities of rust and flakes of scale were found to contaminate the airstream. These were the result of an economy measure. The cost of stainless steel tubing had been considered prohibitive. Instead, common steel pipe was used and this was found to have considerable mill scale that would flake off under the vibration conditions of the facility. In addition, new rust would form after a period of time. It was found, however, that if the heater was never allowed to cool off, the rusting was eliminated. In time, the original mill scale disappeared. Although the airstream was never entirely free of contaminants, the condition was tolerable, and proposals for cleaning the tubes or even replacing them entirely with stainless steel were never considered necessary.

The short running time of the Preflight Jet made it necessary to install automatic sequencing equipment to control the test, and to use fast-response measuring equipment. Although proposals were made at various times for the installation of a complete balance system in the jet, thrust and drag measuring stands were all that were ever used. In addition, arrangements were made to record pressures and temperatures. Fuel-flow rates were also recorded in ramjet tests. A shadowgraph system was installed to provide a picture of the flow conditions either in the empty jet or around various bodies under test.

The control room and observation house for all tests was located near the test area as, shown in figure 72. A periscope-type of observation window provided viewing for all operations, with safety for the test crew.

The development of this unique facility was carried out under the direction of engineers at Langley. At PARD, a special section was organized in 1949 (discussed earlier in Chapter 5), called the Preflight Jet Section, with Paul R. Hill as Acting Head. This section was responsible for all projects in the Preflight Jet. Raymond S. Watson, Jr., was Hill's assistant in this facility and played a key role in its development. As soon as the facility was completed, an engineer was transferred to Wallops and placed in charge of the operation of this facility. This engineer was Eldred H. Helton, who was given the assignment on August 16, 1948. He was joined by a second engineer, Abraham Spinak, on January 13, 1949. These men, with the assistance of mechanics and instrument men at Wallops Island, had this responsibility until the facility was abandoned.

GENERAL MISSILE STABILIZATION RESEARCH PROGRAM: D4

The success of the RM-1 missile stabilization research program discussed in Chapter 3 was overshadowed by aerodynamic control difficulties at speeds beyond Mach 1. With the success of the E5 aerodynamic control research program in solving the control problem at transonic speeds, it became possible to resume the automatic stabilization program for air-to-air guided missiles. A new research authorization, RA 1525, was issued by the NACA on September 29, 1948, for the study of various automatic stabilization systems for pilotless aircraft.

Shortly after Buckley was transferred from IRD in early 1948 to become Assistant Chief of PARD, he obtained the transfer of R. A. Gardiner from IRD to PARD to take charge of the automatic control program. Gardiner had worked on automatic control for the Tiamat and RM-1 missiles, but the overall responsibility for these missiles had been assigned to engineers in PARD. With the resignation of some of the key personnel in this field at PARD, Gardiner was called upon to take over the responsibility. He was ably assisted in the theoretical aspects by Howard J. Curfman, Jr.

The general aspects of roll stabilization with "flicker-control" ailerons that produced continuous oscillations in roll were analyzed by Curfman, and methods for calculating the magnitude and frequency of such oscillations were developed. This analysis revealed that the oscillation problem would really become severe at supersonic speeds for missiles of the RM-1 size, a size typical of air-to-air missiles. With a displacement system only, oscillations as large as 95 degrees could be encountered at Mach 1.5 (ref. 6). Even with rate damping added to the system, the oscillations were still nearly 16 degrees (ref. 7).

The new flight program on missile stabilization was designated RM-4 or D4. A Deacon booster was the only propulsion used, and provided a Mach number of 1.38 for the 150-pound missile. The missile was connected to the booster by a free-to-roll coupling or bearing to avoid interference with the roll stabilization system during boost. The missile had a basic diameter of 8 inches and was 129 inches long.

The body was cylindrical with ogival nose and tail sections. The four wings were of 60-degree-delta planform and of 3-percent thickness at the root, with constant actual thickness out to the all-moving-tip ailerons, which were also of 3-percent thickness. Four 60-degree canard fins in line with the wings were installed for longitudinal and directional control. The initial flight in this program was with only a roll stabilization system. The gyro-actuated control used successfully on the last Tiamet missile launched at Wallops was adapted to the D4 design. A six-channel telemeter was installed within the missile to measure roll rate, aileron position, total and static pressure, and normal and transverse accelerations. Indications of pulse-aileron operation and automatic-pilot torque motor operation were obtained by displacing the reference values of two of the above channels.

Two development missiles were launched in April 1949, and the first stabilized missile was launched on May 24, 1949. The flight was a complete success and verified the wing-tip aileron control system, the adaptation of the gyro-actuated control to supersonic flight, and a method for calculating rolling response (ref. 8). Figure 75 shows a typical D4 missile on the launcher. This particular missile was launched in August 1950, by which time the booster had been changed to a double Deacon system to obtain higher speeds. The D4 missile configuration was also found to be a desirable one from pitch and yaw considerations in later flights. Its general configuration was followed later in the design of the Navy-Martin Bullpup air-to-ground guided missile.

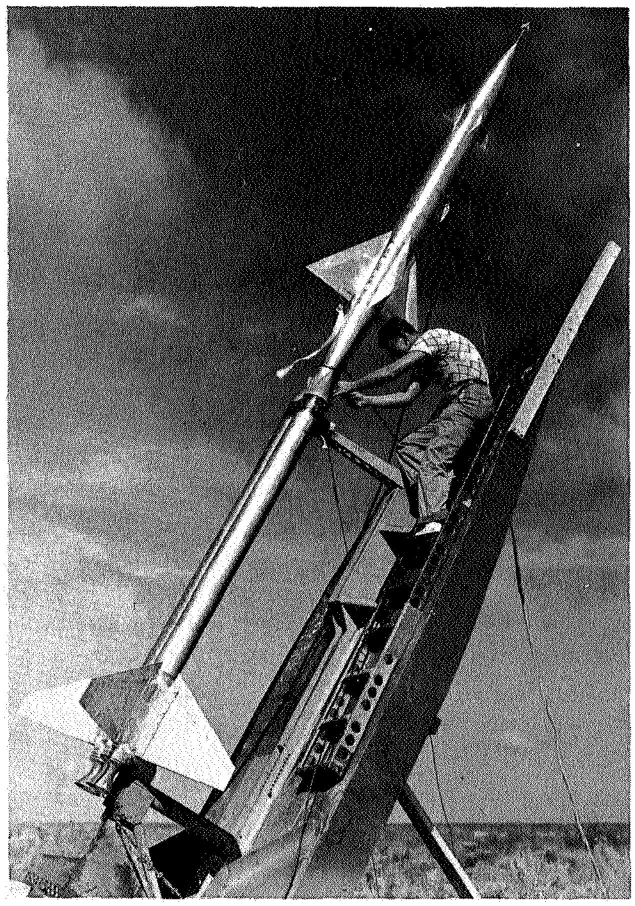


FIGURE 75. Technician William Ferguson adjusts coupling on typical NACA D4 automatic control research missile with double Deacon booster, August 18, 1950.

As an aid in autopilot calculations, a method for calculating the frequency response of a guided missile from a transient response was developed during this period (ref. 9).

GORGON MISSILE

In July 1943, Navy's BuAer authorized the Naval Aircraft Factory to develop the Gorgon, an air-to-air subsonic missile. The first self-propelled guided missile developed by Navy BuAer, it evolved into a generalized research missile and its different versions were powered by turbojet, ramjet, pulsejet, or rocket engines. One version of the Gorgon was tail-first. The Gorgon also served as a test vehicle for a variety of structural and guidance systems.

The influential letter from the Navy on December 19, 1944, which triggered the action to establish Wallops offered "to supply the Committee with certain existing rocket-propelled missiles." These were the Gorgons. In reply, Crowley suggested that 12 Gorgons be obtained from the Navy. He also referred to earlier contacts with the Navy which had indicated that a special version of the Gorgon might attain speeds close to Mach 1. These were the special Gorgons desired by the NACA.

The special Gorgon referred to was to be propelled by a liquid rocket engine whose propellants were fuming nitric acid and aniline. H. A. Soulé and R. A. Gardiner visited the Naval Aircraft Modification Unit (NAMU) at Johnsville, Pennsylvania, on March 10, 1945, to discuss the Gorgon missiles. The NAMU had received authorization to prepare 12 of the rocket-powered missiles (Gorgon IIIC) for the NACA. This version of the Gorgon was under construction, and NAMU was awaiting word from the NACA on the particular arrangement desired in the 12 missiles for Langley. In particular, it was necessary to decide the location of the additional rocket motors required for higher speed. Discussions were held regarding the problems of handling aniline and fuming nitric acid (ref. 10). No decision was made regarding the Gorgons on this trip, but the requirements of the liquid-rocket engines were incorporated into the early design specifications for Wallops. The 400-foot launching ramp at Wallops was also constructed for use in the launching of Gorgon missiles. It was learned during the visit that the Gorgon IIIC would be equipped with a newly developed Diehl autopilot unit which contained a single gyro with a tilted axis.

On April 6, 1945, the NACA sent a request for BuAer for three standard Gorgon II missiles, for familiarization purposes, and three Gorgon IIIC missiles equipped with special 700-pound-thrust rocket engines with a 2-minute duration. It was stated that the remaining Gorgon III's might be requested with different wing shapes.

As time went by, Langley became concerned about the problems of handling the liquid propellants and, in August 1945, sent W. J. O'Sullivan and D. G. Stone of PARD to NAES, Philadelphia, to discuss arrangements for assistance from them in the flight tests of Gorgon missiles at Wallops. In March 1946, the Navy suggested that the NACA send men to Mojave, California, and then to the NAMU for training in the handling of the liquid-rocket fuels. In April 1946, the NACA reduced its request for Gorgon missiles from 12 to 6.

In March 1947, the NAMU was still involved with the construction of the special Gorgon missiles for Langley. During a visit of NAMU people to Langley, R. W. Hooker told them that Langley could now use only three of the missiles. The plan for obtaining speeds near Mach 1 had not materialized, and interest in subsonic missiles had declined.

Although Langley was no longer interested in the Gorgon as a high-speed research tool, there remained an interest in the special canted-axis gyroscope used in some versions for stabilization. A Gorgon II tail-first version with a pulse-jet engine was obtained from the Navy equipped with such an autopilot. The missile and autopilot were subjected to frequency-response tests in the laboratory, and methods of analysis were developed for the complete system (ref. 11). The Gorgon II was selected for these tests because aerodynamic data for it were available from earlier tunnel tests at Langley. This activity closed out the Gorgon program at Langley and Wallops.

BELL RASCAL GUIDED MISSILE PROGRAM

In April 1946, under Air Force Project MX-776, the Army Air Forces contracted with Bell Aircraft Corporation to develop an air-to-ground supersonic guided missile with a range of 100 miles. The missile was later named "Rascal." In December 1947, the design had proceeded far enough for Bell, through the Air Force, to ask for assistance from the NACA in evaluating Bell's design by tests of rocket-propelled models at Wallops. On February 17, 1948, the NACA issued RA 1491 to cover the first program, whose objective was to determine longitudinal stability, drag, and aileron effectiveness.

Six 1/6-scale models of the Rascal were flown during the period from June to September 1948. Two were instrumented with telemeters to measure longitudinal stability, and the other four were used for aileron-effectiveness measurements by the E5 technique. Figure 76 shows one of the models

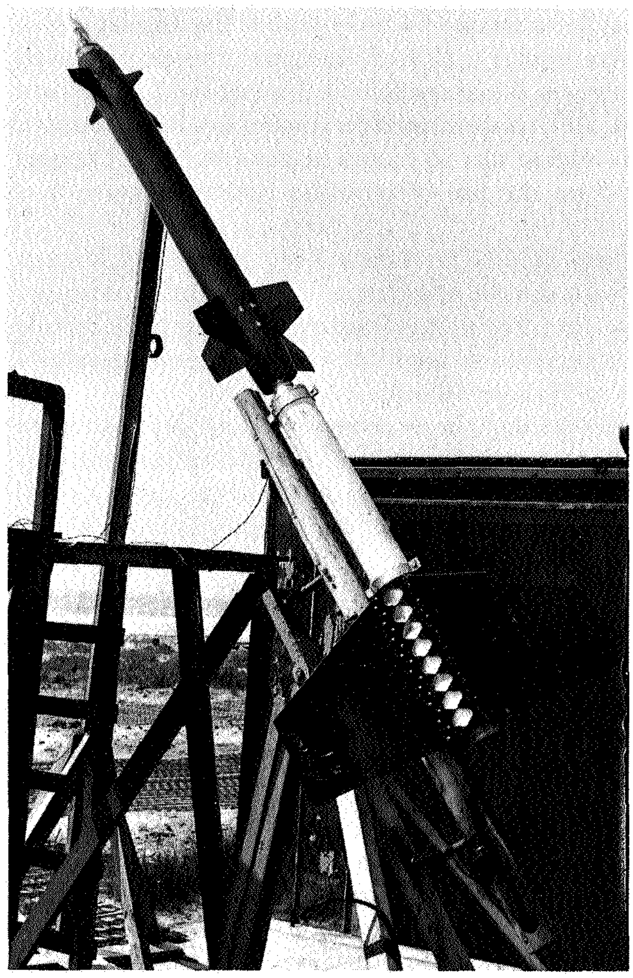


FIGURE 76. Launcher with mounted 1/6-scale model of Bell Rascal guided missile, photographed on July 8, 1948.

mounted with its booster on a short rail launcher. With this 5-inch HVAR rocket booster and a 3.25-inch internal rocket motor, speeds up to Mach 1.7 were obtained.

The tests revealed that the partial-span inboard ailerons had a reversal of effectiveness in the transonic range for deflections of 5 degrees but not with 10 degrees. The wings were 5-percent double-wedge sections. The missile was found to be longitudinally unstable, aerodynamically, at low angles of attack. This was caused by the large canard surfaces in line with the wings. In the directional plane, the canard fins were considerably smaller and did not induce a similar instability. Instability in the longitudinal plane caused considerable difficulty in the rocket-model program—drag, for example, could not be evaluated at zero lift—but its discovery had no effect on decisions affecting the full-scale missile. The contractor planned to overcome the difficulty by proper autopilot design (ref. 12).

LEWIS AIR-LAUNCHED RAMJET PROGRAM

As was discussed in Chapter 1, both the Lewis and Langley Laboratories embarked upon research programs for ramjet propulsion systems. The Lewis Laboratory, which was the NACA's propulsion research laboratory, was primarily interested in fuels and the combustion process, whereas Langley was primarily interested in the aerodynamic aspects of the ramjet and in performance capabilities as a form of missile propulsion. A ramjet panel with members from Lewis, Langley, and NACA Headquarters had overall cognizance of the research conducted by the NACA. NACA Headquarters tried to separate the Langley and Lewis activities to avoid duplication of effort. Eventually, both laboratories conducted research in all phases of this type of engine and conducted ground and flight tests of complete systems. There was no duplication of effort, however, because each laboratory had different ideas as to which direction to take in the development of a system.

Lewis concentrated on development of a large ramjet contained wholly within the fuselage of a missile with four external stabilizing fins. The design was similar to that of the ramjet missile proposed by M. C. Ellis and C. E. Brown in January 1945. Gasoline was the propellant in this engine. Langley, on the other hand, following the recommendations of P. R. Hill, concentrated on smaller engines mounted on struts at the rear of the missile fuselage. The Lewis engine was 16 inches in diameter; the Langley engines were 6 inches. Langley research concentrated on the use of ethylene under pressure as a propellant to simplify the fuel-flow problem.

The basic combustion process of ramjet engines was studied by Lewis in its ground facilities at Cleveland, Ohio. Lewis also conducted burner tests with ramjet engines in captive flight, mounted beneath high-speed airplanes. Initially, Langley was to conduct the flight testing of a complete missile system incorporating the best ramjet arrangement. As it turned out, each laboratory supervised its own flight tests although both sets of tests were conducted at Wallops Island.

The Lewis flight program was patterned after the freely falling body program at Langley. As shown in figure 65, the complete unit was mounted externally beneath the wing of a P-82 airplane and was dropped from high altitude. In the beginning, the Langley B-29 bomb-drop airplane was used, and all instrumentation was installed by Langley IRD. The Flight Research Division of Langley participated in the flight operation.

The 16-inch-diameter Lewis missile was 190 inches long and weighed approximately 525 pounds. Eight and one-half gallons of gasoline and the telemetering equipment were carried within a central body. Fuel flow was induced by pressurized nitrogen. An eight-channel telemeter was used to transmit accelerations and pressures.

In the first phase of the Lewis program, the ramjet unit, after release, accelerated with the aid of gravity and its own engine. The first drop was made July 25, 1947, from an altitude of 30,000 feet and achieved a maximum Mach number of 1.42. At this speed, the thrust still exceeded the drag (ref. 13). Failure of part of the telemeter prevented complete evaluation of performance. Three more flights were made with this same type of ramjet, all with a ducted airfoil-type flame holder with intermediate gutters. In these three flights, one engine would not support combustion; in the other two engines, combustion was sporadic. In a fourth flight, the flame holder was changed to a rake type and exceptional performance was obtained. A Mach number of 1.73 was attained, with a maximum combustion efficiency of 91 percent, and a diffuser total pressure recovery of 0.90 (ref. 14). One of the A-series of 16-inch ram jet units was tested in the Mach 1.4 test section of the Preflight Jet at Wallops in July 1949, as was shown in figure 74.

LARGE-SCALE ROCKET-MODEL DRAG PROGRAM: E17

The availability of the Deacon rocket motor made it possible to obtain drag data at a very high Reynolds number by using large models with the Deacon mounted internally as the propulsion unit. Such a program, designated E17, was undertaken in 1949. For the next 6 years, approximately five such models were launched each year.

In figure 77, the first wing and body combination in this program is shown mounted on a new type of zero-length launcher, from which it was launched April 21, 1949. The launcher is the bed of a trailer which can be elevated by a hydraulic jack. The trailer allows the model to be loaded in the assembly shop and then towed to the launch area. This versatile launcher was used for many years.

The E17 body was derived from the basic freely falling body recommended by John Stack but was cut off at the rear to make room for the Deacon nozzle, which practically filled the base. The first wing flown was "Wing C" of a new transonic-wing research program of the NACA. It had 45-degree sweep-back, aspect ratio 4, taper ratio 0.6, and NACA 65A006 airfoil section streamwise. The body frontal area was 6.06 percent of the wing area. The body was 13 inches in diameter and 130 inches long, while the wing had a span of 93.6 inches. With only the Deacon rocket, a speed of Mach 1.5 was attained with the wing and body combination, and 1.9 with the body alone. In this program, only the two vertical fins were used on the models with wings. A two-channel telemeter transmitted longitudinal acceleration and base pressure.

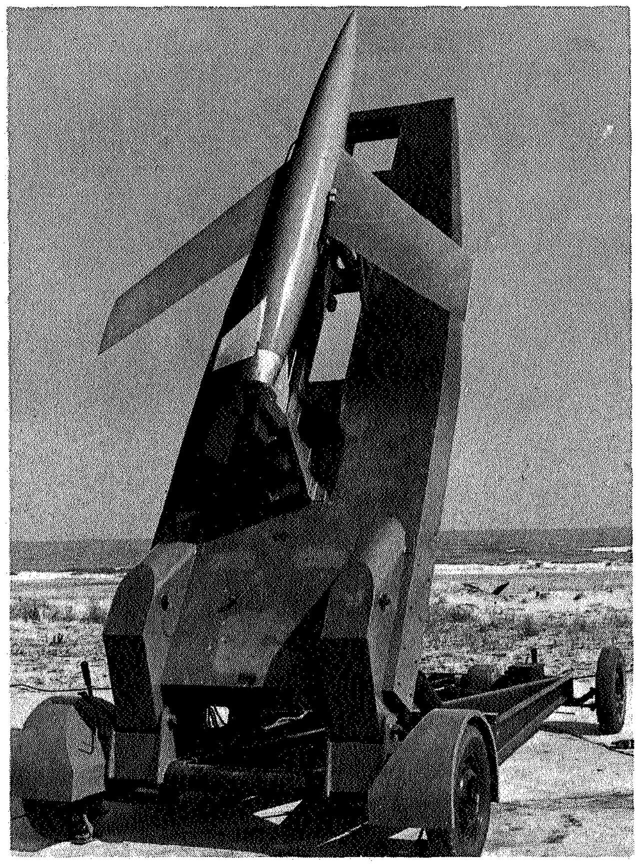


FIGURE 77. Large-scale drag research model, E17 program, shown on launcher, April 21, 1949.

The drag coefficients for this first series of tests were 0.015 for the body and 0.027 for the wing-body combination at supersonic speeds, based on the wing area in both cases (ref. 15).

ROCKET-MODEL TEST OF DOUGLAS XS–3 RESEARCH AIRPLANE

In November 1946, the Army Air Forces requested that the NACA use rocket models to investigate the Douglas XS-3 research airplane, in order to provide aerodynamic information in the transonic range regarding stability, control, and drag characteristics. The NACA issued RA 1448 on January 17, 1947, to cover the program. Five complete airplane models were constructed by the Douglas Aircraft Company for the program, and the first model was flown at Wallops in August 1947.

Figure 78 shows one of the original XS-3 models on its launcher. The models weighed approximately 130 pounds and were propelled to a Mach number of 1.4 by a two-stage propulsion system. Modified 5-inch HVAR rocket motors were used both as booster and as sustainer. The sustainer rocket was fitted with a blast tube to allow location of the motor near the center of gravity. The models were 10 feet long and had unswept wings of aspect ratio 4, 4.6-percent-thick double wedge sections, and 51.47-inch span. These models were somewhat different from the final XS-3 airplane, whose design underwent some changes after the tests.

The models were equipped with a four-channel telemeter which transmitted normal, longitudinal, and transverse accelerations, and total pressure. The technique for obtaining stability and control effectiveness was to vary the center of gravity location and horizontal tail settings between different models. The tests represented the first use of this technique. In the tests, a large longitudinal trim change was encountered between Mach numbers of 0.8 and 1.0, but the horizontal tail was able to overcome this change in trim. The overall drag coefficient was approximately 0.080 (ref. 16).

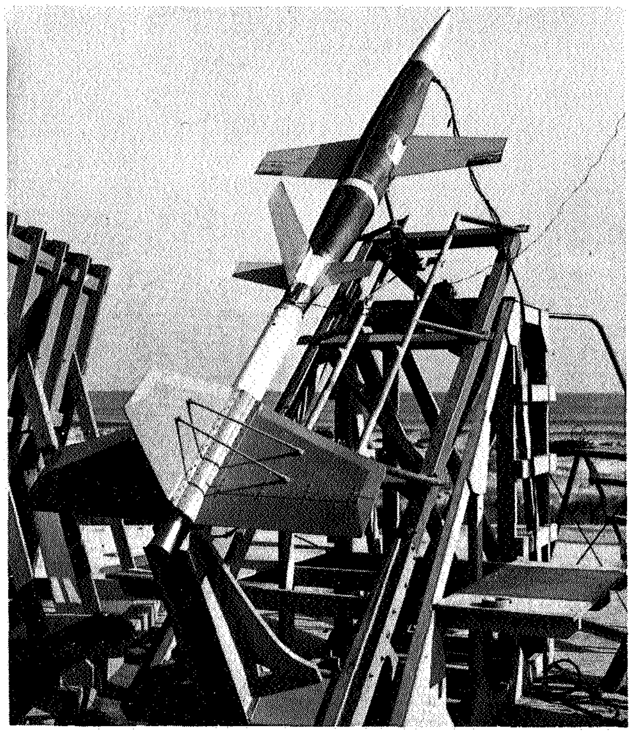


FIGURE 78. Rocket model of early version of Douglas XS–3 research airplane, shown on launcher at Wallops, November 14, 1947.

GENERAL AIRPLANE LONGITUDINAL TRIM AND DRAG PROGRAM: E7

The technique followed with the XS-3 rocket-model program—varying the tail settings and center-of-gravity locations to determine tail effectiveness and longitudinal trim characteristics—was expanded into a general program and designated RM-7 and, later, E7. The models were relatively simple, with only two-channel telemeters transmitting normal acceleration and total pressure. Propulsion was furnished by a 3.25-inch rocket-motor booster and by a second 3.25-inch motor mounted internally. Speeds of Mach 1.2 were obtained in flight.

The first models in the E7 program were patterned after the Douglas D-558-I unswept research airplane and the Douglas D-558-II swept-wing version. The swept configuration, mounted on its zero-length launcher, is shown in figure 79. The straight wing was 6 percent thick while the swept wing was approximately 8 percent in the streamwise direction. The first report on the program included results from four straight-wing models and six sweptback models (ref. 17). From these flights, it was possible to estimate the control settings required for level-flight trim through the transonic range. It was concluded that longitudinal control by means of the stabilizer or all-moving tail was feasible throughout the speed range. Both configurations, however, experienced an abrupt trim change. The drag coefficient was approximately 0.08 with the straight wing and 0.07 with the sweptback wing.

CONVAIR XF–92 AIRPLANE PROGRAM

In September 1946, representatives of Convair (Consolidated-Vultee Aircraft Corporation) and the Army Air Forces visited Langley and discussed their desire for rocket-model tests of the XF-92 (MX-813) delta-wing airplane then under development. A research program was agreed upon, and when the official Army request came, the NACA issued RA 1452 to cover the rocket-model program. A total of six 1/8-scale models was planned to determine drag, stability, and control characteristics through the transonic speed range.

The first model was launched on November 7, 1947. A Monsanto ACL-1 rocket motor was used as a booster, and a 5-inch HVAR rocket motor, shortened to 17 inches in length, was used as a sustainer. The booster was similar to the "all-purpose booster" described in Chapter 4 except that now the fins

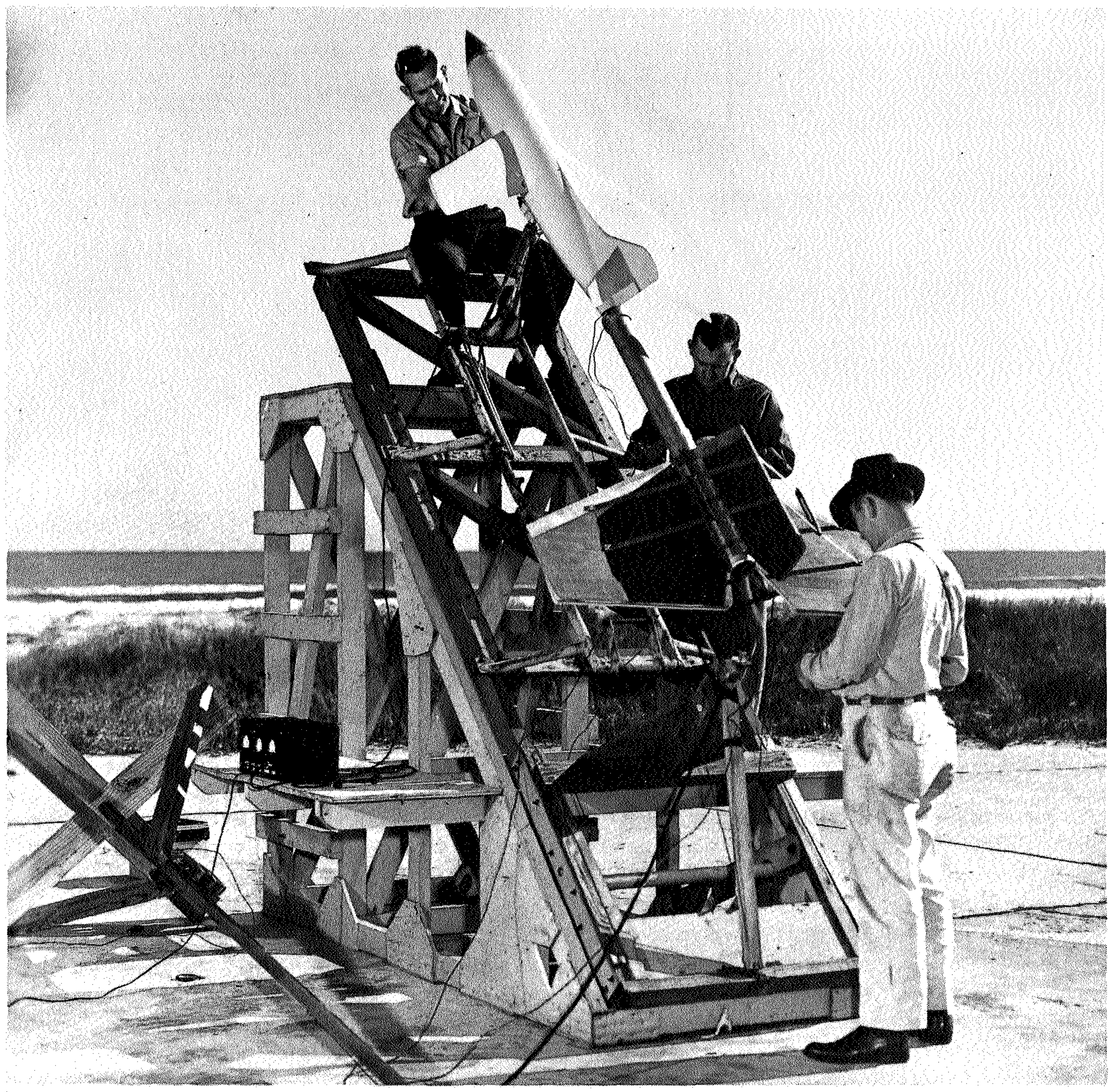


FIGURE 79. Rocket model of Douglas D−558−II research airplane, shown on launcher at Wallops in E7 program, October 20, 1948. From left, project engineer J. H. Parks, Wallops rocket technician N. S. Johnson, and Langley rocket technician G. R. Poole.

were braced with external tie-rods, and a "crutch-type" launcher was used, as shown in figure 80. The internal sustainer rocket served as a positive means for separating the model from the booster, and also provided a short period of constant-speed flight. This model had a large nose inlet which nearly filled the stubby nose of the fuselage. The flight was a failure, attributed to longitudinal instability, and extensive changes were made in the program. The nose of the fuselage was extended, and the inlet was faired over. In addition, the booster rocket was changed to a Deacon. With the modification to the model, the center of gravity could be located far enough forward to insure longitudinal stability. Successful flights were made with the remaining models.

In figure 81, one of the models with the faired nose is shown on its launcher. This faired nose duplicated the flying mockup version of the XF-92 airplane, designated 7002 by Convair and, later, XF-92A by the Air Force. The crutch used with the Deacon booster was a tubular steel structure as contrasted with the short wooden support used in the earlier launch. The crutch served merely as a

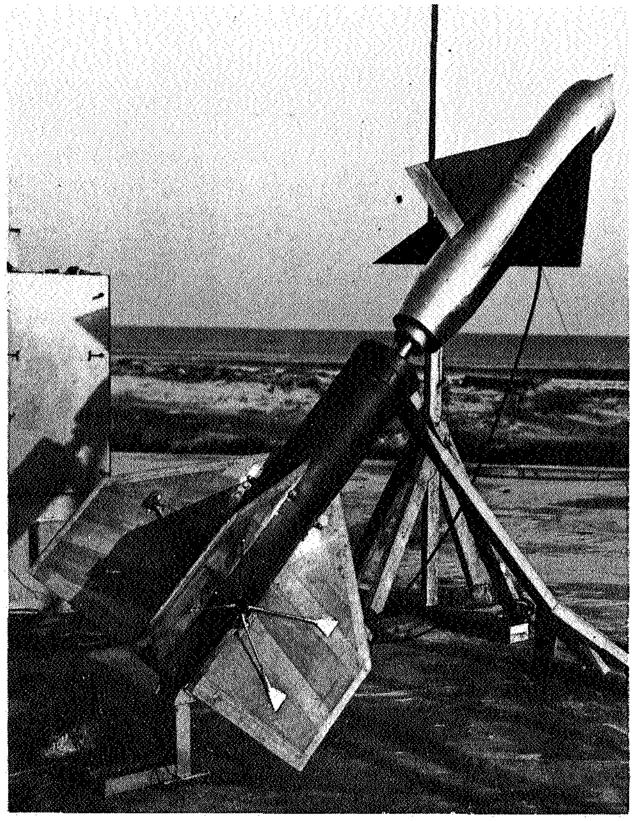


FIGURE 80. Monsanto ACL–1 rocket motor booster with ⅛-scale model of Convair XF–92 airplane ready for launching at Wallops Island, November 7, 1947.

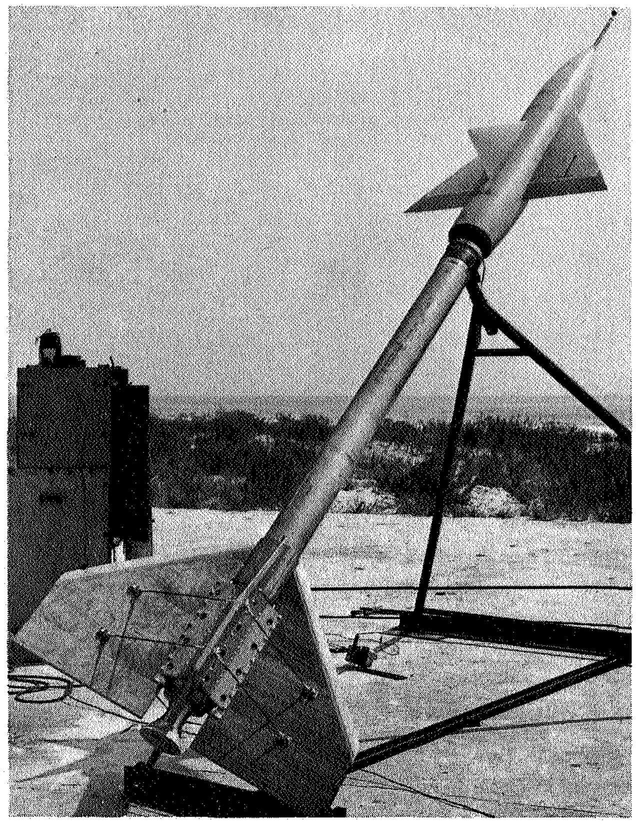


FIGURE 81. Typical ⅛-scale model of Convair XF–92 airplane with faired nose. Model and its Deacon booster are shown on crutch launcher at Wallops, September 24, 1948.

prop to support the front end of the booster at an angle of approximately 45 degrees. At launch, the crutch simply rotated out of the way of the booster fins. This type of launcher was used extensively in later programs.

An eight-channel telemeter, used in these models, transmitted longitudinal, lateral, and normal acceleration, control hinge moments, control position, angle of attack, total pressure, and a reference static pressure. Angle of attack was measured with a floating vane mounted on a sting in front of the nose of the model. This angle-of-attack indicator was a special instrument designed by R. R. Gilruth and developed at Langley for this purpose (ref. 18).

The elevons were actuated in flight by a compressed-air system to produce a series of abrupt pull-ups and push-downs at a frequency of one cycle in 1.2 seconds. Analysis of the resulting motions of the model made it possible to determine dynamic stability and trim by the same procedure that was used in the Lark missile tests discussed in Chapter 3.

A preliminary report for the Air Force was prepared on the results of the first model (ref. 19); and a second report, prepared for general distribution, included the results from all models (ref. 20). This was the first airplane for which flying qualities were predicted from rocket-model tests. Except for small changes in trim and a reduction of control effectiveness at transonic speeds, flight characteristics were found to be quite satisfactory.

GENERAL AIRPLANE DYNAMIC LONGITUDINAL STABILITY PROGRAM: E15

The pulsed-control method for obtaining dynamic longitudinal stability and control with the XF-92 airplane model was adapted to a general airplane research program designated E15. The body shape used for the first models in this general program was the same one used in the D4 program—a cylindrical body with a 7-inch diameter, and with ogival nose and tail sections. Different wing and horizontal tail arrangements were mounted on successive models. The instrumentation and mechanism for pulsing the controls were located within the body and were the same for all models. The models were approximately 125 pounds in weight, and were propelled to a Mach number of 1.40 by a single Deacon booster. The first complete model in this program, launched February 2, 1949, is shown in figure 82 mounted on the crutch launcher for a 45-degree takeoff. Several developmental launchings were made in 1948.

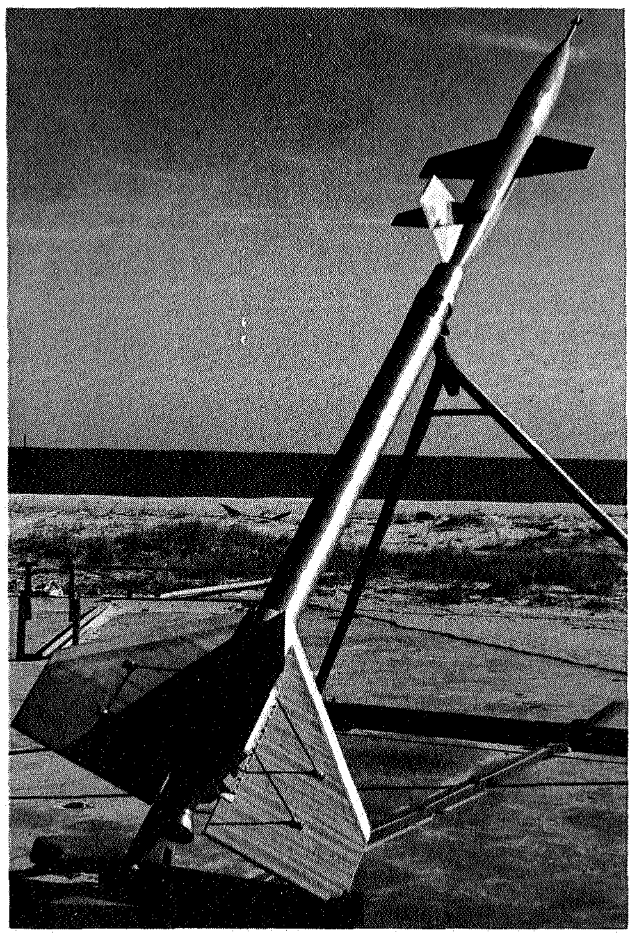


FIGURE 82. Typical E15 research rocket model used to investigate dynamic longitudinal stability. Model is shown ready for launching on February 2, 1949.

A six-channel telemeter transmitted normal and longitudinal accelerations, elevator deflection, angle of attack, total pressure, and a static pressure.

The wing and horizontal tail on the first E15 model were patterned after those of the Douglas X-3 research airplane. Both were tapered and unswept, of aspect ratio 3, and had modified double-wedge airfoil sections 4.5 percent thick. The tests indicated that the corresponding airplane could be readily controlled with the all-moving horizontal tail. The maximum lift coefficients were low because of the sharp leading edges, and the drag coefficient of 0.070 at transonic speeds was believed to be caused mainly by the fuselage (ref. 21). This was the first launching in a program that eventually collected a large mass of data on different airplane arrangements.

CONTROL HINGE MOMENTS RESEARCH PROGRAM: D8

A general rocket-model research program designated RM-8 and, later, D8 placed emphasis on the measurement of control hinge moments. The technique consisted of mechanically pulsing the aileron control surfaces sinusoidally at a rate of four cycles per second and measuring the hinge moments, aileron deflection, rolling velocity, normal and longitudinal acceleration, and total and static pressure. The fuselage was similar to the standard E15 fuselage; for the first test, on March 30, 1949, 60-degree delta wings and half-delta tip ailerons were used. Two equal-span wings were arranged in a cruciform manner and no tails were required. The pulsed ailerons were in only one plane. The wing in the other plane was mounted on a rolling-moment balance to determine damping-in-roll. The rolling moment readings were transmitted by the eighth channel of the telemeter. A single Deacon booster was used to propel the model to a Mach number of 1.52.

The delta wing with half-delta controls was selected because of the favorable results shown earlier for this aileron. The results showed that the hinge moments could be very closely balanced out with the single hinge location of 63.5 percent of the root chord.

From an analysis of the total motion of the missile and the rolling-moment balance measurements, it was possible to calculate the rolling moments produced by the ailerons as well as the damping-in-roll characteristics of the configuration. This was a step forward in control studies beyond the E5 technique. Now the components of the total motion could be evaluated. For this wing arrangement, the damping-in-roll was found to be constant over the speed range. This result showed that the variations in overall rolling effectiveness were caused by changes in the rolling moments themselves. In the supersonic range, these aileron moments decreased as the speed was increased. This finding was in general agreement with theory, although the magnitude in the subject test was approximately 20 percent lower than the corresponding theoretical values (ref. 22).

DAMPING-IN-ROLL GENERAL RESEARCH PROGRAM: D13

Although damping-in-roll of a delta wing was obtained by the D8 technique, a less complicated method for studying many different wing planforms was needed. W. J. O'Sullivan proposed a technique in which an internal rocket motor with four canted nozzles would apply a known amount of torque or rolling moment which, in an equilibrium condition, would be balanced by the damping-in-roll. All that was required, in addition to the torque nozzle, was a spinsonde to measure rolling velocity, and the Doppler radar to measure forward velocity, as in the E5 program. With the damping-in-roll measured, the mass of rolling effectiveness data from the E5 program could then be reevaluated as aileron rolling moments. Such a program, designated D13, was initiated at Wallops.

The models used were similar in construction to the simple E5 models. Four models were flown in December 1948 and another forty-nine in 1949. The model body was 6.5 inches in diameter and 72 inches in length, and had three wing panels at the rear. The wings also served as stabilizing fins. The internal rocket was a 5-inch Cordite rocket motor which had been modified by changing its single nozzle to four smaller nozzles with a cant. A 5-inch HVAR booster was used, as shown in figure 83. Mach numbers of approximately 1.5 were reached. Total drag coefficients were also obtained.

The first tests were made of wings of aspect ratio 3.71 and NACA 65A006 and 65A009 airfoil sections. The results obtained with three identical models 6 percent thick are shown in figure 84. Damping-in-roll is expressed as C_{l_p} or $dC_l d\frac{pb}{2V}$, where C_l is rolling moment coefficient, moment/qbS. The rocket-model results filled in the speed range between the high-subsonic wind-tunnel test data and supersonic theory. The data were somewhat lower than the theoretical figures, but there were no discontinuities in the transonic range (ref. 23).

Damping-in-roll measurements were not only useful in the evaluation of control moments from E5 data, but were useful directly in lateral stability calculations. The development of a simple technique for measuring damping-in-roll was one more step along the way in providing aerodynamicists with the data needed for airplane and missile design.

HOW PROJECTS ORIGINATED: RELATIVE ROLES OF LANGLEY AND WALLOPS; SAFETY CONSIDERATIONS

As was noted earlier, the research projects involving tests at Wallops Island under the NACA were of two types: "specific" or "general." Specific projects were those requested by one of the military services in direct support of a specific missile or airplane. Such research usually involved tests of scaled models of the airplane or missile. In some cases the full-size missile was tested. PARD had attained national

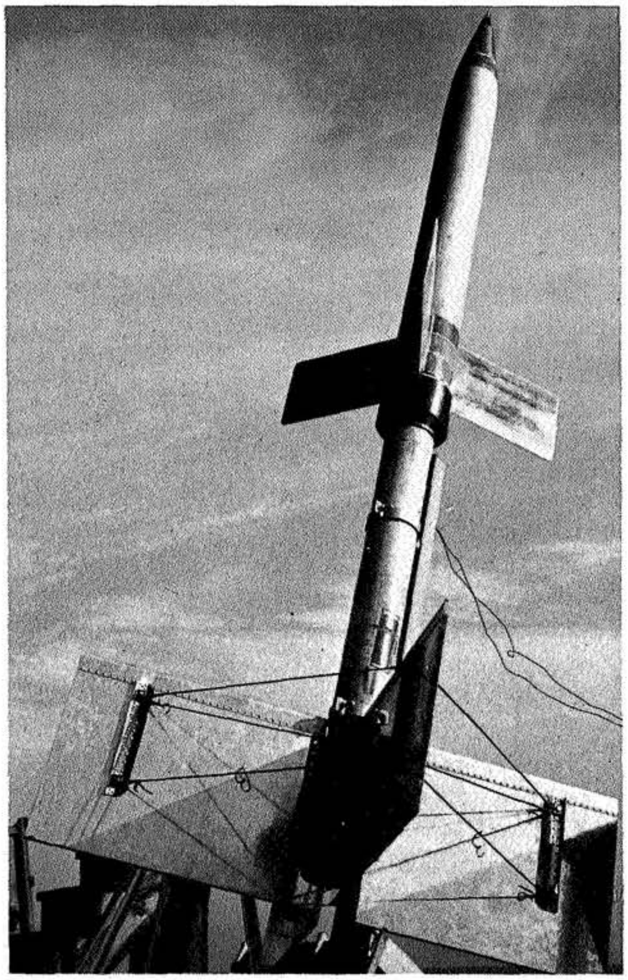


FIGURE 83. Typical D13 research rocket model used to investigate damping-in-roll by the torque-nozzle technique. Model is shown ready for launching at Wallops on January 11, 1949.

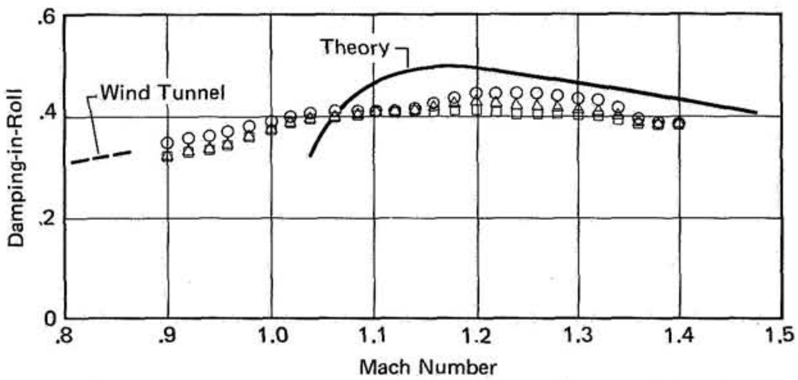


FIGURE 84. Damping-in-roll rocket test results from NACA D13 program compared with wind-tunnel test data and theory.

recognition for its ability to obtain meaningful and accurate data, usually aerodynamic data, from rocket-model flight tests. From 1948 to 1958, practically every supersonic missile or airplane under development in the United States was represented in the Wallops specific research proram. Specific research constituted approximately 20 percent of the overall effort.

When a military service decided upon the development of a new airplane or missile, it was customary for the NACA to assist the military and its contractors by conducting such tests in its facilities that could not be conducted elsewhere. As the manufacturers acquired their own wind tunnels, either directly, or jointly through sponsorship of university facilities, the NACA was relieved of much of the standard wind-tunnel testing. The special facilities, however, remained in great demand. Wallops, with its rocket-model technique, was one of these.

The reason for this great demand for rocket-model tests at Wallops was given quite clearly by Edmond C. Buckley. He wrote: "Wallops Island had an enviable reputation for success and reliability of operation and for trustworthiness and reliability of data at a time when other ranges seemed plagued with launching or instrumentation mishaps. The quality of Wallops' work continued in the decade beyond the period covered thus far (1945–1949) and undoubtedly played a major part in the decision to make NACA the nucleus of NASA."[11]

Early in the development phase of a new supersonic missile or airplane, representatives of the military service and the contractor would visit PARD at Langley and discuss their design problems and their proposed test program. It was customary for the Chief of PARD to be present at such meetings to give the visitors the benefit of other test results that might have a bearing on the current problem, to point out potential problem areas in the proposed design, and to ensure that unnecessary tests were not programmed.

PARD welcomed the visits of manufacturers and the military services, whether for discussion of new design proposals or for consultation on current problems. In this period, the military services were the only users of the end products of PARD research—supersonic airplanes and missiles. The visits kept PARD abreast of current problems, and the general research programs were guided with the knowledge of such problems. At these visits, general research was discussed with the visitors, as well as specific tests under consideration.

The NACA made it a policy not to ask the military for a transfer of funds to cover costs of specific research. The military reciprocated by assisting the NACA to obtain equipment and supplies. The NACA did ask each military service to provide the models to be tested and in many cases to provide the rocket booster for the flight test. Langley always provided the special instrumentation within the models, carried out the tests, and analyzed and reported the results. Frequently the results of specific tests were of such general interest that separate reports were prepared for general distribution.

At Langley, specific projects were generally given priority over the general program, in cases of highest military priority, much overtime and special considerations were given the project.

Although the manufacturers were required to design and construct the test models for a specific rocket-model program, Langley contributed to the detailed design to assure structural integrity and reliability of the test models. Manufacturers were given the benefit of the experience of the Langley engineers and fabricators. Preliminary layouts were usually made by the contractor's representative under the direction of Langley engineers. Construction was not allowed until Langley had approved the design. It was very frustrating to receive a completed model, supposedly ready for test, to find obvious structural errors that experience had shown would probably result in a failure in flight. As a guide to the design of rocket models, a set of notes was prepared and made available to all model designers (ref. 24).

Each specific project required the approval of NACA Headquarters and the prior approval of the military coordinating committee. NACA Headquarters was, therefore, kept aware of all tests being conducted at Langley and Wallops on specific airplanes and missiles.

The relative roles of Langley and Wallops in connection with specific projects is of interest. All such projects had to start with PARD at Langley. Any visitor or any correspondence relating to rocket-model tests was always referred to PARD. It was up to PARD to call in or refer such visitors to other units of the Langley Laboratory as required. C. C. Johnson was usually called in for preliminary comments on engineering design and H. H. Youngblood gave advice on instrumentation. PARD had the final say as to whether a particular model would be launched at Wallops.

As was mentioned earlier, Wallops at this time was a branch of PARD. Wallops was responsible for operations at the range and made decisions on the launching of particular models as affected by range instrumentation, weather, and safety considerations. Normally the Chief of PARD did not interfere in such decisions but his opinion was usually obtained ahead of time in questionable cases. The Engineer-in-Charge of Wallops was also consulted in connection with new projects requiring unusual range equipment or the procurement of new equipment.

Normal operations between Langley and Wallops were handled by the PARD Operations Section, headed by C. A. Hulcher. The operations office was the focal point for all information going to or

11. Letter from Edmond C. Buckley to Joseph E. Robbins, February 27, 1968, commenting on first draft of Wallops History.

returning from Wallops. A communication radio was located in the operations office, and information on all countdowns was obtained there. Travel to and from Wallops was coordinated by this office, whether by boat, NACA airplane or private car.

The general, or basic, research program at Wallops was somewhat less exciting than the specific model program because it did not relate directly to airplanes and missiles in being. On the other hand, the general program had the excitement associated with new discoveries and out-front research programs. The military and the industry looked to PARD for guidance in new designs. It was up to PARD to anticipate such requests and have the answers ready when needed. This they succeeded in doing. In recognition of the contribution of the Wallops program, the 1950 Sylvanus Albert Reed award was presented to Robert R. Gilruth for "the conception and development of new techniques for obtaining transonic and supersonic data using freely flying models" (ref. 25).

As noted before, the general research authorizations were quite broad in scope, and great freedom was given the NACA research laboratories, not only in execution of the programs but in their earliest conception. The main committee of the NACA and its various working committees and subcommittees met at regular intervals and received presentations of the latest results of NACA research. Overall policy and areas requiring research were set by these bodies, but the detailed ideas for new research nearly always came from the research engineers directly involved with a program. At PARD, practically every new idea proposed at the working level was allowed a trial, provided it related to the general problems at hand. This willingness of management to give new ideas a trial stimulated and encouraged the development of forward-thinking researchers.

The basic research programs at PARD did not have the usual limitations placed on wind-tunnel facilities. Tunnels were usually confined to particular speeds or types of research. The rocket technique could be used in almost any problem of flight, and speed was merely a question of selection of rocket motors. As a result, the PARD research program came under the cognizance of many of the NACA committees and subcommittees. Those normally receiving regular reports and theoretically directing the research in their areas were the following:

Committee	*Subcommittee*
Aerodynamics	Fluid Mechanics
	High-Speed Aerodynamics
	Stability and Control
	Internal Flow
	Upper Atmosphere
Powerplants	Combustion
Aircraft Construction	Aircraft Structures
	Aircraft Loads
	Vibration and Flutter
	Aircraft Structural Materials

In actual practice, many flight projects originating at PARD were of interest to several different subcommittees. For example, tests of a wing and fuselage in combination would yield data concerning high-speed aerodynamics, stability and control, aircraft loads, and sometimes vibration and flutter. This "across-the-board" coverage in a single project did not bother PARD personnel at Langley or Wallops although, when presentations were required before particular committees, the researchers making such presentations had to be sure to "wear the right hat." One lasting effect of this multidisciplined effort was to train men to be "broad-gauge" researchers uninhibited by adherence to a single discipline.

The representatives on the High-Speed Aerodynamics Subcommittee from the three NACA laboratories—Langley, Lewis, and Ames—together with the NACA Headquarters representative constituted a High-Speed Panel that would meet prior to the subcommittee meetings to compare results and agree upon a position. At its meeting on August 27, 1948, the Panel recommended that a special interlaboratory group be appointed to coordinate NACA research applicable to guided missile problems. Such a group was appointed in November 1948 to examine the NACA program with the specific needs of guided missile contractors in mind.[12] The High-Speed Panel at this time consisted of R. G. Robinson, NACA Headquarters; John Stack, Langley; H. Julian Allen, Ames; and Abe Silverstein,

12. Crowley, J. W., NACA letter to Langley, Nov. 9, 1948, regarding special interlaboratory group to coordinate NACA research applicable to guided missile problems.

Lewis. The Special Interlaboratory Group consisted of R. R. Gilruth and J. V. Becker, Langley; J. C. Evvard, Lewis; and R. F. Huntsberger, Ames. This is just one example of attempts to obtain maximum effectiveness from NACA general research.

At Langley, there were local committees which paralleled the NACA committees; their function was to facilitate the exchange of information on common problems at the working level, and to coordinate general research activities. Most new proposals for research were referred to such committees for comment. The committees were useful as a means of keeping up with new research findings all over the laboratory, but they were rarely a source of new ideas. Ideas came from individual workers. To these idea men, the various committees were a part of the system they had to tolerate.

At Wallops under the NACA, no attempt was made to establish launch schedules ahead of time. Every model was prepared for flight as soon as possible, with recognition of certain priorities, and was sent to Wallops when it was ready. At Wallops, the models were launched when they were prepared, almost on a first-come, first-served basis. This provided freedom to inject new urgent models at any time, without disrupting a schedule.

The various technical conferences held at the NACA laboratories provided another source of inputs to the general research program of PARD. These conferences were attended by airplane and missile experts from all over the country, and afforded industry and the military alike an opportunity to propose additional research.

On two occasions, there was a demand for an expansion of the general rocket-model program. The first such demand came at a conference of Army, Navy, NACA, and industry representatives in September 1945, shortly after Wallops had been set up (ref. 26). The second demand came at a meeting of a Special Subcommittee on Research Problems of Transonic Aircraft Design held in June and July, 1948. The subcommittee stated, "It is therefore recommended that full encouragement and recognition be given to the work of the Langley Pilotless Aircraft Research Division and that steps be taken to increase immediately the manpower and facilities available for rocket-test work, preferably by a factor of at least 3." A resolution to this effect was unanimously passed (ref. 27). Such encouragement from industry was very helpful in obtaining the backing of NACA management as well as that of Congress for increased emphasis on this type of research. In addition, the recommendations of this subcommittee were the basis for an expanded general research program.

As the fame of Wallops grew, more and more people wanted to visit the facility and witness rocket launchings. The base was still closed to visitors except in certain special cases. The general policy was to limit visitors to those people having a need to go there. The committees of NACA scheduled one or more meetings there to allow the members to see firsthand what was going on. The first such group to hold a meeting there was the NACA main committee, which met at Wallops April 21, 1949. (See figure 85.) Eventually, all committees having an interest in this type of research met at least once at Wallops.

The problem of safety in Wallops operations was of continual concern to Langley management, principally because of the unknown hazard of the rocket motors. Inasmuch as Wallops was officially a part of Langley, the Executive Safety Committee of Langley had cognizance over safety matters there. This committee held a meeting at Wallops June 24–25, 1948. Concern was expressed about the number of people allowed in hazardous areas, and the adequacy of warning signals. The need for a full-time nurse was also discussed. Although nothing was settled at this meeting, a full-time technician was obtained soon afterward to operate the first aid dispensary and to conduct first aid classes. The need for a ferry to replace the rather unsafe LCM boats for transporting trucks and buses to the island was agreed to be a real one (ref. 28).

From the beginning of Wallops, there was concern over the safety of the Doppler radar operators. All other personnel could take cover during actual launchings, but the radar operators were required to be close to the launcher. The solution adopted was to erect portable barricades between the Doppler radar and the launchers. These were made of marine plywood and filled with cotton waste. While such a barricade would not withstand a direct hit from a rocket in flight, the chances for such an event were practically zero. The barricades would at least stop flying particles in case of an explosion. As it turned

FIGURE 85. Group attending NACA meeting at Wallops Island on April 21, 1949. Shown from left to right are John F. Victory, Executive Secretary, NACA; Catherine Wheeler, NACA Hq.; R. G. Robinson, NACA Hq.; J. W. Crowley, NACA Hq.; R. L. Krieger, Wallops; A. M. Rothrock, NACA Hq.; H. L. Dryden, Director, NACA; R. R. Gilruth, Chief, PARD; Maj. Gen. D. L. Putt, USAF; R. M. Hazen, General Motors Corp., Allison Div.; H. J. E. Reid, Director, Langley; J. C. Hunsaker, Chairman, NACA; W. Littlewood, American Airlines, Inc.; F. W. Reichelderfer, Chief, U.S. Weather Bureau; T. P. Wright, Cornell University; A. E. Raymond, Douglas Aircraft Co.; Vice Admiral J. D. Price, USN, Vice CNO: Rear Admiral T. C. Lonnquest, USN, Asst. Chief, BuAer.

out, there never were any explosions directly on the launcher. The only real hazard to the operators was from parts of model structure, when structural failures were encountered in flight. Such failures usually occurred at altitudes of a few hundred feet, and the air was filled with pieces, as from an explosion. No real damage was ever done by such particles, however.

During the developing years of Wallops, there appeared to be a high percentage of failures in flight. Some programs were carried out with a reliability in excess of 95 percent, while in others over half the flights experienced some type of failure. The main reason for such failures was that there were no design criteria to cover the speed range of the tests. In fact, one purpose of the tests was to obtain the information really needed for proper design. In most cases, the researchers were operating beyond the frontiers of knowledge. No failure, however, was ignored or considered a chance occurrence. All data, including telemetered information from onboard instrumentation as well as numerous high-speed motion pictures, were closely examined; and the next flight was not permitted until some change in design had been made, unless an obvious operational error had been located. In retrospect, it is amazing that so many correct diagnoses of the trouble were made, in view of the explosive nature of many failures. The key in any investigation was to locate the very first item of failure or source of trouble in a chain of events.

References

1. Permit granted by the NACA to the Navy Department for the use of certain U.S. Government-owned lands on Wallops Island, Virginia, Jan. 14, 1952.
2. Hooker, Ray W., Memorandum to Chief of Research, Feb. 14, 1947, regarding conference to discuss danger area requested by NAOTS.
3. Hooker, Ray W., Memorandum to Chief of Research, Feb. 26, 1947, regarding Wallops Island Danger Zone.
4. Ninth Air Force and Fifth Naval District, Memorandum of Understanding regarding operational use of Chincoteague-Virginia Capes Off-Shore Air Space Warning Areas, Sept. 30, 1949.
5. O'Sullivan, W. J., Memorandum to Chief of Research, Oct. 3, 1949, regarding reallocation of range space in vicinity of Wallops Island.
6. Curfman, Howard J., Jr.; and Gardner, William N.: *Theoretical Analysis of the Motions of an Aircraft Stabilized in Roll by a Displacement-Response, Flicker-Type Automatic Pilot.* NACA RM L8D19.
7. Curfman, Howard J., Jr.: *Theoretical Analysis of the Rolling Motions of Aircraft Using a Flicker-Type Automatic Roll-Stabilization System Having a Displacement-Plus-Rate Response.* NACA RM L8K23a.
8. Gardiner, Robert A.; and Zarovsky, Jacob: *Rocket-Powered Flight Test of a Roll-Stabilized Supersonic Missile Configuration.* NACA RM L9K01a.
9. Curfman, Howard J., Jr.; and Gardiner, Robert A.: *Method For Determining the Frequency-Response Characteristics of an Element or System From the System Transient Output Response to a Known Input Function.* NACA TN 1964, Oct. 1949. Reissued as NACA TR 984, 1951.
10. Soulé, Hartley A., Memorandum, to Chief of Research, March 13, 1945, regarding visit of Soulé and R. A. Gardiner to NAES and NAMU.
11. Gardiner, Robert A.; Zarovsky, Jacob; and Ankenbruck, H. O.: *An Investigation of the Stability of a System Composed of a Subsonic Canard Airframe and a Canted-Axis Gyroscope Automatic Pilot.* NACA TN 2004, Jan. 1950.
12. Michel, David H.; and Mitcham, Grady L.: *Preliminary Results of a Free-Flight Investigation of the Static Stability and Aileron Control Characteristics of 1/6-Scale Models of the Bell MX–776.* NACA RM SL9D21.
13. Kinghorn, George F.; and Disher, John H.: *Free-Flight Investigation of 16-Inch-Diameter Supersonic Ramjet Unit.* NACA RM E8A26.
14. Carlton, William W.; and Messing, Wesley E.: *Free-Flight Performance of 16-Inch-Diameter Supersonic Ramjet Units. I, Four Units Designed For Combustion-Chamber-Inlet Mach Number of 0.12 at Free-Stream Mach Number of 1.6* (Units A–2, A–3, A–4, and A–5). NACA RM E9F22.
15. Katz, Ellis: *Flight Investigation From High Subsonic to Supersonic Speeds to Determine the Zero-Lift Drag of a Transonic Research Vehicle Having Wings of 45° Sweepback Aspect Ratio 4, Taper Ratio 0.6, and NACA 65A006 Airfoil Section.* NACA RM L9H30.
16. Gillis, Clarence L.; and Mitchell, Jesse L.: *Flight Tests at Transonic and Supersonic Speeds of an Airplane-Like Configuration With Thin Straight Sharp-Edge Wings and Tail Surfaces.* NACA RM L8K04a.
17. Parks, James H.; and Mitchell, Jesse L.: *Longitudinal Trim and Drag Characteristics of Rocket-Propelled Models Representing Two Airplane Configurations.* NACA RM L9L22.
18. Mitchell, Jesse L.; and Peck, Robert F.: *A NACA Vane-Type Angle-of-Attack Indicator For Use at Subsonic and Supersonic Speeds.* NACA RM L9F28a. Reissued as NACA TN 3441, May 1955.
19. Mitcham, Grady L.: *A Preliminary Analysis of the Flying Qualities of the Consolidated Vultee MX–813 Delta Wing Airplane Configuration at Transonic and Low Supersonic Speeds as Determined From Flights of Rocket-Powered Models.* NACA RM SL9E13.
20. Mitcham, Grady L.; Stevens, Joseph E.; and Norris, Harry P.: *Aerodynamic Characteristics and Flying Qualities of a Tailless Triangular-Wing Airplane Configuration as Obtained From Flights of Rocket-Propelled Models at Transonic and Low Supersonic Speeds.* NACA RM L9L07. Reissued as NACA TN 3753, Nov. 1956.
21. Gillis, Clarence L.; Peck, Robert F.; and Vitale, A. James: *Preliminary Results From a Free-Flight Investigation at Transonic and Supersonic Speeds of the Longitudinal Stability and Control Characteristics of an Airplane Configuration With a Thin Straight Wing of Aspect Ratio 3.* NACA RM L9K25a.
22. Martz, C. William; and Church, James D.: *Flight Investigation at Subsonic, Transonic, and Supersonic Velocities of the Hinge-Moment Characteristics, Lateral-Control Effectiveness, and Wing Damping in Roll of a 60° Sweptback Delta Wing With Half-Delta Tip Ailerons.* NACA RM L9L14. Revised and reissued as RM L51G18.
23. Edmondson, James L.; and Sanders, E. Claude, Jr.: *A Free-Flight Technique for Measuring Damping in Roll by Use of Rocket-Powered Models and Some Initial Results For Rectangular Wings.* NACA RM L9I01.
24. *General Engineering Notes for the Design of Rocket-Powered Models for the Langley Pilotless Aircraft Research Division.* Langley Aeronautical Laboratory, Feb. 1950.
25. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Science and Technology in the Exploration of Space, 1915–1960.* NASA, 1961, p. 191.
26. Minutes, Conference of Army–Navy–NAOA–Industry on NACA High-Speed Research Program, Wright Field, Ohio, Sept. 6–8, 1945.
27. Minutes, Special Subcommittee on Research Problems of Transonic Aircraft Design of the Committee on Aerodynamics, June 10 and July 8–9, 1948.
28. Minutes, NACA–Langley Executive Safety Committee, Wallops Island, June 24–25, 1948.

CHAPTER 7

YEAR OF RAMJET ACHIEVEMENT: 1950

CONSTRUCTION OF NEW FACILITIES

The permanent facilities at Wallops authorized by Congress in 1945 had to suffice for several years because of the reluctance of Congress to appropriate funds for capital outlay after the war ended. Although some construction work was done with funds budgeted for General Operating Expenses (GOE), the first major new construction was undertaken with funds authorized for Wallops in fiscal years 1948 and 1949. In 1948, Construction and Equipment (C & E) funds were allotted for the construction of a greatly enlarged Control Center at the launching area (Project 648) and three new rocket facilities (Project 647). The rocket facilities consisted of Propellant Magazine, Igniter Magazine, and Rocket Test Cell. In 1949, C & E funds were appropriated for the construction of a large Instrumentation Laboratory (Project 790).

The Control Center, originally termed Bombproof Instrument Station, was built as an addition to the original Bombproof Observation House, although it was many times larger. As soon as operations began at Wallops, it was realized that a much larger center was needed for control of flight operations and for housing of range instrumentation.

The budget request was for a station of 1,000 square feet to adjoin the original structure containing 250 square feet. Funds were requested at the same time for a Research Equipment Building which was to contain a room of 15,000 square feet for storage and maintenance of radars, and an adjoining building of 5,000 square feet subdivided into a telemeter room, control laboratory, darkroom, and instrumentation laboratory. When the request for the Research Equipment Building was turned down as a part of the 1948 budget, Langley proposed to NACA Headquarters that the Control Center be enlarged to 5,000 square feet and be designed to accommodate many of the functions originally planned for the Research Equipment Building. This proposal was approved by NACA Headquarters on November 18, 1947.

The Control Center, 115 feet by 44 feet, consequently contained not only the central firing control and observation room but separate rooms for the receiving stations for telemetry, spinsonde, Doppler radar, and radiosonde. It also contained a darkroom, a battery-charging and storage room, and a room for storage and adjustment of instruments. In addition, it contained its own central heating and air conditioning system. Pending construction of this Control Center, the various instruments and receiving stations were housed in temporary trailers and wooden shelters.

The budget proposal was for a structure to be built mostly underground for safety, and to reduce interference with the radar and cameras. This idea was abandoned, however, and the building was constructed with the floor high enough above sea level to minimize damage from flooding during storms and high tides. The completed center is shown in figure 86. The small room on the right end is the original Observation House. Telemetry antennae were located on the roof. The center was of cast concrete construction, with small observation ports. It was built by Doyle and Russell for $183,750, as a part of contract NAw-5555, and was completed in March 1950.

The original launching slab, 50 feet by 50 feet, was also found to be inadequate, and general operating funds were used for a two-phase enlargement of the launching area. The first phase, completed in April 1948, was a 170-foot extension of the original 50-foot-wide slab in a curve following the circular access roadway. This construction, approved as project 725 on November 13, 1947, was performed by Ferguson Corporation for $8,150, under contract NAw-5528. The second phase consisted of extending the launching area in both directions parallel to the shoreline, to provide a continuous area 600 feet long and at least 50 feet wide. This second extension, also constructed by Ferguson Corporation, cost $89,319 under contract NAw-5728. The work was approved as Project 885 on December 7, 1948, and was completed in January 1950. The contract also covered construction of utility ducts under ground, a ramjet fire control system, and a launch control shelter.

The new rocket-motor facilities, also constructed from the fiscal 1948 C & E appropriation, are also shown in figure 86. The facilities constructed were somewhat different from those requested when the budget was prepared in 1946. The original plan called for a rocket-conditioning building and a model assembly building in addition to the three buildings actually constructed. The needs and priorities for facilities at Wallops changed continually, and the most urgent needs had to be met first. When available C & E funds were exhausted, some of the buildings had to be postponed or reevaluated. The model assembly building was to be constructed later from the 1950 appropriation while the rocket conditioning building was canceled.

The three rocket-motor facilities, Project 647, were constructed by Doyle and Russell as a part of contract NAw-5555, for a cost of $312,500. This cost covered utilities, roads, grading, and fencing, as

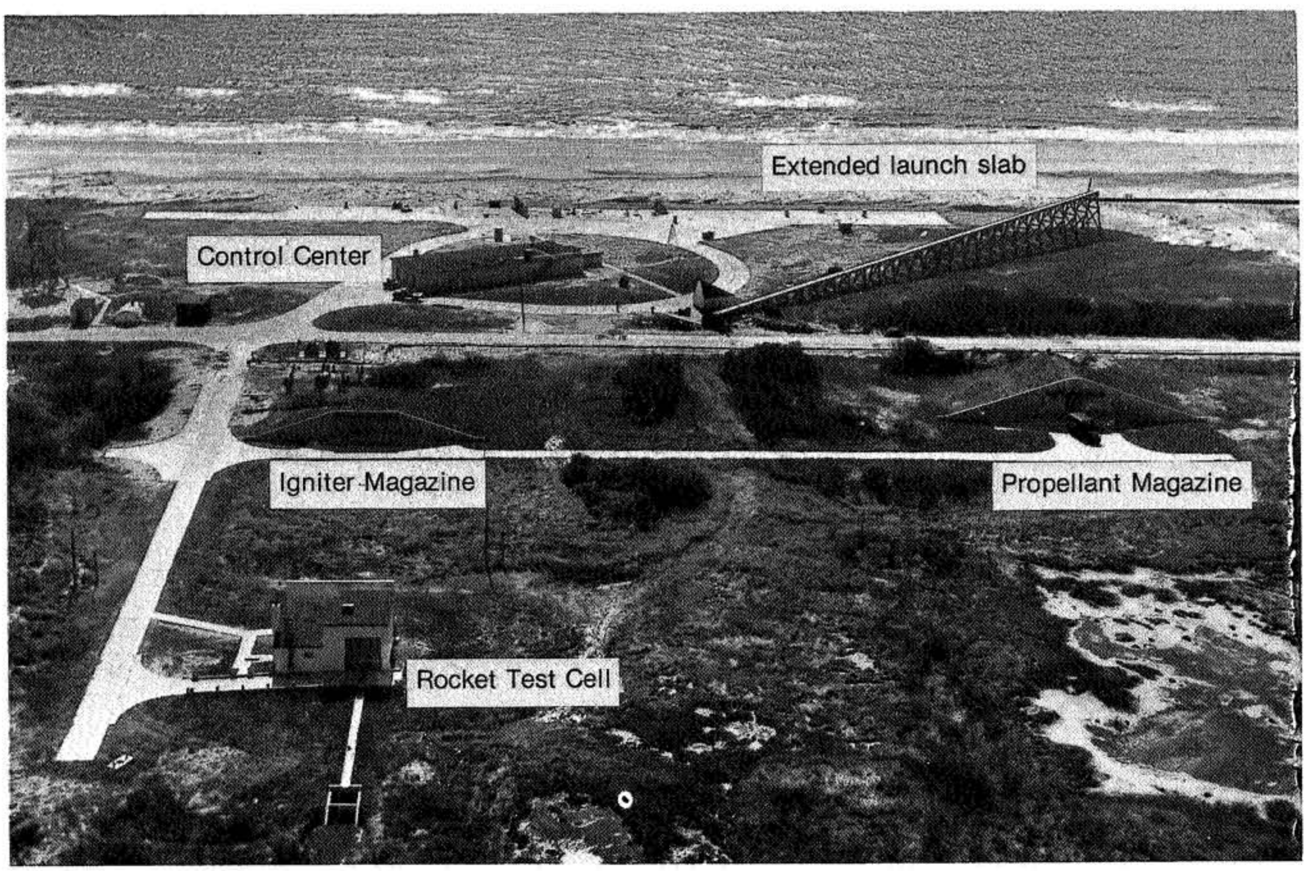


FIGURE 86. Aerial view of launching area in April 1950 showing new launch slab, Control Center, Igniter Magazine, Propellant Magazine, and Rocket Test Cell.

well as the buildings. The facilities were constructed in a restricted zone across the road from the launching area and were completed in March 1950.

The Propellant Magazine, formerly called Rocket Storage Magazine, was the largest of the three structures, being a 37-foot by 52-foot concrete building covered with earth to make a total width of 139 feet. This magazine was a vast improvement over the small igloos constructed in 1945 and 1946, and was to fill the needs of Wallops for many years. Rocket motors formerly stored at the Chincoteague Air Station and at Langley could now be moved to Wallops where they were more readily available.

The Igniter Magazine was similar in construction to the Propellant Magazine although it was much smaller. It consisted of three separate cells 8 feet square, in a row with a common outside loading platform. The different cells made it possible to separate the different classes of explosives used in igniter manufacture, as well as to store completed igniters.

The Rocket Test Cell was given priority because of the expected need for ground tests of liquid-rocket engines. Small thrust stands for test of solid-rocket motors were available at Langley, but the hazards involved with liquid-rocket testing necessitated the use of a remote area such as Wallops Island. In addition, a test cell was needed at the launch site for making final adjustments in the liquid-rocket engines before their use in a flight model. The Rocket Test Cell consisted of the test cell proper with a drain and catch basin for spilled propellants and an adjoining observation room separated by a thick concrete wall containing a special periscope-mirror viewing system. A large concrete barricade, 18 feet high and 38 feet long, was erected on the east side of the building for protection in case of an explosion. By the time this building was completed, interest in liquid-rocket engines for Wallops had almost disappeared, and only one such engine was ever run in the test cell. Other uses were found for the facility. It was found to be a good place for "blowdown" tests of ethylene fuel tanks prior to flight testing of ramjet vehicles, to check out the fuel-flow control system. Later, the facility was to be equipped with a dynamic-balancing machine for payloads, particularly those containing loaded rocket motors.

The Instrumentation Laboratory was essentially a resubmission in the 1949 budget of a part of the Research Equipment Building disapproved in the 1948 budget. Even though the smaller instrument rooms originally requested as a part of the building in 1948 were obtained by enlargement of the Control Center as explained earlier, the need for a controlled-atmosphere shelter for the Doppler radars remained a real one. By the time of the preparation of the 1949 budget it was also realized that a model preparation and storage area for the Preflight Jet was needed. These two needs provided the justification required to obtain approval of the project in the 1949 budget.

The Doppler radars were found to be very temperamental and difficult to keep in operating condition. Unlike the SCR-584 radar which was housed in its own air-conditioned trailer, the Doppler radar was very much exposed to the weather in the launching area. Exposure to moist, salt air and blowing sand made it extremely difficult to maintain. Experience in storing the unit inside an improvised air-conditioned cubicle in the main shop building indicated that a vast improvement could be achieved.

The Instrumentation Laboratory was completed in February 1950 and may be seen in figure 87. It was located directly across the street from the main shop for easy access to the Preflight Jet. The building was 84 feet by 152 feet, and was divided equally between radar and Preflight Jet operations areas. It was about 30 feet high and was generally similar to the main shop in construction. Doyle and Russell constructed the building under contract NAw-5670, for a cost of $228,890.

In this period, the storage capacity for fuel oil on Wallops Island was expanded from 15,000 gallons to 75,000 gallons, by adding two 30,000-gallon steel tanks mounted above ground on concrete saddles, and surrounded by a concrete overflow dam. The two tanks supplemented the original five 3,000-gallon earth-covered tanks. The new installation was performed by Doyle and Russell as Project 827 under contract NAw-5650, approved July 19, 1948. The work was completed in September 1949 for a cost of $23,885, financed from general operating expense funds.

HELIUM GUN

Paul E. Purser, head of the General Aerodynamics branch of PARD, was continually on the lookout for ways of expediting the flight model programs. He spearheaded the E2 drag program and the E5

FIGURE 87. Aerial view of shop area in April 1950, showing new Instrumentation Laboratory and oil storage tanks.

control program, in which hundreds of models of each type were launched. When a piece of equipment capable of propelling small models to transonic speeds was declared surplus at the Langley Laboratory, Purser seized upon the opportunity of launching even greater numbers of drag models by moving the equipment to Wallops. He assigned David H. Michal the task of working out the details.

The equipment at Langley had been called the "Free-Flight Apparatus" and had consisted of a gun in which lightweight wooden models were propelled to transonic speeds by a charge of compressed helium. At Langley, the gun fired into a long cylindrical tank which had four windows with shadowgraph equipment that enabled making observations of the test models in flight. The 100-foot tank limited the test period to essentially a single speed in each test, and the difficulties encountered in the program were such that the project was cancelled in November 1949.

Purser and Michal proposed that the propulsion part of the apparatus and the shadowgraph units be moved to Wallops and located on the existing 400-foot launching ramp. The models would be launched in free flight just above the ramp, along which the four shadowgraph units would be mounted. The high-voltage equipment needed to provide the high-intensity spark for the shadowgraph was to be located in the Instrumentation Laboratory (ref. 1).

The proposal was approved by F. L. Thompson on January 5, 1950, and by NACA Headquarters on March 28, 1950, as project 999, for a cost not to exceed $5,300. The proposal sent to NACA Headquarters stated that initially the apparatus would be used only with Doppler radar tracking to provide velocity and drag data, as in the E2 program. Later, the apparatus would be located near the 400-foot ramp for supplementary shadowgraph studies. Actually, the apparatus worked out so well as a simple device to measure drag that it was never moved to the launching ramp.

The apparatus at Wallops was officially named the Helium Gun, but at times it was called the "popgun." In figure 88, it is shown mounted behind the Doppler radar. Operation and maintenance were assigned to technician Waldorf Roberson who, as an old artilleryman, was pleased that he now had a gun of his own to look after.

The Helium Gun consisted of an insulated steel storage tank 4.5 feet by 10 feet, which contained the heated and pressurized helium, a breech assembly, a quick-acting valve, and a 6-inch steel barrel 25 feet long. Michal calculated that when charged with helium at 200 pounds per square inch and a temperature of 500 degrees F, the gun would be able to propel a model and cradle weighing 2 pounds to a Mach number of 1.6. Such models would provide data at Reynolds Numbers comparable to those of the Ames 6-foot supersonic tunnel and would cover the transonic speed range as well. In figure 88, the gun is shown on a steel frame elevated for launching. Later, wheels were added to the lower bed, and the gun was towed to the air-conditioned storage area of the Instrumentation Laboratory when not in use.

The first firings from this gun at Wallops were made on August 2, 1950. The test models were supported within the barrel by a balsa sabot and were accelerated by pressure acting on a plywood pushplate. Some development was necessary before acceptable test results could be obtained, but by the end of the year the Helium Gun was in regular use at Wallops. Most of the models flown were simple bodies of revolution with stabilizing fins, but a few had small wings in addition, and some even carried small internal rocket motors to provide higher speeds. Before the gun was abandoned in 1959, over 400 test models were launched from it.

NEW ROCKET MOTORS

In June 1949, Langley personnel learned of a new rocket motor being developed by BuOrd Naval Ordnance Test Station (NOTS) under the designation HPAG (High Performance Air to Ground). NACA Headquarters attempted, without success, to obtain a supply of these motors. In April 1950, it

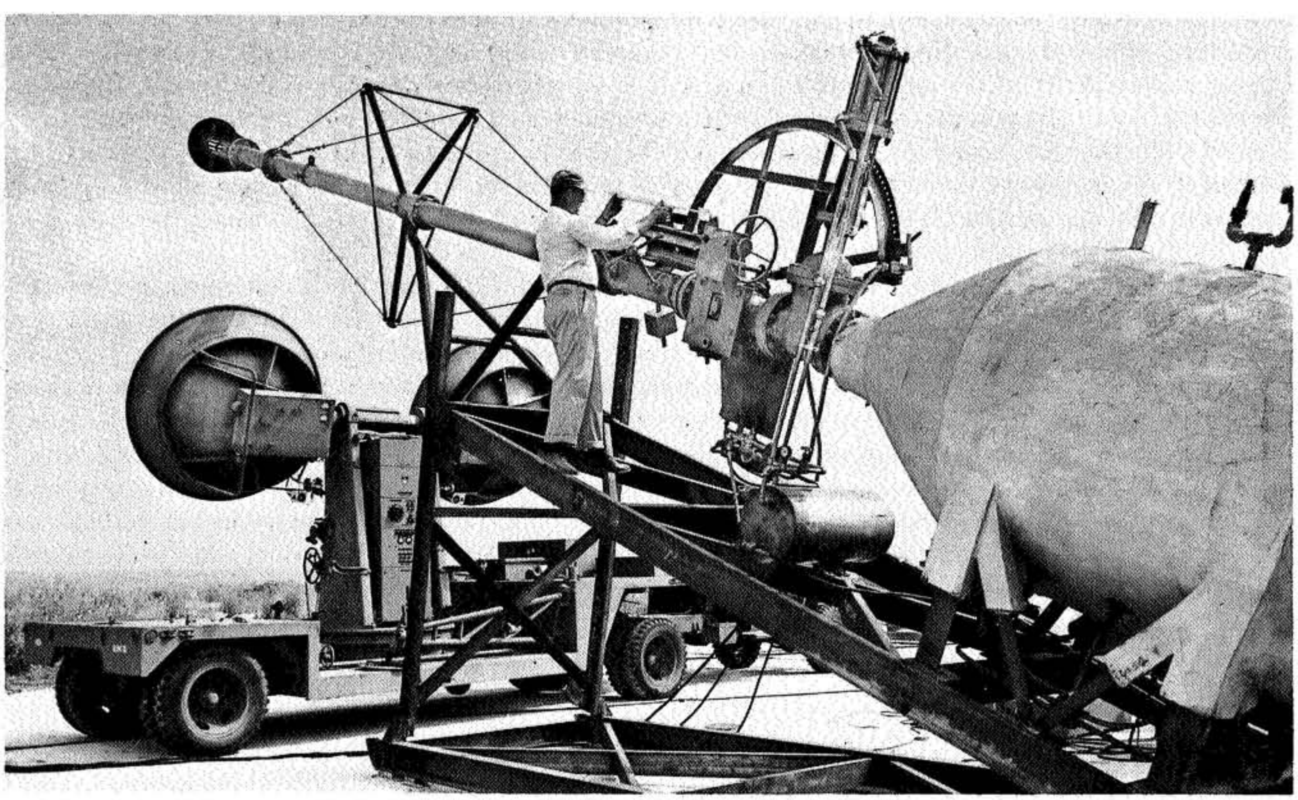


FIGURE 88. Wallops Helium Gun elevated for firing along axis of Doppler radar. Technician Waldorf Roberson inserts a test model in the opened breech, August 2, 1950.

was learned that difficulties with the propellant had caused NOTS to postpone placing the motor in production. Later, the propellant problem was overcome and the NACA was able to obtain some of the motors. They were not available in quantity at first, and the NACA had to furnish the metal cases and nozzles for those to be used at Wallops. The propellant grains were furnished by NOTS.

The HPAG rocket motor was smaller than the Deacon but had about the same efficiency. It used a double-base propellant with internal burning, as did the Deacon. It was 5 inches in diameter and 70 inches in length, and weighed 66 pounds, including 40 pounds of propellant. The thrust was 2,830 pounds for 2.7 seconds. This motor was used as either a booster or sustainer in various rocket model programs, as will be discussed later. The first flight test of an HPAG motor at Wallops was made on December 20, 1950.

The 5-inch HVAR motor was a standard booster motor for many small models at Wallops. As an interim measure to obtain a more powerful, yet inexpensive, booster for such models, a special motor was devised by the PARD rocket propulsion section under J. G. Thibodaux. Initially, a motor case from an HVAR motor was cut in half and welded to a full-length case to make a so-called "1-1/2" HVAR. The propellant grain was likewise modified. Later, new steel tubing was obtained, of the proper length to eliminate the welding operation; but the propellant was still made from standard HVAR grains. The motor was then called the 65-inch HVAR. It weighed 90 pounds with 37 pounds of propellant, and gave a thrust of 7,300 pounds for 1.0 second. This motor was used principally in the E5 control effectiveness program.

A high-performance motor of small diameter was needed to obtain higher speeds with such models as those used in the E7 airplane stability program. On July 13, 1948, Thibodaux visited NACA Headquarters and the Army Office of the Chief of Ordnance to discuss the possibility of developing two new motors that would contain the Thiokol-base propellant developed by California Institute of Technology (CIT) (ref. 2). Thibodaux had learned of the new propellant during a visit to CIT in June 1948. The motors desired were to be 4 inches in diameter and 55 inches in length. One was to produce 1,000 pounds thrust for 4 seconds, and the other, 2,000 pounds for 2 seconds. The longer burning motor was planned as an improved replacement for the Cordite motor. On September 21, 1948, Langley officially requested NACA Headquarters to ask the Army and CIT to develop these motors, with the NACA furnishing all metal parts. NACA Headquarters complied with Langley's request on October 12, 1948. On December 17, 1948, the Army agreed to have these motors developed, but by the Elkton, Maryland plant of Thiokol Corporation, under the technical guidance of the Ordnance Department instead of that of CIT. Development was finally undertaken by the Redstone Division of Thiokol at Huntsville, Alabama. These motors, the first polysulfide-propellant rocket motors to be developed for Wallops use, were officially designated T44 jato 5KS-900 and T45 jato 2KS-2000. The Army asked the NACA to transfer $24,990 to cover development and delivery of 30 motors of each kind.

Development of the T44 motor was completed in April 1950, and it was added to the Wallops inventory. The first flight test of a T44 motor was made at Wallops March 2, 1951. Continued difficulty with ignition of the higher thrust T45 motor finally resulted in its cancellation.

From the beginning, PARD had been unsuccessful in attempts to obtain liquid-fuel rocket engines for its propulsion needs. The inherently higher performance potential possessed by liquid fuels caused PARD to reevaluate the availability of such engines during this period. The most promising such motor of the size suitable for PARD use was the British Typhoon liquid-fuel rocket. Eight of the rockets were obtained through Navy BuOrd for evaluation purposes. The Typhoon rocket was 4 inches in diameter and 75 inches in length, and weighed 52 pounds, including 24 pounds of propellants. It developed 1,900 pounds of thrust for 2 seconds. The propellants were nitric acid and aniline. Static test firings of three of these motors were made in the new Rocket Test Cell at Wallops, as shown in figure 89. In one test, a propellant leak resulted in a fire that engulfed the entire test cell. No further attempts were made to adapt this motor to Wallops' needs.

SECURITY AND EXCLUSIVE FEDERAL JURISDICTION

One of the advantages of Wallops Island as a flight test station was its inaccessibility. The NACA controlled the southern boat channel, and Navy personnel guarded the boat dock at the northern end of

FIGURE 89. Propulsion technician Carl G. Baab readies British Typhoon liquid-rocket motor for firing. Rocket is shown in Wallops rocket test cell, June 6, 1951.

the island. In the beginning, the existence of the NACA station on the island was considered confidential, but soon afterward only the models of specific military airplanes and missiles were classified. All data obtained from the flight tests were classified, but the original test records were not because they could not be interpreted without the calibration data available only at Langley, where data reduction and analysis were conducted.

Security of classified models was maintained by restricting the assembly and launch areas and the Preflight Jet to employees having a need to be there, as well as providing appropriate clearance. In some cases, when more than one classified model was at the island, any manufacturer's representative would be restricted to the area in which his model alone was being prepared.

At the request of H. J. E. Reid, Langley Director, in July 1950, R. L. Krieger outlined the security situation as it existed on Wallops Island (ref. 3). No one was allowed to visit the island without prior approval and any visitor was limited to the areas covered by the approval. The Engineer-in-Charge took the responsibility for seeing that such visitors did not violate this approval. At night and on weekends, guards were on the island and any unauthorized person was challenged. In addition, all buildings were kept locked when not in use.

Contractors and contractor personnel were not allowed in restricted areas and their activities were under the constant surveillance of the Resident Engineer and his staff. Contractors were not allowed to bring anyone to the island on their boats without prior approval.

The overall security record at Wallops was very good from all standpoints: espionage, sabotage, and theft. On the night of March 22, 1952, however, the guards on the island were surprised by what appeared to be an invasion from the sea. At 1:30 a.m., a boat came ashore below the south camera station. It turned out to be a fishing trawler from Atlantic City, New Jersey, the *Captain Swann*, under the command of Captain Burt Whitaker. The crew had apparently mistaken the Wallops lights for the Chincoteague Inlet. The Coast Guard removed the crew at 4:45 a.m., but the boat was a total loss. A second unannounced visitor arrived by air on August 8, 1952. A light airplane used to spot schools of fish in nearby waters was caught in a rain squall and was forced to land on the beach. The pilot was able to take off in about 40 minutes without any trouble.[1]

In April 1950, the question arose in NACA Headquarters as to whether the NACA should obtain exclusive jurisdiction over Wallops Island from a criminal as well as a security standpoint. As pointed out by J. F. Victory, Executive Secretary of the NACA, with exclusive Federal jurisdiction, crimes involving injury to individuals or loss of private property on the island would be investigated by the FBI rather than by local police and would be tried in Federal courts rather than in local State courts. The principal advantage would be that there would be no question of having to permit local police to enter areas where highly classified material might be located.

H. J. E. Reid, Director of Langley, was of the opinion that such exclusive jurisdiction would not be desirable, and recommended to NACA Headquarters on May 11, 1950, that no action be taken; but he did ask Krieger to discuss the situation with local Eastern Shore authorities. On May 17, 1950, the local circuit judge, trial justice, Commonwealth Attorney, and sheriff, accompanied by the State senator, State delegate, and County treasurer, visited Wallops Island at the invitation of Krieger. The County and State officials said they had no objection to the NACA's seeking exclusive jurisdiction, but they pointed out that help would be available much more quickly from the sheriff's office than from the FBI. Also, in case of any trial involving Wallops employees as witnesses, a local court would be more accessible than the Federal court in Norfolk. The officials stated further that they would certainly cooperate in connection with any matter involving classified material. This meeting was helpful in cementing relations with local officials, and Krieger recommended to Reid that no further action be taken.

ATTEMPTS TO ESTABLISH A WEST COAST AERODYNAMIC TEST RANGE

The success of PARD with its rocket-model flight program at Wallops led other ranges to consider duplicating the system. Most of the ranges had SCR-584 or similar tracking radars and had procured Sperry Velocimeters cooperatively with the NACA; but the mission of these ranges was generally

1. Based on Daily Log on file at Wallops.

developmental flight testing of actual missiles as opposed to research with models. One exception to this was the Naval Air Missile Test Center (NAMTC) at Point Mugu, California.

In the early deliberations concerning location for the NACA missile station, it was felt that it would be desirable to locate such a station on a Navy range. When, in December 1944, the NACA heard that BuAer might locate a missile development station at Cherry Point, North Carolina, first consideration was given to locating the NACA range there. Soon afterward, however, the Navy decided on a Southern California location; and other considerations, as discussed earlier in Chapter 2, led to the selection of Wallops Island by the NACA. In March 1945, Captain H. B. Temple, USN, suggested that the NACA locate its base at the new naval missile station in California, later to be designated NAMTC. Dr. Hunsaker, Chairman of the NACA, replied that the NACA "preferred a site near the NACA Langley Field laboratory" (ref. 4).

The first missile was launched from NAMTC, Point Mugu, California, in January 1946. By 1950, the station had acquired some personnel with NACA research experience who persuaded BuAer to authorize the initiation of a new program entitled "Aerodynamic Free-Flight Testing." Two of the personnel involved were Robert S. Swanson, formerly a section head in the Langley Stability Research Division, and N. Mastrocola, a former employee of PARD. Mastrocola visited Langley on June 27, 1950, and informed PARD that NAMTC was planning to copy PARD techniques used at Wallops for missile testing. This was just a beginning of a series of visits to PARD by Mastrocola or Swanson to obtain details of all techniques used, including copies of drawings of typical systems. BuAer officially acknowledged the valuable assistance of PARD in this regard, in their request of August 7, 1950, for drawings of control-pulsing mechanisms.

The NAMTC program got off to a good start, and many articles were published describing the techniques that were to be used. As time went by, however, the promises failed of realization, and the aerodynamic test program was canceled. One phase of the program, tests of models of the Grumman Rigel missile was canceled in October 1953, and BuAer offered to give all of the models and related equipment to the NACA with no strings attached. The offer was accepted because of the unique control-pulsing system employed, but little use was made of it.

Soon after the NAMTC program was canceled, Dr. Allen E. Puckett of Hughes Aircraft Company recommended to the NACA that a facility similar to that at Wallops be established on the west coast.[2] The NACA replied that it would be improper for the NACA to duplicate the Wallops facility elsewhere.[3] Several proposals by the NACA Ames Laboratory at Moffett Field, California, to embark on a rocket-model program with launchings from NAMTC were rejected by the NACA for the same reason.

WALLOPS PHOTOGRAPHY AND THE HULCHER CAMERA

The need for good photographic coverage of rocket-model operations at Wallops was recognized from the beginning. Complete documentary pictures were even more important in its work, because, unlike the situation in wind-tunnel testing, the model was no longer available for examination after the test was over. In addition, events took place so rapidly during the test that high-speed photography was a necessity.

In the early days, photographers from the Langley Photographic Division were sent to Wallops for each flight operation; but by 1946 three photographers had been assigned to the PARD Operations Section, which was headed by Charles A. Hulcher. Of the three, John H. Rumer was stationed at Wallops, while the other two, Numa E. Thomas and Robert D. Collie, were stationed at Langley but traveled to Wallops during operations. Additional photographers, when needed, were still borrowed from the Langley photographic laboratory. On February 9, 1949, Donald S. Foster was transferred from Langley to Wallops to head the photographic unit there. His duty at Langley as a motion picture photographer had begun on September 29, 1941. After Foster's transfer, the need for Langley photographers at Wallops decreased, but Collie continued to travel there to assist with the tracking cameras during flight tests.

2. Letter from Dr. Allen E. Puckett, Hughes Aircraft Company, to Ira H. Abbott, Assistant Director, NACA, October 23, 1953, regarding establishment of a PARD-type facility on the west coast.
3. Letter from Ira H. Abbott to Dr. Allen E. Puckett, regarding duplication of Wallops facility on the west coast.

The processing of the exposed film was a major operation. All color film had to be sent to special processing centers, but all black and white film was processed either at Wallops or at Langley. Rolls of photographic paper were normally processed at Wallops. Black and white negatives of photographs from still cameras were numbered serially as a part of the Langley photographic system and were filed there. Prints of these photographs were usually made by Langley on demand. The 16-mm color motion picture film, after processing, was filed at PARD and used in the preparation of documentary film, as well as in analysis of rocket-model operation. All of the remaining film was considered as technical data and turned over to the engineer in charge of each project.

Approximately 2,000 feet of film were used in each major flight operation. The Doppler radar data were recorded on high-speed 35-mm motion picture film, and the telemeter data were recorded on rolls of wide photographic paper. The SCR-584 radar yielded 35-mm motion pictures from its bore-sighted top camera and from the cameras photographing the special data boxes. The spinsonde recorder also yielded film requiring processing. All of these records were in addition to the many motion picture, still, and sequence cameras used in the flight operation, particularly in tracking the models in flight. The Preflight Jet also turned out many rolls of oscillograph paper, shadowgraph film, and motion picture film requiring processing. The PARD Operations Section at Langley was charged with obtaining the needed equipment, such as cameras and special processing facilities, as well as serving as a control center for all the records coming to Langley from Wallops. This meant not only the ordering of available equipment but also the designing of special equipment not available on the market. One such item was a special piece of equipment for processing 1,000-foot rolls of 35-mm film. The equipment was devised by Hulcher and Thomas and constructed in the Langley shops.

Many still photographs of each model and any unique component were made at Langley prior to shipment to Wallops. At Wallops, photos were made of the model and booster on the launcher and during different stages of assembly. Still cameras were also used for such routine purposes as recording construction progress on new facilities, photographing special visitors, recording accident damages, and photographing any special research equipment or installation.

The most demanding photographic operation was tracking photography, i.e., the photographing of the rocket model and booster from the time just before launch to the end of the flight. The problem was severe because the rocket models were launched with high acceleration, normaly 10 to 50 times the acceleration of gravity, and the most vital period might be during the first second. Such photography was desirable for documentary purposes, but it was frequently the only source available for analysis of failures in flight. For example, after a particular failure, ground observers might report that a model exploded or simply went all to pieces. Corrective measures to prevent the same occurrence in the next test were difficult to take from only this evidence. Good tracking pictures, however, might show that the initial failure had been the result of flutter of a tail surface a fraction of a second before total disintegration.

The first tracking cameras used at Wallops were Eastman Kodak 16-mm Ciné Special cameras for color photography, and Mitchell 35-mm motion picture cameras loaded with black and white film. Later 16-mm Mitchell cameras were also used. Two cameras of each size were usually positioned in the launch area as a fixed point of photography. These motor-driven cameras were started and stopped by the automatic programmer in the Control Center. Two additional 16-mm cameras and one 35-mm camera were mounted on tripods a safe distance from the launch area and were operated by the tracking photographers in a "panning" movement during the flight. The photographer started the cameras at about minus 5 seconds in the countdown heard through the intercommunication system headset.

Successful operation of the tracking cameras was very much of an art. Quick reaction time on the part of the operator was essential, and the ability to anticipate events was even more valuable. After a successful tracking operation had been completed and the developed film was projected on a screen, the problem did not appear too difficult; but when it was realized that the projected images had been slowed by a factor of 4 or more, the real magnitude of the task was appreciated. Rumer and Collie usually operated the 16-mm cameras while Foster handled the larger cameras. The cameras were equipped with special optical sights, but it was said of Rumer that he swung the camera along the flight path more by instinct than by sight.

At first, the tracking cameras were mounted on standard tripods down the beach from the launch area. Later, the tripod head was mounted on a single pipe support and a bicycle handlebar type of control was added. This modification was the suggestion of Rumer who is shown in figure 90 operating one of these supports with a Mitchell 16-mm camera mounted on it. Sockets for the central pipe support were set in concrete in various locations in the area. Still later, the tracking cameras were located either on the roofs of buildings nearby or on the roofs of special camera stations. It was found that better pictures were possible when the camera was above the ground haze. (See figure 91).

In August 1954, two Mark 51 gun directors, obtained from NAOTS, were modified for use as mounts for tracking cameras. Several cameras were mounted side by side on the gun director, and a single operator could then handle several cameras at once. (See figure 92).

The 16-mm and 35-mm motion picture cameras provided excellent coverage of general flight operations; but in case of failures, larger images and better resolution were desired. The first attempt to obtain large pictures of launch events was made with Fairchild K24 aerial cameras of the type shown in figure 93. They were set up as fixed cameras in the launch area. The K24 took pictures 5 inches by 5 inches but was able to take only three sequence pictures per second. With the high acceleration of the models, events happened too quickly, and many more pictures were needed for failure analysis. This problem is illustrated by figure 94, which shows that only a single picture of the complete model was obtained after it left the launcher. The model acceleration in this case was 10 g.

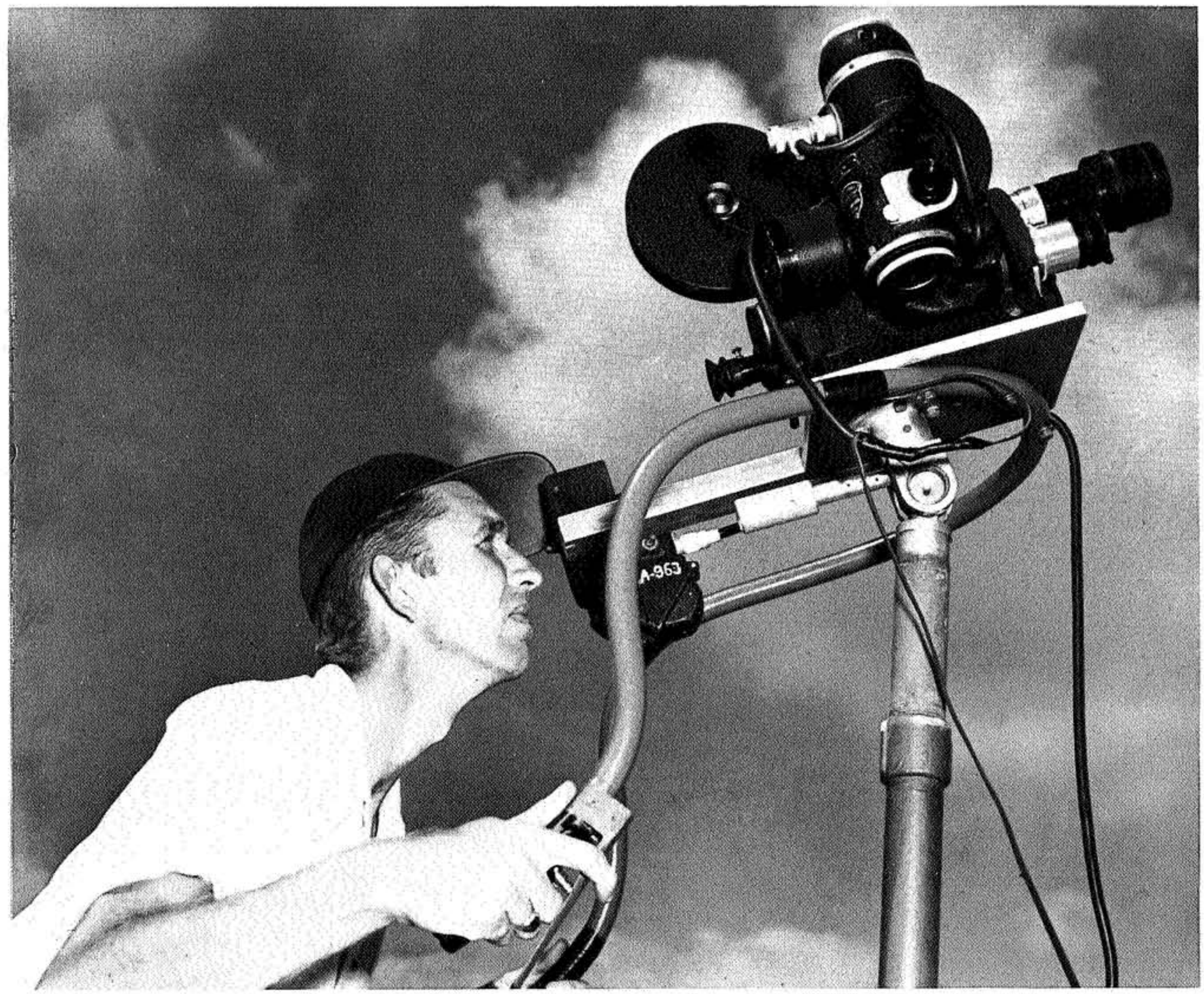


FIGURE 90. Photographer John Rumer operates Mitchell 16–mm motion-picture camera on special tracking mount at Wallops, July 1952.

FIGURE 91. South camera station, No. 2, with typical arrangement of tracking cameras for a flight operation.

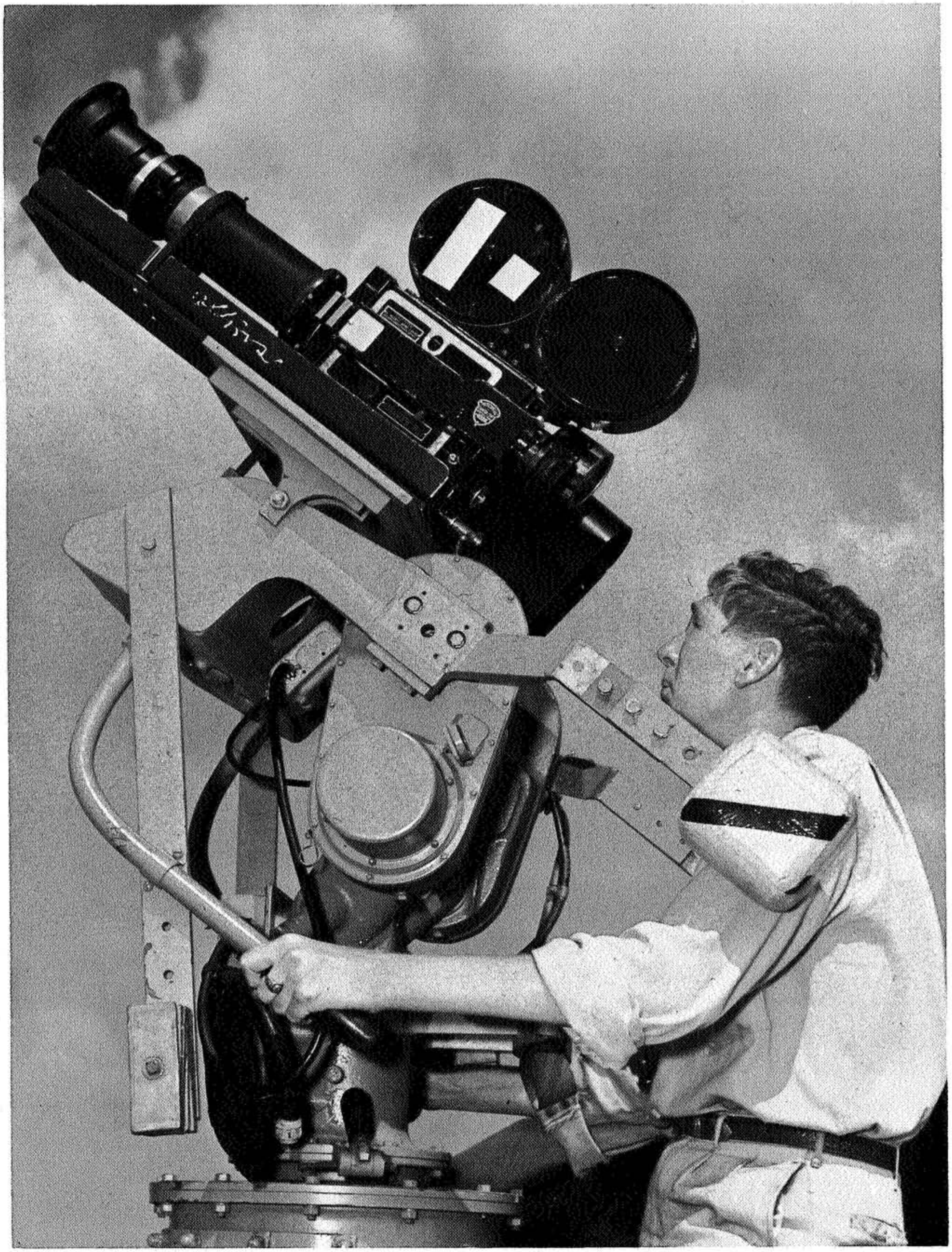


FIGURE 92. Photographer Donald S. Foster tracks a missile in flight, July 1952. A modified gun director serves as a tracking aid.

FIGURE 93. Photographer Robert D. Collie adjusts a Fairchild K24 sequence camera in launch area at Wallops.

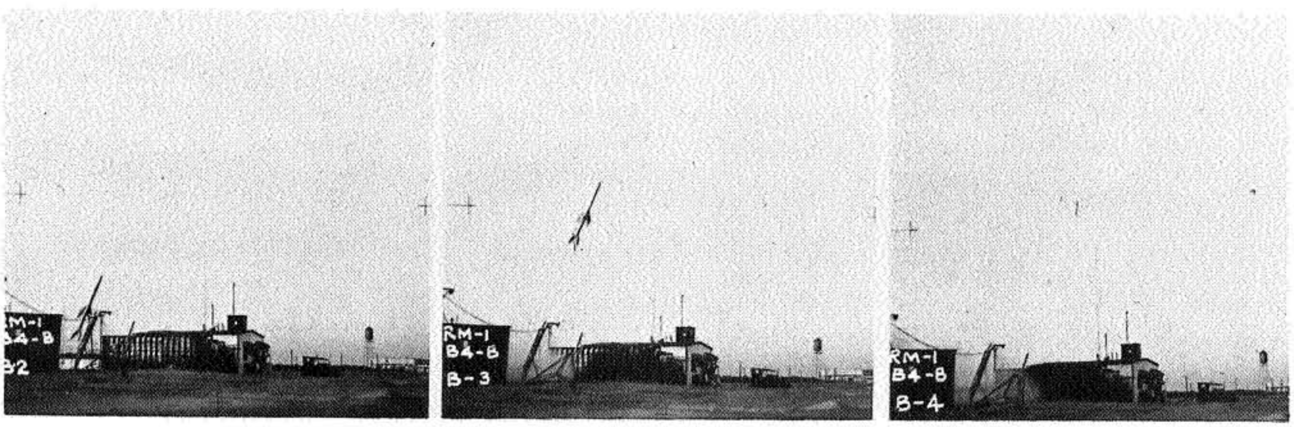


FIGURE 94. Launch of RM−1 missile, as photographed with fixed Fairchild K24 sequence camera (missile acceleration, 10 g; camera speed, three frames per second).

Realizing the need for a higher speed sequence camera of about this size, Hulcher, in January 1948, conceived a design for a new type of camera. His design, later to be known as the Hulcher camera, used the existing K24 camera lens and 70-mm motion picture film, with a capability for taking pictures 5 inches long at the rate of 17 per second. A simple modification allowed pictures 2.5 inches long to be taken at a rate of 35 pictures per second. Hulcher was assisted in the development of this camera by Numa E. Thomas. Drawings of such a camera were made at Langley in July 1948, and a prototype was constructed in the Langley shops in October 1948. Its first use in photographing a model in flight was at Wallops on January 20, 1949.

Figure 95 shows Don Foster using the first Hulcher camera as a tracking camera. Normally, the 2.5-inch pictures were taken when the camera was used for tracking, and the 5-inch pictures were taken when the camera was fixed near the launch area. When the camera was used for tracking, it was located farther from the launch area and longer focal-length lenses were used. (See figure 96.)

The sequence of pictures of a model in flight, shown in figure 97, was taken at Wallops with the first Hulcher camera in a fixed position. The acceleration of the model was approximately 40 g, and the camera speed was 17 frames per second. Fifteen pictures of the model were taken before it left the field of the camera. The first eight of these are shown in the figure. The resolution of pictures taken with the Hulcher camera was usually high enough to allow enlargement of model components at failure, to assist in establishing the cause of failure.

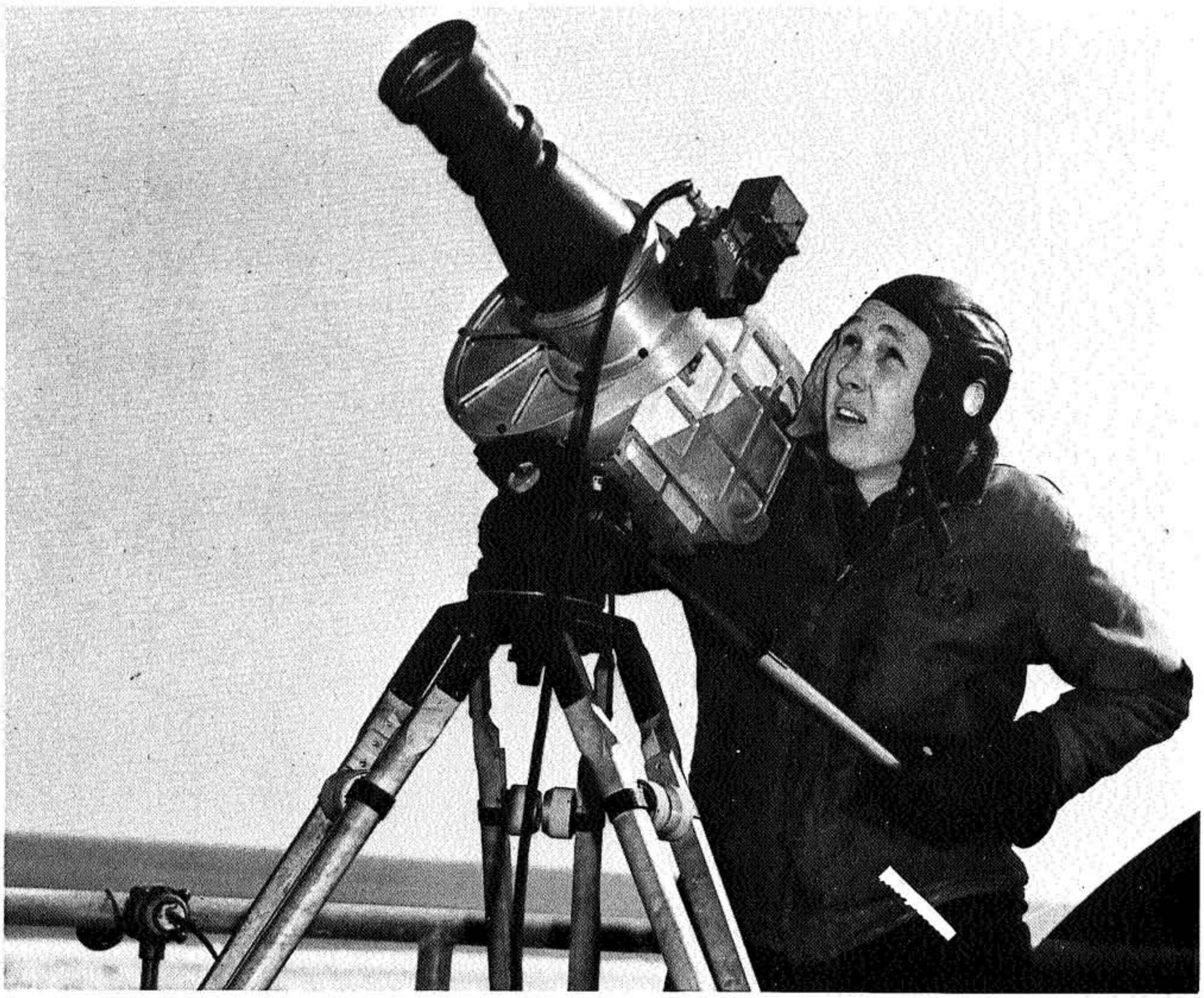


FIGURE 95. Photographer Donald S. Foster operates first Hulcher sequence camera at Wallops. Camera is shown mounted on tracking tripod.

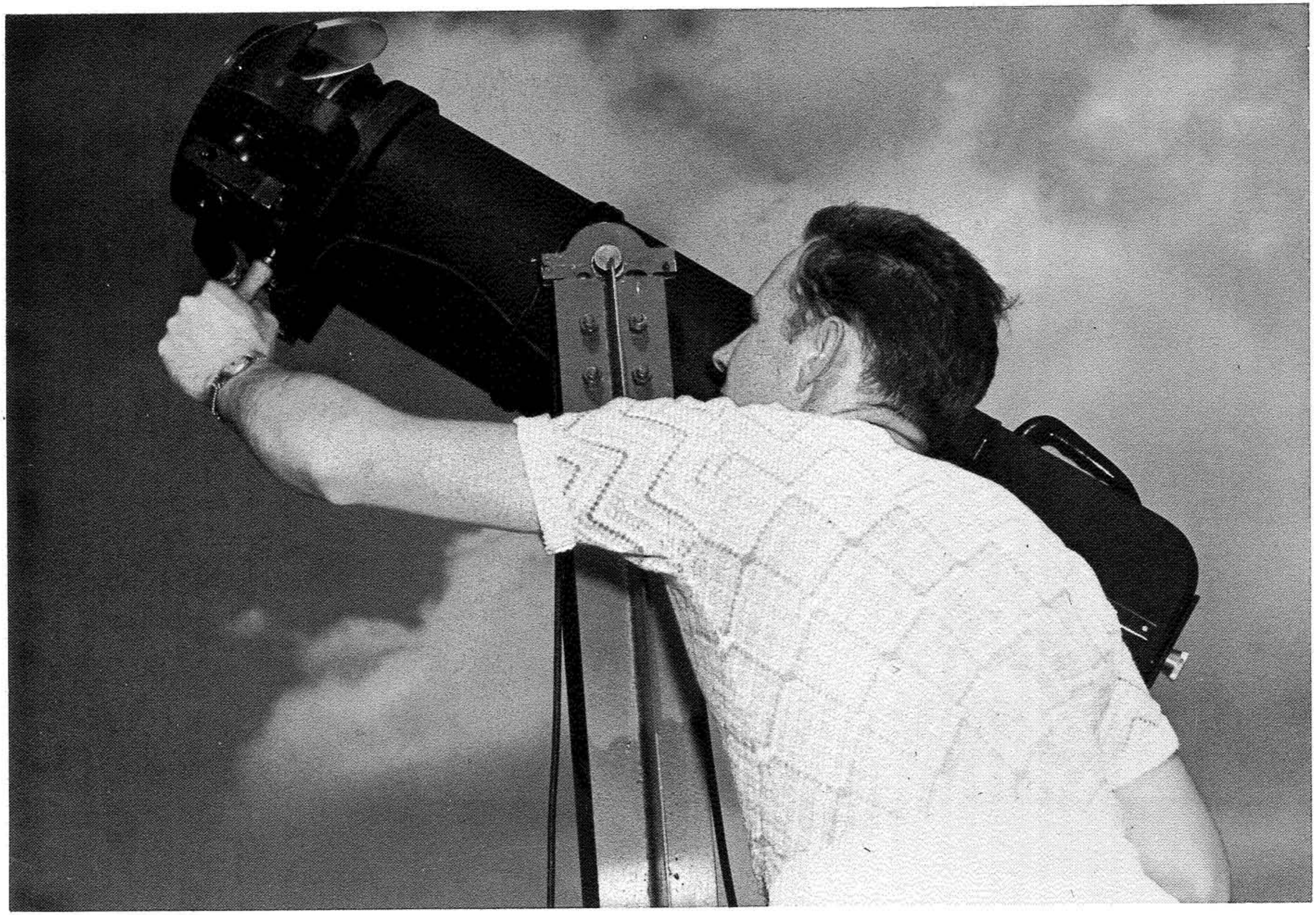


FIGURE 96. Photographer William Carr operates a Hulcher tracking camera with a 40-inch lens. Camera is shown on special mount.

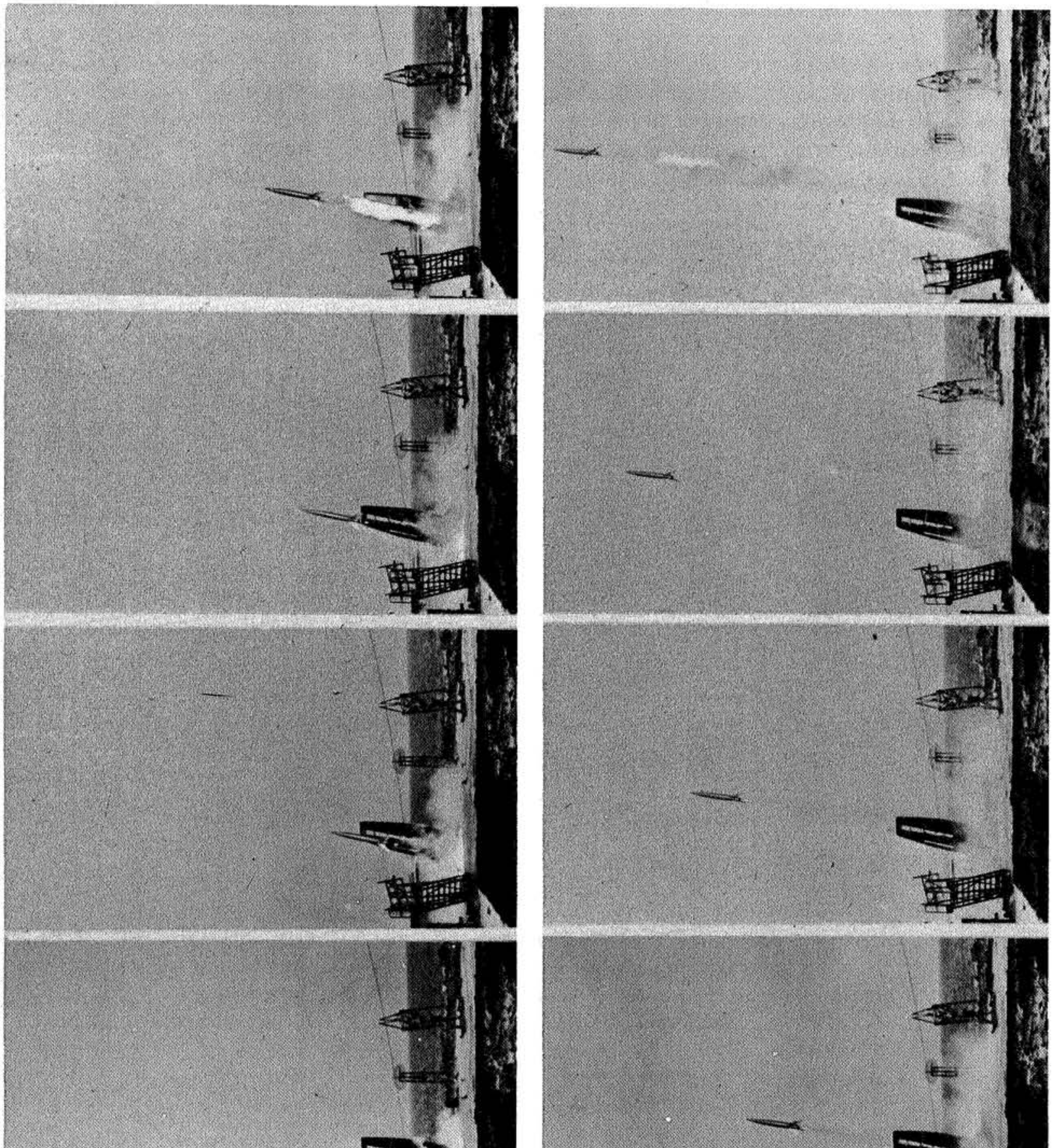


FIGURE 97. Launch of E17 body, as photographed with fixed Hulcher sequence camera (accelerations, 40 g; camera speed, 17 frames per second).

The Hulcher camera had two unique design features: the film transport mechanism and the shutter. The film was moved through the camera by a mechanism that provided continuous rotation, as opposed to the intermittent stopping and starting customary in most movie cameras. Of course, the portion of the film being exposed at a given time was stopped in front of the lens but the following film from the storage reel formed a slack loop during this time period. After exposure, the film was pulled past the pressure plate and the slack was taken up by the "beater" action of a rotating crank geared to the rotating shutter for synchronization. The camera utilized two shutters rotating in the same direction, one four times the speed of the other. This arrangement gave high motion-arresting ability and high shutter efficiency.

In October 1949, E. G. Crofut, an official of Aerolab Development Company who had seen the camera during a visit to Langley, wrote to Hulcher and made a proposal to manufacture the camera for commercial use under a royalty agreement. Hulcher declined the offer but did apply for a patent to protect the Government's interest. First, application for a patent was made through the usual NACA channel for such actions—the Office of Naval Research. When this action proved to be too slow, Hulcher, with NACA and ONR approval, employed private counsel in January 1950, to obtain a patent. On January 13, 1950, Hulcher's counsel advised him that the transport mechanism on which a patent was desired could not be patented because "prior art anticipated the structure disclosed." No further patent action was taken by either the NACA or Hulcher at this time.

After the experimental version of the camera had been used at Wallops for some time, the Langley Engineering Division was requested to design an improved version incorporating changes found desirable during the trial period. Hulcher was dissatisfied with the progress made by this design group and independently revised the design in his spare time, employing an outside contractor to construct the components which he then assembled. The first such new design of the camera was purchased by Langley for use at Wallops, and the design project underway at Langley for a different version was canceled. Hulcher had more of these cameras constructed, and started the development of a 35-mm camera of the same general type.

On March 15, 1954, Hulcher resigned from the NACA to devote full time to the camera business. Hulcher cameras were procured by all the missile ranges for tracking operations; and, in addition, many other applications were to be found. Among these were films of spectacular sports, and publicity photographs for newspapers, magazines, and advertising agencies. At Wallops, the cameras were used both as fixed cameras and as tracking cameras during a launch. They filled a void at the time and were to provide valuable photographic coverage at Wallops for the years ahead.

NAVY SPERRY-DOUGLAS SPARROW GUIDED MISSILE

The first supersonic air-to-air guided missile developed by the Navy Bureau of Aeronautics was the XAAM-N-2 Sparrow I. The program was established by former Langley researcher, Marvin Pitkin, after he transferred to BuAer on January 5, 1947. He had been the PARD project engineer on the RM-1 research missile and, later, a PARD section head. The Sparrow I was the first missile to be developed under the complete systems concept. For his efforts in this and other Navy guided missile programs, Pitkin received the Meritorious Civilian Service award from BuAer in 1955.

According to Pitkin, "We did indeed utilize Wallops to give us our early aerodynamic information in flight; and the Sparrow I program, in fact, incorporated a good deal of the lessons that we learned in the early Wallops programs, RM-1 et al."[4]

The Sparrow missile was to be the mainstay of the Navy—and later of the Air Force—for many years.

The Navy assigned highest priority to the Sparrow missile. Sperry Gyroscope Company was the prime contractor on Sparrow I and Douglas Aircraft Company was the subcontractor for the airframe. Most of the contacts at Langley with the manufacturer were with representatives of Douglas, since the Langley program involved airframe aerodynamics.

4. Letter from Marvin Pitkin, Navy Joint Surface Effect Ships Program Office, to Joseph A. Shortal, December 8, 1967.

One of the first contacts made by BuAer for outside assistance on the Sparrow missile was to propose an extensive test program at Wallops Island. By December 1947, the general plans for these tests had been completed. A series of 19 missiles was proposed for a study of roll-control and hinge-moment characteristics of the all-movable wings, and the effect of body shape on total drag. In an attempt to attain speeds of Mach 2, the Wallops models were designed to have an internally mounted Deacon rocket motor. This necessitated that the models actually be larger than the full-scale missile by a factor of 9 to 8. For example, the bodies of the models were 9 inches in diameter instead of the full-scale 8 inches. Model construction was the task of the Naval Aircraft Factory, Philadelphia, Pennsylvania. On December 31, 1947, Pitkin telephoned PARD chief, Gilruth, that BuAer was obtaining 20 Deacon rocket motors for use in this flight program.

BuAer officially requested the PARD program on April 1, 1948, and the NACA issued RA 1503 on May 10, 1948, to cover the work. (In 1951, this RA was changed to A22L44 under a new system.) Carl A. Sandahl was assigned as project engineer at the beginning. Later, he was joined by James R. Hall, who took over the project after it was underway. The project was designated E100 at PARD.

The first model was launched at Wallops on August 19, 1948. It is shown in figure 98 on the mobile launcher.

Eighteen of the nineteen models supplied by BuAer were flown: five in 1948, six in 1949, four in 1950, two in 1951, and one in 1952. The remaining model was returned to the Navy. Of the eighteen flown, twelve were successful. Of the six failures, four were structural and two were associated with the telemeter. In addition to the originally planned measurements of roll effectiveness, hinge moments, and drag, measurements of dynamic longitudinal stability and control were determined, with two of the models modified by the addition of control-pulsing mechanisms. In addition, one wingless model was diverted to the RM-10 skin friction program, as will be discussed later with that program. A small complete model was added to the program to determine damping-in-roll by the E14 technique. During 1948, two uninstrumented development models, constructed at Langley, were flown to solve early booster problems.

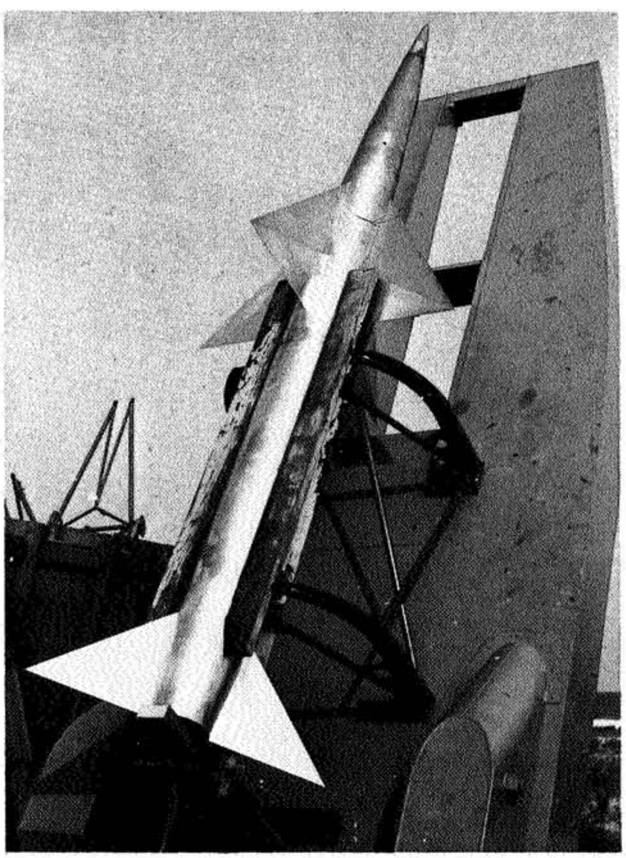


FIGURE 98. Model of Navy Sperry-Douglas Sparrow guided missile (9/8-scale) with internal Deacon rocket motor. Model is shown on launcher at Wallops.

The models supplied by BuAer were about 12 feet long and weighed 200 pounds without the sustainer rocket motor. They were flown first with only a Deacon sustainer motor, and reached a Mach number of 1.8 (See figure 98.) Later, an HVAR booster, as shown in figure 99, was added to increase the Mach to 2.2. In later tests in which a pulsing mechanism was added, the internal Deacon was replaced with a 65-inch HVAR motor, and a Deacon booster was used, as shown in figure 100.

As may be seen in the photographs, the Sparrow had an ogival nose followed by a cylindrical body that ended in a short boat-tailed section. Four fixed 45-degree delta fins were at the rear of the body. The missile had four 60-degree delta wings all-movable for lateral, longitudinal, and directional control. In operation, the missile was designed to have a continuous low roll rate and a special internal intelligence system that directed the proper wing settings for any required maneuver. The need for a roll stabilization system was thereby avoided.

Six models were flown successfully in the drag program. Two nose fineness ratios, two wing-thickness ratios, and wingless models were tested (ref. 5). The tests showed that increasing the fineness ratio of the nose from 5.0 to 6.25 reduced the drag about 10 percent. Increasing the wing-thickness ratio from 3 percent to 4 percent almost doubled the drag contribution of the wing. The remaining tests were made with the nose of 6.25 fineness ratio and the wings of 3-percent thickness.

One model was flown to determine lateral control effectiveness of the wings deflected differentially. Each of the four wings was set at 3 degrees to produce roll. The internal Deacon rocket motor was equipped with four small canted nozzles that provided a roll torque as well as a thrust. A four-channel telemeter transmitted measurements of rolling velocity, longitudinal acceleration, rocket-chamber pressure, and total pressure. Damping-in-roll was determined as in the D13 technique, and control effectiveness as in the E5 program. The additional small model flown sting-mounted to provide damping-in-roll as in the E14 program is shown in figure 101. Rolling effectiveness was found to be fairly constant in the transonic range and increased with a Mach number above 1.4. The small model

FIGURE 99. Sparrow guided missile model and HVAR booster mounted on launcher.

FIGURE 100. Sparrow guided missile model with Deacon booster. Project engineer James R. Hall measures elevation angle, November 2, 1950.

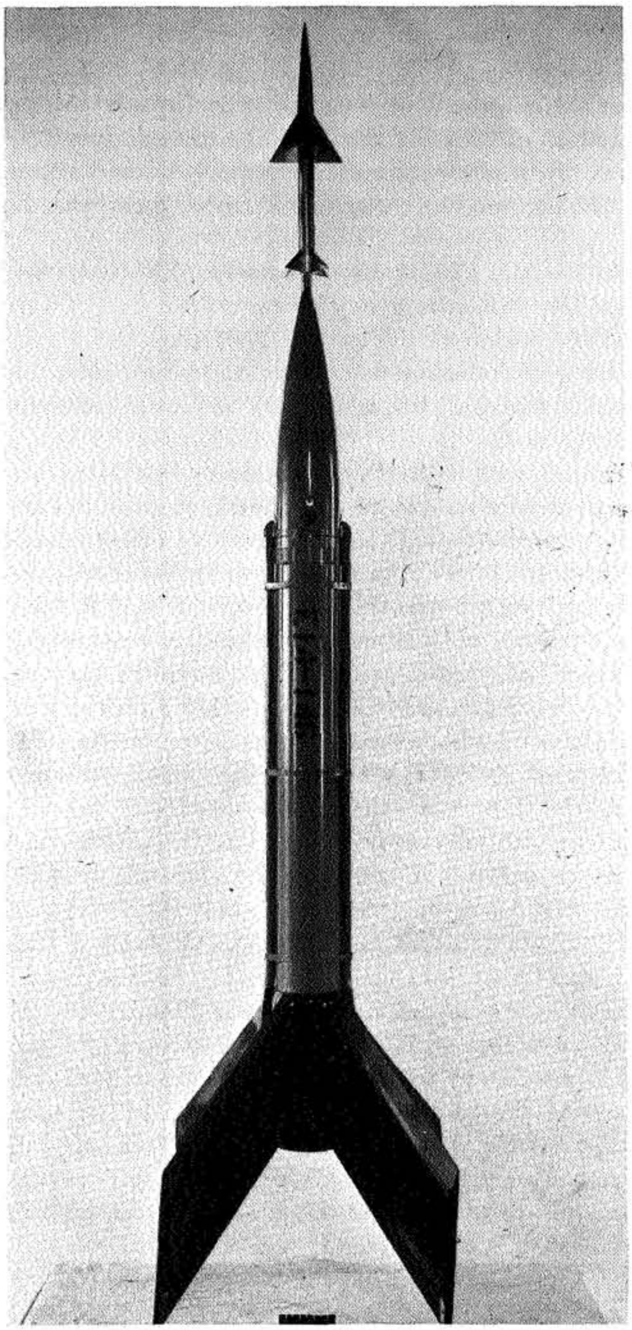


FIGURE 101. Model of Sparrow guided missile sting-mounted on E14 vehicle for damping-in-roll flight test, August 24, 1950.

gave higher damping-in-roll values than the large model—explainable by aeroelastic considerations. Aeroelasticity was found to decrease both the damping-in-roll and the rolling moment, but increased the total rolling effectiveness (ref. 6). Two of the large models with canted nozzles on the Deacon sustainer had to be flown to obtain the desired data. The first one unscrewed itself at a fuselage joint in flight.

Two models were flown to determine dynamic longitudinal stability characteristics. The first model had the tail surfaces interdigitated with respect to the wings (ref. 7), whereas the second model had the tails in line with the wings (ref. 8). A pneumatic mechanism was installed within the fuselage to pulse one set of wings together for longitudinal control. The resulting motions were analyzed as in the E15 technique. Eight-channel telemeters were used. These tests showed that because of a beneficial downwash effect, the control effectiveness of the deflected wings was magnified when the tails were in line with the wings. The stability was about equal with either tail arrangement. The in-line arrangement was the one adopted for the actual missile.

NORTHROP BOOJUM SUPERSONIC STRATEGIC MISSILE

In 1946, the Army Air Forces awarded contracts for development of three strategic missiles—long-range intercontinental weapons. Convair was awarded a contract for the MX-774 ballistic missile, a forerunner of the Atlas missile; North American was given a contract for a ramjet-powered supersonic missile, the MX-770 Navaho, later identified as SM-64; and Northrop was awarded a contract for the MX-775 turbojet-powered missile.

The MX-775 project was divided into two phases—the MX-775A subsonic Snark or SM-62 missile, and the MX-775B, a supersonic version called Boojum. The Boojum never got beyond the study phase, but early in the study, Northrop recognized the need for rocket-model tests at Wallops.

The Boojum was essentially a tailless airplane with a 67.5-degree delta wing of 45-foot span and 4-percent thickness. Two fuselage sizes were considered in the study phase: one, 77 feet long, called the small body, and the other, 100 feet long, called the large body.

A series of nine 1/14-scale rocket models were planned, with model construction by Northrop, and instrumentation and testing by PARD at Wallops. A two-channel telemeter measured longitudinal and normal accelerations. The program covered basic drag measurements and roll-control effectiveness. The models were boosted to a Mach number of 1.8 with a single Deacon rocket booster. In figure 102, one of the models is shown with its booster on the mobile launcher. The first launch was on May 8, 1950.

Of the nine models flown, good data were obtained from five. In one case, the booster remained in the way after separation and interfered with the Doppler radar signal, while with a second model the booster fired prematurely by accident and no records were obtained. The two other failures were caused by structural divergence of the first design of the model-booster coupling. Nevertheless, all of the objectives were reached with the remaining models. (See references 9 and 10 for a presentation of the test results.)

This missile was very beautiful from an aerodynamic standpoint and had very low drag, with either the small or large fuselage, as shown by the drag results presented in figure 103. The transonic drag rise did not begin until a Mach number of 0.98 was reached with the small body, and the total drag coefficient was close to 0.010 throughout the speed range covered. This was a result of the body of high fineness ratio, and the thin wing.

The rolling effectiveness of the trailing-edge controls was found to be positive throughout the speed range. A condition of dynamic instability was encountered with the rolling model in flight as it slowed to subsonic speeds, which was not a fault of the design but resulted rather from the conditions of the model test. As the model slowed to subsonic speeds, the rate of roll induced by the deflected controls finally equaled the natural frequency of the model in the yaw plane. This resulted in a coupling between roll and yaw, and caused an instability of the type explained by Phillips in NACA TN 1627.

Although this missile was intended as a supersonic follow-on to the Snark, it was never completed because it, too, was to be replaced by ballistic missiles.

AIR FORCE REPUBLIC XF–91 AIRPLANE

The results of preliminary rocket-model tests of the Air Force Republic XF-91 airplane with a vee tail have been discussed in Chapter 4. Additional tests were made after the design was changed to a conventional tail arrangement. The tests were made with one fixed-control 1/9-scale model, weighing 38 pounds and propelled to Mach 1.04 with a single 3.25-inch internal rocket motor, and two 1/6.67-scale models with pulsed controls, weighing 160 pounds, and propelled to Mach 1.2 by a Deacon booster. Tests of rolling effectiveness of the ailerons on this unique inverse-taper wing were also made with simple E5 models. Figure 104 shows one of the larger complete models with its Deacon booster on a crutch launcher.

With the large models, the horizontal tail was pulsed in a square-wave pattern to allow evaluation of dynamic and static longitudinal stability and control. The two models had different tail settings to cover a wide angle of attack range. The small model contained a two-channel telemeter to transmit measurements of longitudinal and normal accelerations. The larger models contained six-channel

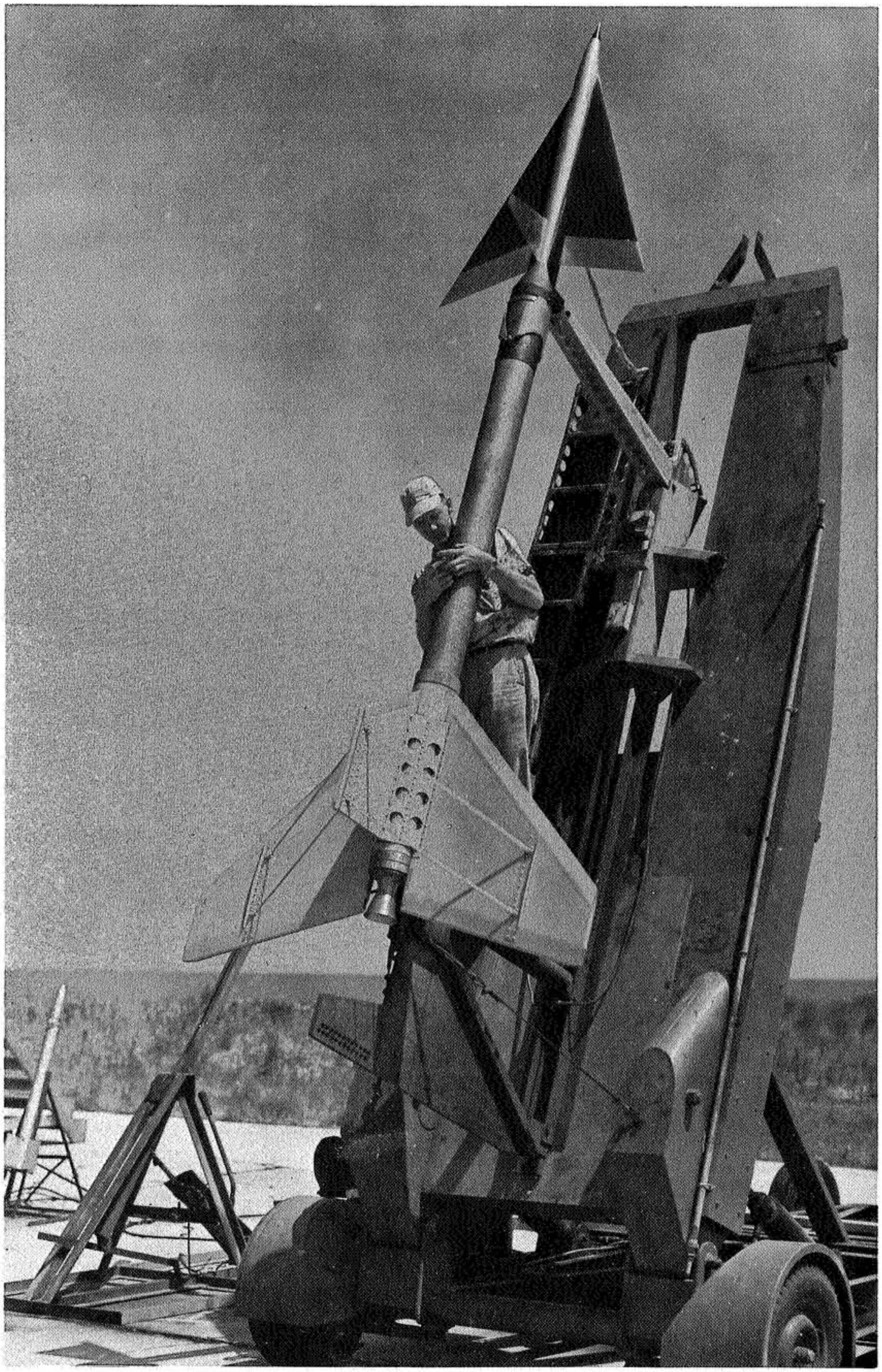


FIGURE 102. Model of Northrop Boojum MX–775B supersonic strategic missile shown with Deacon booster on launcher at Wallops, August 2, 1951. Technician Durwood A. Dereng measures elevation angle.

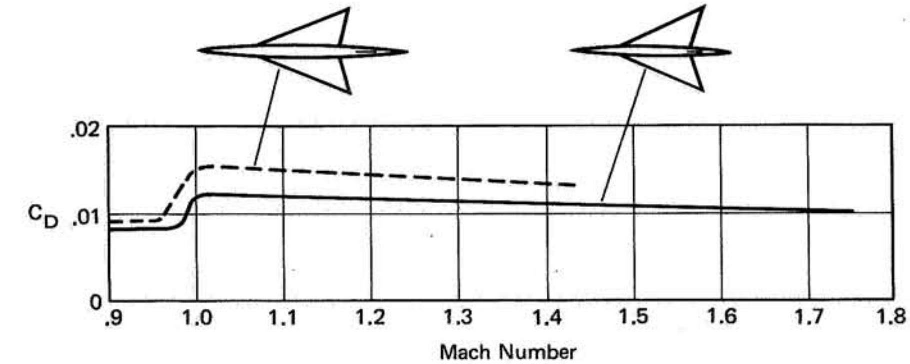


FIGURE 103. Wallops rocket-model test results showing drag coefficients for two body sizes of Northrop Boojum guided missile.

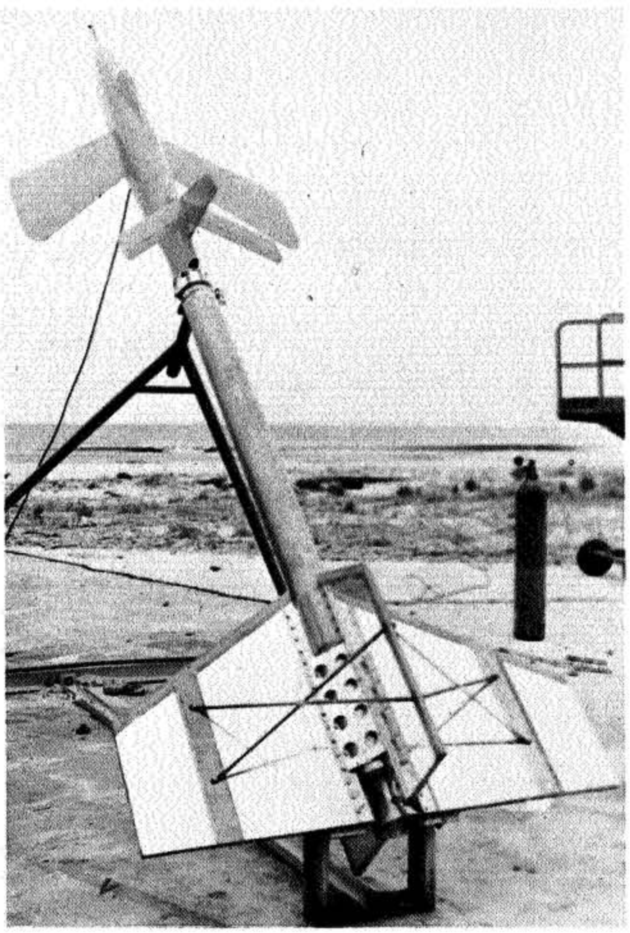


FIGURE 104. Model of Republic XF–91 airplane, shown with Deacon booster on crutch launcher, March 28, 1949.

telemeters to provide data on longitudinal and normal accelerations, control position, angle of attack, and static pressure.

The tests showed that the conventional tail had much higher drag than the original vee tail; but with either tail, only a slight trim change was encountered at transonic speeds. The conventional tail provided control over the speed range, and the dynamic stability was good although indications were that damping at high altitudes might be lower than desirable. Buffeting at high lift coefficients was encountered at transonic speeds (ref. 11).

The lateral control tests indicated that aileron effectiveness varied smoothly over the speed range, with only a slight discontinuity at a Mach number of 0.95. The effectiveness decreased in a normal manner in the supersonic speed range (ref. 12).

ROCKET MODELS OF BELL X–2 RESEARCH AIRPLANE

The Army Air Forces contracted with Bell Aircraft Corporation on December 14, 1945, to construct the X-2 research airplane for NACA evaluation. It was initially called XS-2. This was considered the most effective way to introduce the Jones swept-wing theory into the research airplane program. The X-2 airplane was heavier than the X-1, had higher thrust rocket engines, and was designed for a speed of Mach 2.

The NACA Stability and Control Subcommittee recommended, at its meeting on July 11, 1946, that rocket models of the X-2 airplane be flown to investigate dynamic stability and control characteristics. On August 15, 1946, the NACA approved RA 1434 to cover the investigation. The models used in the program were supplied by Langley, and several attempts were made before successful flights were achieved.

A new rocket-model program was initiated with four all-metal models. The wings were of steel and the fuselage, aluminum and magnesium. The fuselage was made from a standard PARD D3 general research model body adapted to the X-2 design by the addition of a pilot's canopy and several fairings. The wing had 40-degree sweepback and 10-percent circular-arc sections. The models weighed 160 pounds and were propelled to a Mach number of 1.36 by single Deacon boosters. Charles T. D'Aiutolo was project engineer in this new X-2 program.

The first model of this series was flown on May 12, 1950. It is shown in figure 105 with its Deacon booster and crutch launcher. For this model, a new booster fin with vertical endplates was developed by D'Aiutolo. In the test, the dynamic longitudinal stability characteristics were determined from evaluation of motions following disturbances from small pulse rockets (ref. 13). The model contained a six-channel telemeter to transmit measurements of normal, longitudinal, and transverse accelerations, angle of attack, and total and static pressure.

In the tests, it was found that the drag coefficient increased from 0.015 at subsonic speeds to 0.065 at supersonic speeds. A large abrupt nose-up change in trim occurred just below Mach 1.0. The overall damping-in-pitch was satisfactory except for a low-amplitude high-frequency oscillation (80 cycles per second) which was found throughout the speed range. In addition, a low-amplitude "snaking" oscillation in yaw was found, although the directional stability was high.

Two other models, equipped with pulsed controls, were flown in July 1951 and January 1952. In these tests, a double Deacon booster was used, as shown in figure 106, in an attempt to reach higher speeds. The flights were unsuccessful because of booster failure shortly after launch. This ended the attempt to adapt a double Deacon booster to the X-2 models.

The fourth and last model of this series was equipped with a pulsed rudder to disturb the model in the directional plane and thereby allow an evaluation of lateral stability. A 12-channel telemeter was used to measure normal, longitudinal, and transverse accelerations near the center of gravity, and normal and transverse accelerations in the nose of the model. Normal accelerations of each wing tip were also measured, as were angular acceleration in roll, angle of attack, angle of sideslip, total pressure, and rudder position. The single Deacon booster used successfully in the first flight was employed. This flight took place on December 2, 1953, and was successful. The model weighed 190 pounds and reached a Mach number of 1.18 (ref. 14).

The time-vector method was used in the analysis of the data and was found to be a satisfactory procedure for flight analysis of lateral stability. The basic lateral stability characteristics were evaluated and found to be about as expected from calculations and previous wind-tunnel tests. In addition, high-frequency oscillations in pitch and yaw were encountered with this model and were believed to be associated with some type of buffeting or nondestructive flutter.

JETTISONABLE-NOSE PILOT-ESCAPE SYSTEM

The problem of providing a means for safe escape from high-speed airplanes in flight was of continual concern to the Navy and the Army Air Forces. The conventional procedure of pilot ejection was considered too hazardous at speeds in excess of 550 miles per hour. With the advent of the high-speed

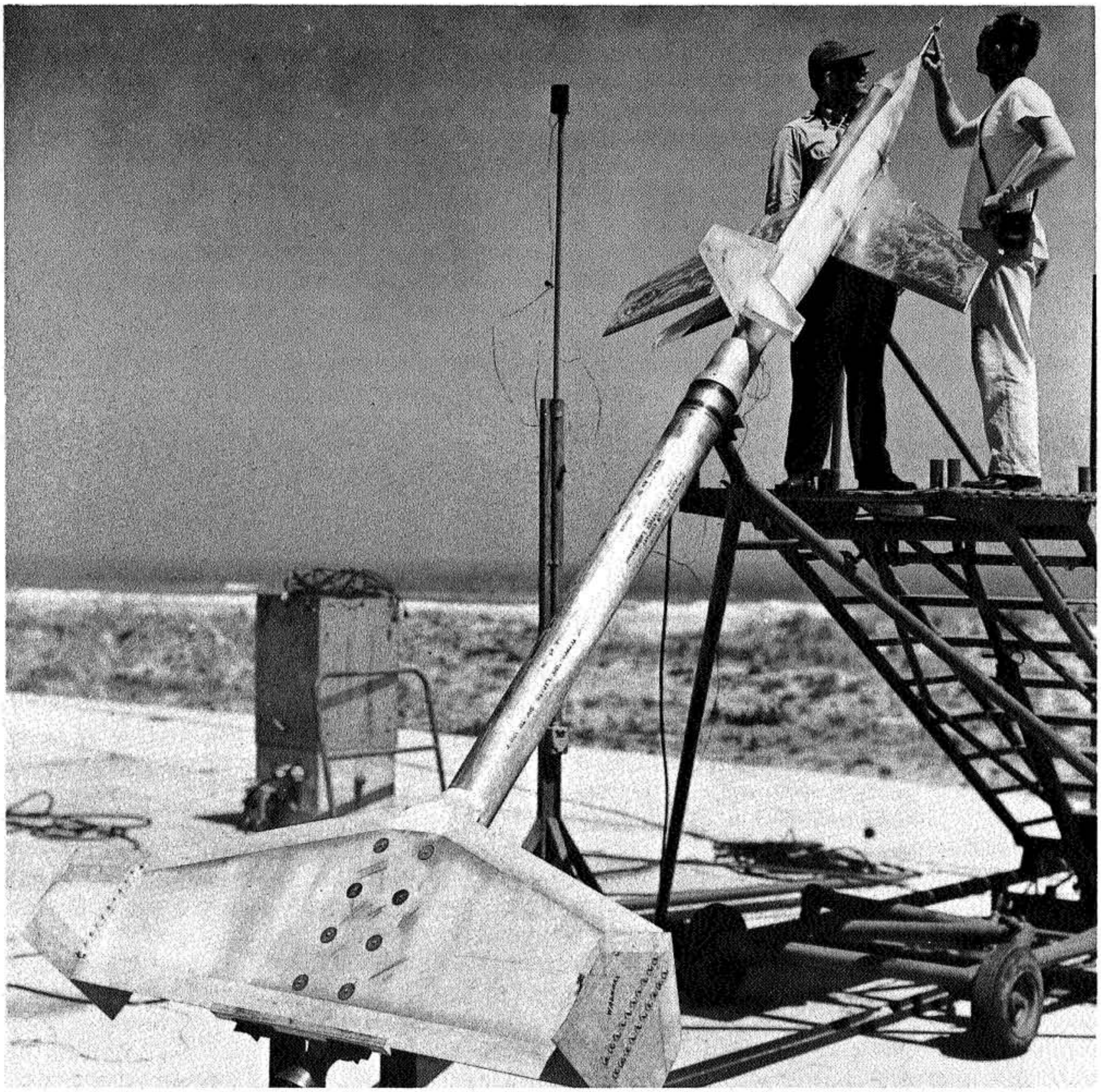


FIGURE 105. Model of Bell X–2 research airplane with Deacon booster on crutch launcher. Project engineer C. T. D'Aiutolo, at left, and technician Thomas Bigger inspect angle-of-attack instrument, May 12, 1950.

research airplanes, both military services were considering unconventional methods of escape, for example, jettisoning of the complete nose of the airplane, including the pilot's compartment. Various programs were instituted for both the Army's Bell X-2 and the Navy's Douglas D-558-II research airplanes. In separate letters, BuAer, on July 16, 1947, and AAF, on August 29, 1947, requested the NACA to assist in development of suitable methods for pilot escape from high-speed aircraft in case of an emergency.

On September 11, 1947, the NACA issued RA 1475, which authorized tests of rocket-models of high-speed aircraft equipped with jettisonable portions simulating the pilot's enclosure.

The need for an improved method of pilot escape under emergency conditions was clearly shown on May 3, 1948, when Howard C. Lilly was killed in an accident occurring during the takeoff run of a D-558-I research airplane. He was the first NACA test pilot to be killed in line of duty. That the problem was to remain a real one as late as 1956 was shown by the death of Captain M. G. Apt in a crash following his recordbreaking Mach 3 flight in the X-2 research airplane.

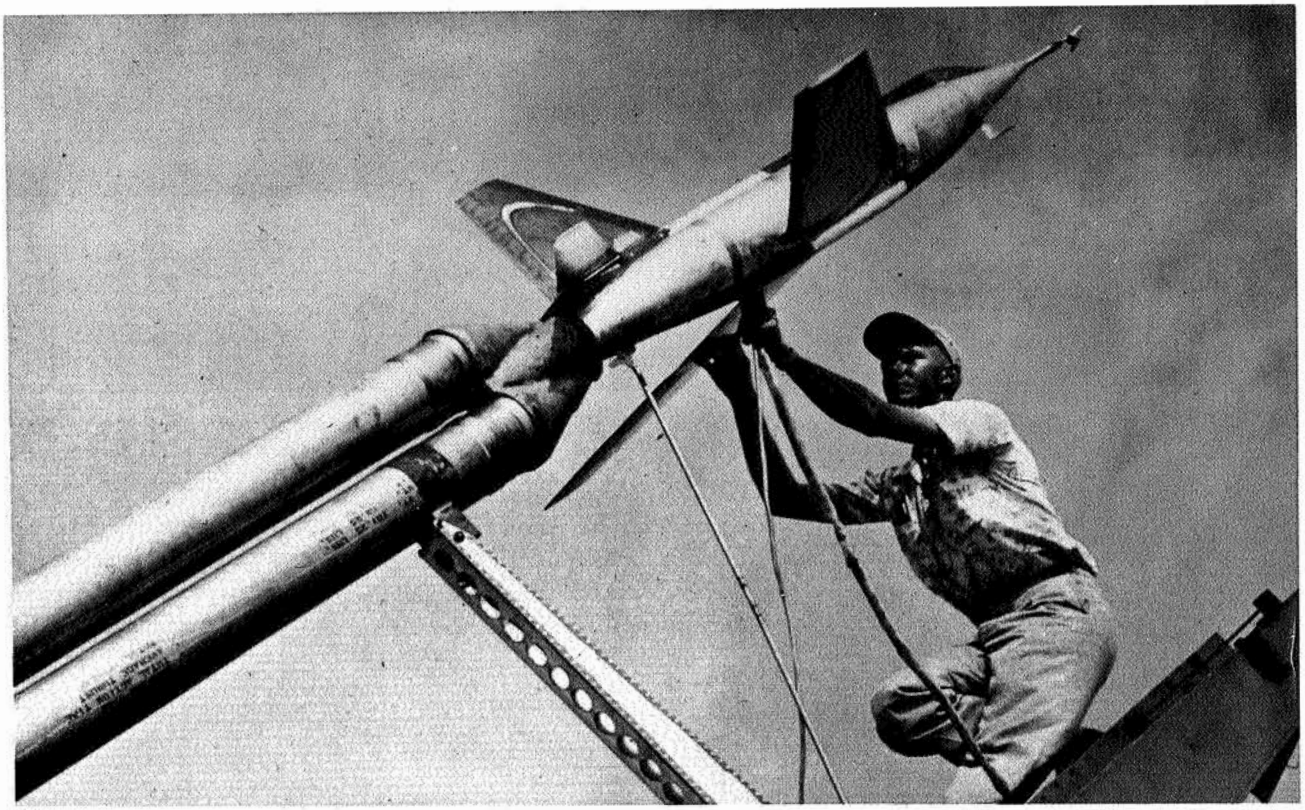


FIGURE 106. Technician Durwood Dereng prepares to remove external power plug from model of X–2 research airplane shown on launcher with double Deacon booster, July 18, 1951.

Various proposals had been made and studied at low speeds for jettisoning portions of the nose of both the D-558 and X-2 airplanes. The problem of safety after detachment was one of assuring safe separation of the pilot's compartment from the remainder of the airplane, and then of assuring safe deceleration of the jettisoned nose. This latter problem necessitated the addition of fins to stabilize the nose and prevent hazardous tumbling and rolling motions. Unfortunately, such fins would affect the characteristics of the complete airplane if they were exposed and would need to be extended quite rapidly if kept in a retracted condition during normal flight. A drogue parachute was found to be effective in stabilizing the nose capsule, but it could not be used during the critical period immediately after separation because of contact with the airplane. These same problems were to be found later with the Mercury capsule in NASA's first manned satellite program.

The rocket-model program at Wallops (RM-11 or D11) was quite brief. Two models were flown, one of which is shown in figure 107. The basic body was similar to those used in the earlier FR-1 flutter program, with propulsion provided by an internal Aerojet 12AS1000 rocket motor. The nose capsule, shown in the figure slightly separated from the main body, was equipped with a powder charge that forcibly separated it from the body upon command. In flight, this was accomplished soon after burnout of the main motor at a Mach number of 0.87.

The nose portion in general simulated either the D-558 or X-2 nose. Stabilizing fins were selected from tests of the capsule in the Langley Spin Tunnel. The nose weighed 41 pounds and contained a four-channel telemeter which transmitted data from accelerometers. These measured normal, transverse, and longitudinal accelerations of the nose and longitudinal acceleration of the rear body until separation distance exceeded the 15-foot length of a trailing wire. Motions of the capsule and separation distances were computed from these readings.

The rocket model tests at a Mach number of 0.87 indicated that the jettisonable nose system of pilot escape could be a safe system provided certain requirements were met. Stability of the nose had to be maintained at all times to prevent dangerous motions, and the separation system must have sufficient energy to ensure separation of a distance equal to at least several body diameters, because of the

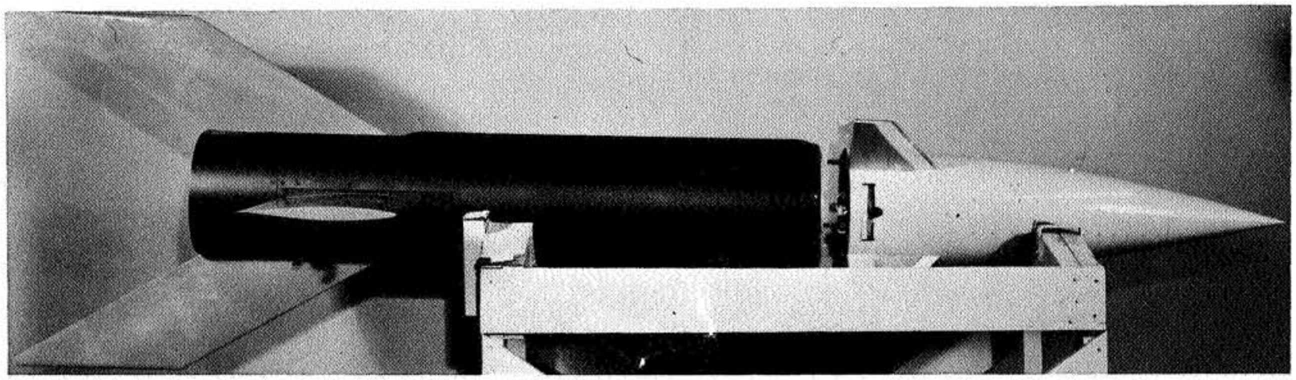


FIGURE 107. View of RM-11 pilot-escape nose capsule in slightly separated position on test vehicle, August 5, 1948.

shielding effect of the separated nose on the drag of the following body. In addition, the ratio of drag to weight must be lower for the nose than for the remaining body (ref. 15).

In view of the straightforward solution to the escape problem, no additional flight investigation appeared to be required at that time. The application of the principles to particular airplane designs, however, was always accompanied by considerations of effect on the mission of the basic airplane as well as those of added cost and weight.

LANGLEY RAMJET RESEARCH PROGRAM: F23

At the time Langley Laboratory began concentrated research on the problems of supersonic flight, the ramjet engine was a strong contender for adoption as a means of propulsion. Theoretically, it combined some of the simplicity of the solid-rocket motor with the high specific impulse of the turbojet engine. The specific impulse of 1,000, compared with only 200 for a solid rocket was very appealing. Unfortunately, there were no supersonic ramjets available, and a considerable engine-research program was required. Several manufacturers selected ramjet engines for propulsion of their proposed supersonic guided missiles and were likewise involved in ramjet development. Within the NACA, a cooperative program was undertaken by the Langley and Lewis laboratories. The initial phase of the Lewis air-launched ramjet research program at Wallops has already been described (see Chapter 6).

On June 30, 1944, the Bureau of Aeronautics requested the NACA to initiate an extensive research program leading to the development of ramjet engines for supersonic flight. Langley's reply to this request led to resumption of tests of the thin-plate Sherman burner in a ramjet engine in the new Langley Internal Aerodynamics Laboratory. On March 31, 1945, the NACA issued RA 1340 to cover the program. Unfortunately, the IAL program was limited to subsonic speeds (ref. 16). Supersonic research in a ground-based facility could not be conducted until the Preflight Jet was completed at Wallops in 1948. As was mentioned earlier, the chief use of this facility was indeed for ramjet research for the first several years. RA 1340 was used for the ramjet program at Wallops even though such usage was not specifically authorized. This usage was in line with the philosophy of keeping the number of RA's to a minimum.

The ramjet-powered supersonic airplane and missile configurations proposed at Langley by M. C. Ellis and C. E. Brown, with the backing of John Stack, envisioned a single large engine located within the fuselage. The Lewis program continued with this general concept, and its flight program was centered around a single 16-inch-diameter engine.

The superiority of mounting the engines in the wing or tail surfaces, leaving the fuselage available for fuel and payload, was indicated in an analysis by Langley PARD researchers Paul R. Hill and A. A. Gammal in 1947 (ref. 17). Gilruth had persuaded Hill to transfer to PARD in 1946 to take charge of ramjet research there after Hill had demonstrated competence in the aerodynamics and thermodynamics of ramjet engines by an analysis made while he was in the Physical Research Division at Langley (ref. 18).

In anticipation of developing a flight vehicle at PARD incorporating a ramjet in the horizontal tail, M. A. Faget made a flight test in 1947 on a model of a possible arrangement of such a system. In this case, the horizontal tail was constructed as a ducted airfoil with airflow throughout its span. The model, designated RJ-4 or F24, weighed 107 pounds and was propelled to a Mach number of 1.45 by two Cordite rocket motors, one mounted internally and one used as a booster. A six-channel telemeter was used. A high diffuser efficiency was measured but there were considerable pressure losses behind the central island following the diffuser wedge (ref. 19).

The configuration decided upon at Langley for PARD flight tests of operating ramjet engines differed from the F24 model in that the ramjet engines, while still in the horizontal tail, were two separate circular nacelles, 6.6 inches in diameter. This flight program was designated F23. The fuselage, containing fuel and payload, was 8 inches in diameter and nearly 16 feet in length. Inasmuch as the ramjet engine was designed for supersonic flight speeds, a booster was necessary to provide such speeds before the engines were started. For the F23 ramjet vehicle, a double Deacon booster was selected. In figure 108, the first successful vehicle and its booster are shown on the mobile launcher. It was flown at Wallops on March 24, 1950. Actually, this was the second F23 vehicle launched; the first one failed after the booster fins broke off during launching on November 16, 1949.

The March 1950 test set speed and altitude records for ramjet propulsion. The double Deacon booster propelled the 246-pound vehicle to a Mach number of 1.89. The twin ramjet engines were ignited just before burnout of the booster at Mach 1.50 and, after booster separation, the ramjets accelerated the vehicle to a Mach number of 3.02 and continued to operate to an altitude of 40,900 feet. At this point, the 25 pounds of ethylene fuel, initially loaded at a pressure of 1,200 pounds per square inch, had been exhausted. The vehicle, which had been launched at an elevation of 45 degrees, coasted after engine burnout to an altitude of 56,340 feet and splashed in the ocean at a range of 36 miles. The vehicle was instrumented with a six-channel telemeter which measured longitudinal acceleration, static pressure at several points in the ramjet engine wall, and total pressure. The total-pressure channel was also used to indicate position of the fuel-flow valve. A combustion efficiency of 81 percent and a specific impulse of 1,059 were indicated in flight (ref. 20).

A second successful flight of a similar F23 vehicle was made on June 6, 1950. In this flight, the launch elevation was 75 degrees, and the vehicle broke the earlier record for both speed and altitude for ramjet operation. A maximum Mach number of 3.12 was reached, and the engine burned to an altitude of 67,200 feet (ref. 21). The vehicle then coasted to an altitude of 159,000 feet and impacted at an estimated range of 40 miles.

PARD researchers were pleased with the outstanding success of the ramjet engines in flight. They were more interested, however, in overall configuration design and aerodynamic performance than in specific engine development. For this reason, they had selected ethylene gas as a propellant for the F23 ramjet engines because of its convenience. They were content to leave detail engine research with liquid fuels to the NACA's propulsion experts at the Lewis laboratory. Ethylene, stored cold at a pressure of 1,200 pounds, provided its own means for flow to the engines; only control of a flow valve was required. The use of ethylene and a simple control valve yielded an extra dividend in connection with engine evaluation. By programming the valve setting in flight, it was possible to vary the fuel-air ratio and thereby cover a range of fuel-air ratios from 0.012 to 0.065 in a single flight.

The detail design of the ramjet engine as used in the March 1950 flight is shown in figure 109. Each engine was 6.6 inches in diameter and 50.2 inches in length, and weighed 35.6 pounds. A supersonic inlet diffuser of the Ferri type, developed at Langley, reduced the internal flow to subsonic speeds. Fuel burning took place in a section 19.7 inches long in which four doughnut-shaped rings were located. The most forward ring was used as a fuel-spray ring for injecting the fuel, while the other three rings served as flame holders. This burner was called a "donut" burner. For fast starting, a 3/32-inch magnesium disk, blocking 69 percent of the area, was attached to the rear of the last flame holder. This disc allowed proper mixing of the fuel and air prior to ignition, and burned away less than a second later to permit normal engine operation.

The flame-holder rings were made of inconel, as was the external shell of the engine. The flame holder was regeneratively cooled; the cold fuel flowed through these rings before it reached the fuel-spray ring. The "donut" burner was developed by M. A. Faget and the PARD team after a series of tests in the Preflight Jet. Roland Breitweiser of Lewis first demonstrated the effectiveness of a series of wedge-shaped flame holders immersed in the combustion zone (ref. 22). Since this type of burner showed great promise by producing high efficiency combustion in a short-length chamber, the engineers at PARD started experimenting with it. First tests were made with uncooled flame holders as in Breitweiser's experiments, but no practical method could be found to keep the flame holders

FIGURE 108. First successful F23 twin-engine ramjet vehicle with double Deacon booster. Project engineer H. R. Dettwyler, on ladder, inspects one of the engines while engineer J. E. Stevens examines electrical wiring, March 24, 1950.

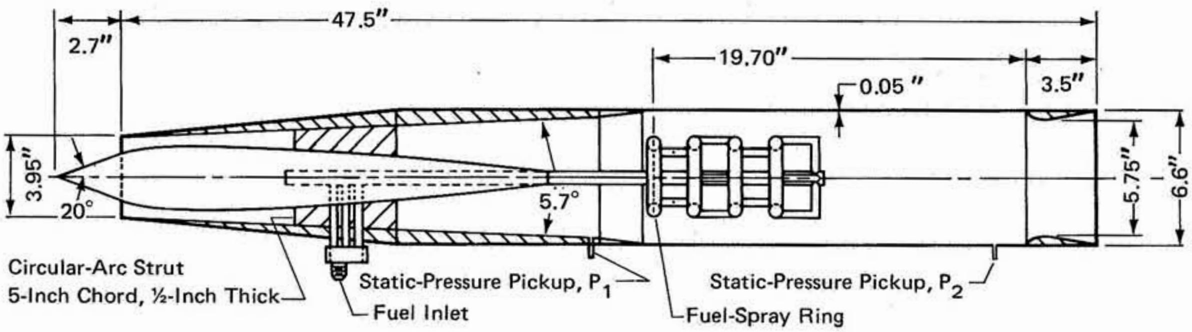


FIGURE 109. Cross section of F23 ramjet engine.

attached to the combustion chamber for more than a few seconds. According to Faget, "One of the most spectacular tests made during this period lasted about 5 seconds, at which time some 24 white-hot graphite flame holders came spitting out like balls from a roman candle." Finally an intricate flame holder assembly of five regeneratively cooled flame holders of triangular cross section was fabricated of inconel sheet. Although long-duration tests could be conducted with this burner, it showed sufficient degradation after a few tests that flame holders with a round cross section were tried, with satisfactory performance. Experimentation with size, shape, and number of flame holders then led to the "donut" burner as a simple, more rugged arrangement. The "donut" burner was adopted as the standard for the program. The tremendous amount of heat generated in this small engine necessitated great attention to structural heating problems. As finally developed, the inconel shell, during a typical test run, would glow a bright red color without burning through.

Considerable development testing was necessary in the Preflight Jet before the engine was considered suitable for flight testing. (See figure 110.) The flow conditions in the jet were the same as those to be encountered in flight, and the results therefore could be applied directly. As Paul R. Hill pointed out in his reply to a request from NAMTC, Point Mugu, California, regarding the necessity for preflight testing of ramjet missiles prior to a launching:[5]

> It is desirable to test the ramjets in the Preflight Jet to insure that they will (1) start quickly, (2) stand the temperatures and pressures imposed without disintegrating, (3) have the needed flexibility to operate over the required range of fuel-air ratios, (4) produce sufficient thrust, (5) burn efficiently, and (6) regulate the fuel adequately.

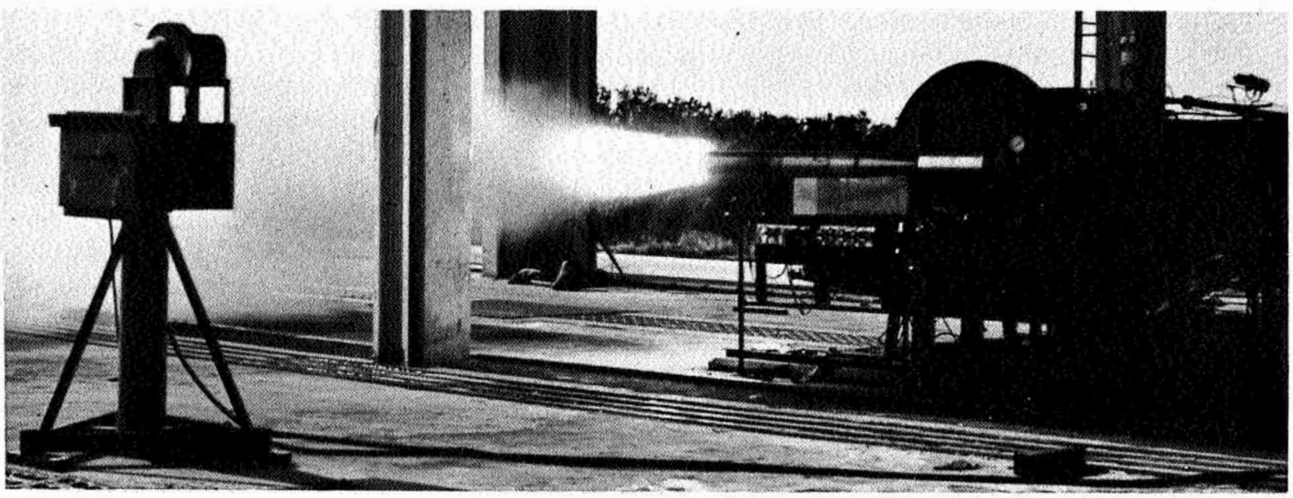


FIGURE 110. Typical F23 ramjet engine during operational test in Wallops Preflight Jet.

5. Letter, Langley to NACA, May 10, 1949, regarding preflight tests of ramjets.

Following the successful flight tests of the F23 vehicle, a duplicate of one of the engines was extensively tested in the Preflight Jet at Mach numbers of 1.81 and 2.00. Good agreement was obtained between these tests and the flight results (ref. 23).

A need existed for a small jet engine to be used in model tests in the Preflight Jet for study of the interference resulting from jet-engine operation near aerodynamic surfaces. One method proposed for simulating a jet engine in such tests was to use a small ramjet engine. A special engine designed for this purpose had a diameter of 1.1 inches and a length of approximately 8 inches. For convenience, hydrogen was chosen as the fuel. In a program in the Preflight Jet, combustion was smooth over a Mach number range of 1.42 to 2.28 and fuel-air ratios from 0.008 to 0.082. Although this engine was not used in the jet interference program, its development demonstrated again the utility of the Preflight Jet (ref. 24).

DIFFICULTIES WITH RANGE CLEARANCE FOR RAMJET FIRINGS

Despite previous arrangements between Langley and the Navy and Air Force units having cognizance over the sea range out from Wallops Island, when a request was made on June 1, 1950, for clearance for a 58-mile launching on June 6, 1950, the Commander in Chief of the Atlantic Fleet (CINCLANT) refused clearance and requested that the firing be postponed. The Commander, Naval Air Base, Fifth Naval District, Norfolk, Virginia (Comnab 5), and the Ninth Air Force, Langley Air Force Base, Virginia, granted permission for the use of area Xray; but CINCLANT persisted in his objections and carried the matter to higher naval authority, the Chief of Naval Operations (CNO). When CNO requested that Langley postpone the firing until suitable arrangements had been made with CINCLANT, J. A. Shortal, Assistant Chief, PARD, decided to satisfy the objections of CNO and keep the firing within area Xray by increasing the launch elevation angle from 45 degrees to 75 degrees. He so informed CNO on June 5; and, without further objection, the launching operation proceeded on schedule.

The problem of searching the sea area for ships that might be endangered by the missile was turned over to Herbert H. Hoover, Head, Flight Operations Branch, NACA Langley. Hoover visited Patuxent NAS, Maryland, and Norfolk NAS, Virginia, and made arrangements with Rear Admiral D. V. Gallery, Operational Development Force, Norfolk NAS, for radar surveillance by a Patuxent-based airplane equipped with an APS/20 radar. Gallery sent out the order, and the sea search was carried out as planned. This was the first search of this type performed at Wallops. The search airplane not only located ships but also was able to identify the splash point of the missile. The fact that this splash point was somewhat beyond area Xray caused no repercussions.

In response to the request of CNO that arrangements for clearance for long-range firings be made well in advance, a tentative schedule of firings was transmitted to the Fleet Training Group. On July 10, 1950, CNO, to whom the matter once again had been referred, requested that "NACA study practicability of limiting the Wallops Island range to test firings of missiles having a range of not over 25 miles. For missile firings requiring a longer range the Navy desires to offer to NACA the use of facilities at the Naval Air Missile Test Center, Point Mugu, California."[6] The NACA replied that firing from Point Mugu would be unnecessarily complicated, and again asked for permission for firings for a series of five missiles with ranges increasing to 100 miles by February 1951.[7] A reply was received on September 7, 1950, which again requested that the NACA refrain from firing into Fleet Operating Areas. This time it was stated that the decision was based on the "strong recommendation of the Commander-in-Chief, Atlantic Fleet."[8] Langley was informed privately that no relief could be expected as long as the incumbent CINCLANT was in command.

6. CNO letter by J. H. Cassidy, Deputy Chief of Naval Operations (Air), to the NACA, July 10, 1950, regarding missile firings at Wallops Island test range.
7. Letter from Hugh L. Dryden, Director of the NACA, to Vice Admiral J. H. Cassidy, Deputy CNO, July 21, 1950, regarding clearance for long-range firings from Wallops Island.
8. Letter from J. H. Cassidy, Deputy CNO, to Hugh L. Dryden, Director of the NACA, Sept. 7, 1950, regarding missile firings at Wallops Island test range.

CONTINUATION OF LEWIS AIR-LAUNCHED RAMJET PROGRAM

In the Lewis air-launched ramjet program, four series of vehicles designated A, B, C, and D, having combustion chamber Mach numbers of 0.12, 0.16, 0.21, and 0.24, respectively, had been flown by the end of 1949. The series A engines have been discussed in Chapter 6. Sixteen vehicles of the B, C, and D series, air-launched in 1948 and 1949 and reported in 1950, are discussed in this section.

The Lewis vehicle was approximately the same length as the PARD F23 vehicle—16 feet—but was 16 inches in diameter. It was launched from an F-82 airplane at an altitude of 30,000 feet. The ramjet engine was ignited in all cases just prior to launch at a Mach number of 0.50.

Two types of flame holders were used in the Lewis test engine: a ducted airfoil flame holder, and a rake. The ducted airfoil consisted of three concentric rings or circular airfoils with blunt trailing edges. The rake flame holder consisted of seven tubes whose rear sections were flared into eight prongs. Magnesium flares were used for ignition and they burned throughout the flight. The fuel used was 72-octane gasoline, and normally weighed 64 pounds. Pressurized helium was used to induce fuel flow. An eight-channel telemeter was used.

After launch, the vehicle accelerated under the combined action of gravity and engine thrust. Unfortunately, in the successful flight tests the vehicle was usually still accelerating when it hit the ocean, and the maximum Mach number attainable, therefore, was not determined. In general, the ducted airfoil flame holder performed very poorly, in comparison with the rake. In either case, considerable difficulty was encountered with uneven burning, instability, and engine blowout.

Five flights were made with the B series engines (combustion-chamber Mach number of 0.16). Three had the ducted airfoil flame holder and performed very poorly. The other two had the rake flame holder. One of these performed very well and achieved a Mach number of 1.85, whereas the other blew out when the fuel-air ratio increased to 0.082 at a Mach number of 1.45 (ref. 25).

Six flights were made with the C series engines (combustion chamber Mach number of 0.21). Three flights were unsuccessful, and in two others, burning was so rough that a maximum Mach number of only 1.1 was reached. In the one successful flight, a Mach number of 1.83 was reached for a fuel-air ratio of 0.04 to 0.06 with smooth burning. The rake flame holder was used and a combustion efficiency of 98 percent was achieved (ref. 26).

Four flights were made with the D series engines (combustion-chamber Mach number of 0.24). All of these engines had the rake flame holder. One engine did not burn because of lack of fuel flow, and a second engine achieved a Mach number of only 1.2 because of rough, explosive burning with engine blowout at a fuel-air ratio of 0.058. Two engines operated satisfactorily and achieved Mach numbers of 1.73 and 1.78 before blowing out at a fuel-air ratio of approximately 0.030 (ref. 27).

These sixteen flights, plus the first six discussed in Chapter 6, provided badly needed data on four different ramjet designs. Although all of the ramjets did not attain their design Mach numbers of 1.6 or 1.8, at least one of each did so, and thus data were provided over the design range for each series. A primary objective, the gathering of flight data at transonic speeds with burning ramjet engines, was achieved in 16 of the 22 tests. Such data could not be obtained in existing ground-test facilities. A partial summary of these tests was presented in a paper by J. H. Disher and W. W. Carlton at the NACA 1950 Supersonic Aerodynamic Conference (ref. 28), and a complete summary was prepared later by W. J. North (ref. 29).

INITIATION OF A TRANSONIC INLET RESEARCH PROGRAM: F26

In 1948, very few data were available on the drag associated with air inlets in the transonic speed range. High critical-speed subsonic inlets were available by 1945 from a Langley development (ref. 30), and the Ferri supersonic inlet with central conical body and external compression, developed in 1946, was the accepted design for supersonic speeds (ref. 31). When former Langley-researcher Richard I. Sears returned to Langley on December 1, 1948, and was assigned to PARD, Gilruth gave him the job of evaluating the inlet situation in the transonic range by using the rocket-model technique.

For the initial test, Sears selected a good subsonic inlet from the NACA 1-series (1-40-250) for evaluation through the transonic and low supersonic ranges. A parabolic body with a pointed nose, generally similar in shape to the first inlet model except for the inlet itself, was also tested for comparison. The flight program was designated F26. The test bodies were 10 inches in diameter and 85 inches in length, and had four 60-degree delta stabilizing fins. The models were propelled to a Mach number of 1.8 by means of a Deacon booster. Figure 111 shows the first inlet model with its booster on the mobile launcher at Wallops. The first F26 model, launched on January 11, 1950, was one of the basic parabolic comparison bodies. The models flown comprised two of each of the parabolic bodies and the models with series 1 nose inlets.

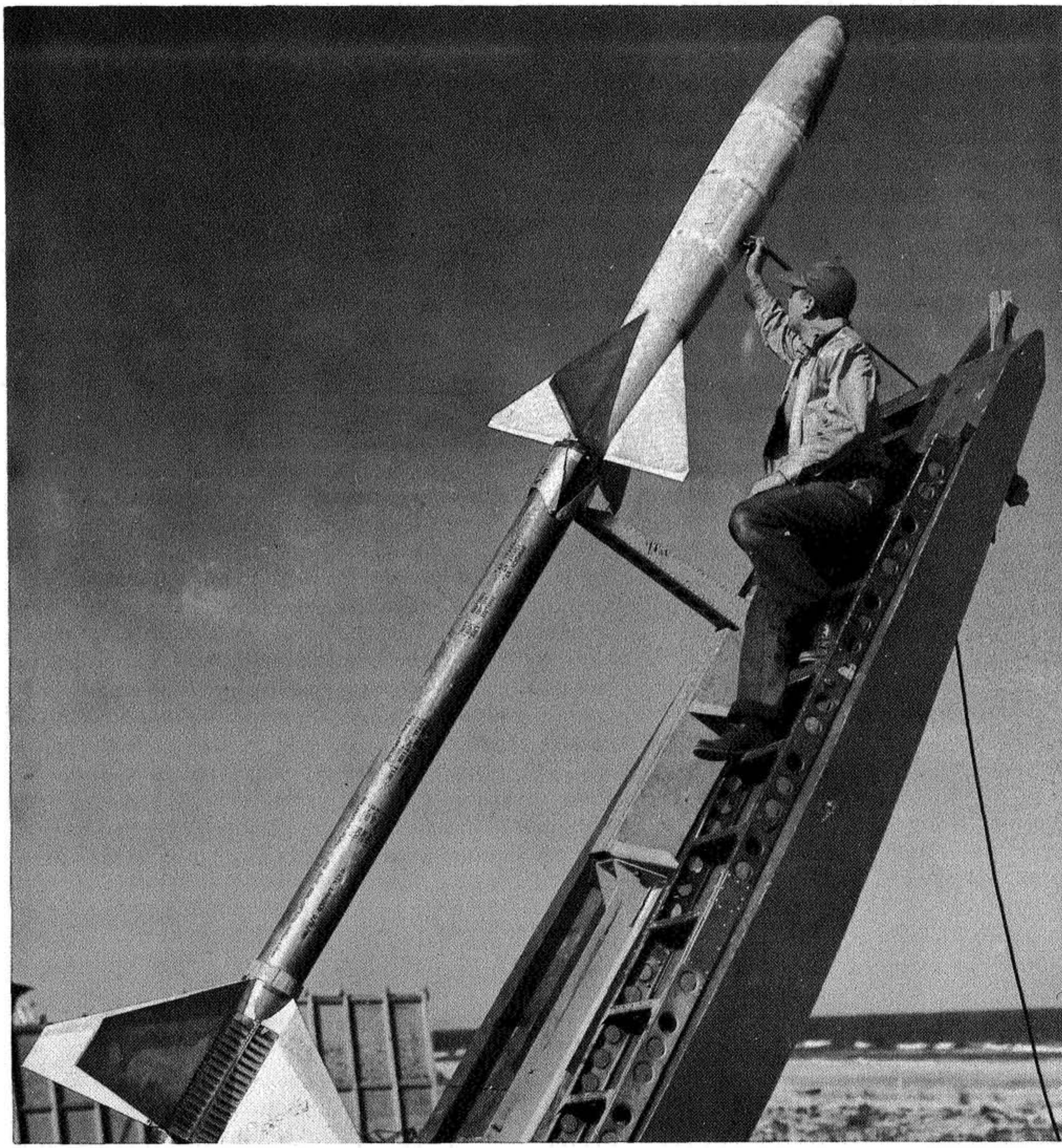


FIGURE 111. First F26 transonic inlet model with Deacon booster. Project engineer R. I. Sears checks external-power plug, May 23, 1950.

The basic parabolic body contained a two-channel telemeter to measure longitudinal acceleration and base pressure. The inlet model contained a six-channel telemeter to measure the same characteristics plus total pressure and static pressure within the duct. Inlet performance over a wide range of mass flow conditions was determined by installing four vane-type shutters inside the duct in the model and rotating them in flight at 2 cycles per second. A special model duplicated the internal geometry, including the rotating shutters, but only the external nose shape. This special model was tested in the Preflight Jet for calibration, with both the 12-inch Mach 1.4 nozzle and the 27-inch subsonic nozzle being used.

That the series 1 inlet was a good subsonic inlet was indicated by two facts: the transonic drag rise did not begin until Mach 0.96; and, at speeds up to Mach 1.4, the inlet model had less drag than did the basic parabolic body. Beyond Mach 1.4, however, the inlet caused an increase in drag, which was 50 percent higher than that of the basic body at Mach 1.8. The pressure recovery was high, to a Mach number of 1.3, beyond which the series 1 inlet became progressively worse than a Ferri type (ref. 32).

The next inlet tested in the F26 flight program was designed by Sears to have low drag and good pressure recovery at low supersonic speeds. The shape was derived by cutting off the basic parabolic body 5.45 inches aft of the nose to form a thin-wall inlet. The test technique was the same as before. With this inlet, the drag remained approximately the same as that of the basic body up to Mach 1.7, while the pressure recovery exceeded that of the Ferri inlet at all Mach numbers below 1.4 (ref. 33). The advantage of the thin-wall nose inlet over the more rounded subsonic design in the transonic speed range was evident.

TRANSONIC WING DROPPING AND BUFFETING

The year 1950 saw the defeat of the mysterious and, heretofore, unconquerable transonic region of flight. At first, the sonic barrier was considered to be mainly a wall of high drag that began at the drag-rise Mach number, identified in high-speed wind-tunnel tests. Some experts even predicted that airplanes would not be able to penetrate the barrier. Conventional propellers could not do so, but in 1947 the X-1 research airplane did exceed the speed of sound with its rocket engine. The high drag in this region, however, was just one of the problems confronting the airplane designer. As many pilots of World War II airplanes found from experience, their airplanes, upon approaching the transonic region in high-speed dives, would encounter buffeting vibrations, large changes in longitudinal trim, and in some cases, aileron buzz. It was to be found that the thickness ratio of the wings and tail surfaces was the chief factor governing this dangerous behavior.

The NACA, with its laminar-flow airfoil design, had shown how thick wings with their high structural advantage could be designed to have as low a drag at subsonic speeds as the earlier thin wings. Wings 15 to 18 percent of the chord in thickness were commonplace, and even thicker wings were considered. At the time the X-1 research airplane was designed, the merit of thin wings at high speed was beginning to be realized and this airplane was constructed with what was then considered thin wings, of 8- and 10-percent thickness. When the X-1 penetrated the sonic barrier, it encountered additional dangerous phenomena. Severe wing dropping and reversal of aileron control were encountered, in addition to violent buffeting.

The violent behavior of airplanes in the transonic range was so severe that some experts felt the only way out was to accelerate rapidly through this range so as to spend as little time there as possible. In fact, researchers at the NACA's Ames Laboratory made an analysis of just such a solution (ref. 34).

By 1950, PARD had accumulated a great body of data relating to problems in the transonic range. A solution to the problem of loss of lateral control in this region had been found in the use of sweepback, thin wings, and low trailing-edge angles. (See Chapter 5.) The phenomenon of wing dropping, however, had not been attacked until David G. Stone, head of the PARD Stability and Control branch, noticed peculiarities in the power-off portion of the D13 damping-in-roll flight data. Stone noticed that during coasting flight, some models experienced severe rolling in the transonic range even though the controls were not deflected. Examples of this are shown in figure 112, which indicates an extreme condition for a wing of 12-percent thickness, a less severe condition with a 9-percent wing, and no wing dropping tendency with a 6-percent wing. Reducing the thickness to 6

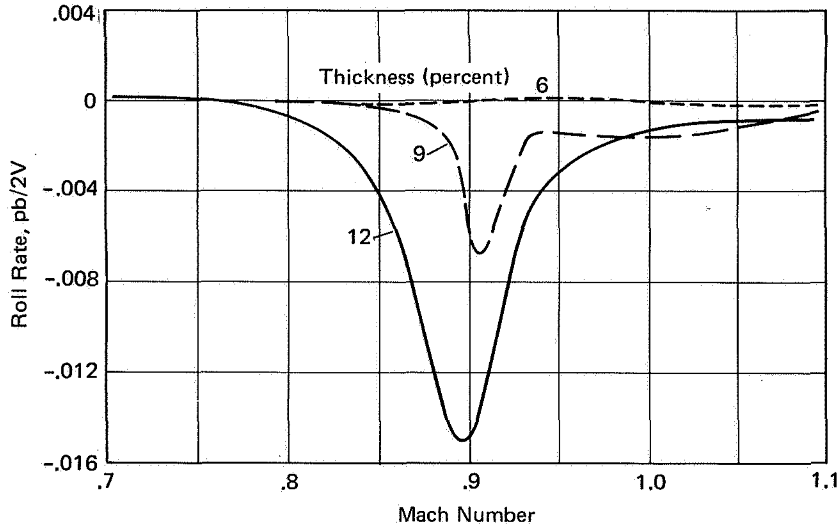


FIGURE 112. Graph showing effect of wing thickness on roll rate due to wing dropping at transonic speeds (aspect ratio 3.7 unswept wing, NACA 65A series airfoil sections).

percent or sweeping the 9-percent wing back 45 degrees seemed to provide a cure. Straight wings with abrupt changes in section, such as that found with a double-wedge section, experienced wing dropping even for a 6-percent thickness ratio (ref. 35).

Paul E. Purser looked into the phenomenon of wing dropping even further in a later analysis, and related the phenomenon to low-lift buffeting and to shifts in lift coefficient at a given angle of attack in the transonic range. Schlieren photographs of flow around airfoils in wind tunnels showed asymmetric shock patterns with strong oscillatory flow in separated regions behind the shock for the thicker wings. No such separation was observed for a 3-percent airfoil. Purser showed that fighter airplanes such as the F-80, F-51, and F8F, with their wings of 12- to 18-percent thickness, experienced low-lift buffet at Mach 0.80, and the research airplanes X-1, D-558-I, and D-558-II, with their 10-percent wings, experienced it at Mach 0.90. Purser concluded:

> A study of the available transonic Mach number data on low-lift buffeting, wing dropping, and changes in the angle of zero lift for symmetrical airfoils indicates that these phenomena are allied and are probably the result of shock-induced separation. The study has indicated that there are combinations of airfoil-thickness ratio, aspect ratio, and sweep which may allow flight through the transonic speed range without experiencing buffet or wing drop at low lift (ref. 36).

In a later investigation, two rocket-models having unswept wings of 4.5-percent thickness traversed the transonic speed range without experiencing any low-lift buffeting (ref. 37). The finding of the beneficial effect of thin wings in traversing the transonic region had immediate influence on the design of supersonic airplanes. Wing-thickness ratios of 3 to 5 percent were accepted, and such airplanes were to fly through the transonic range smoothly and without mishap.

WING-DRAG PROGRAMS: F25 AND E2

Late in 1948, a new rocket-model program was initiated to explore wing and engine nacelle arrangements that might be suitable for a transonic bomber. The program, designated F25, was carried out by the Performance Aerodynamics branch of PARD, initially under the direction of W. B. Pepper and S. Hoffman. The program was part of the laboratory-wide Transonic Airplane research program. The fuselage was taken from that program and was the same body shape used earlier in the freely falling body program. The wing used initially was wing H of the Langley Transonic Wing series. The wings had been selected as a range of likely candidates for transonic airplanes, and were to be used by all Langley researchers in their general research programs, to enable ready comparison of results. Wing H had an aspect ratio of 6, a 45-degree sweepback, 0.60 taper ratio, and NACA 65009 wing section. This thickness (9 percent) was believed to be necessary for structural reasons, in a sweptback wing with such a high aspect ratio.

The basic F25 program was concerned with determining the drag penalties associated with adding two engine nacelles to this wing, in various wing locations. In addition, various other wing arrangements were tested as alternate configurations. The nacelle part of the program, carried out over a period of several years, will be discussed in a later chapter. The results of tests of the wing modifications without nacelles are to be discussed here, along with other wing-drag results from a continuation of the basic E2 drag program.

The F25 program made use of the same technique employed in the E2 program. The models initially used a 3.25-inch rocket motor as a sustainer and a lightweight HVAR motor as a booster, and reached a Mach number of 1.25. Later, the HVAR booster was replaced with a 65-inch HVAR motor to attain a Mach number of 1.4. The data were obtained chiefly from ground-based radars, although in some flights, particularly with those models having nacelles, base pressures were obtained with the aid of a two-channel telemeter. A typical F25 model without nacelles is shown in figure 113. Note the small canard fins near the front end of the booster motor. The fins had been added to this standard booster to divert it from the main flight path after separation, and thus ensure that it did not interfere with radar tracking.

The first launching in the F25 series was made on May 12, 1949, without success; but on the following day a successful flight was made. This successful flight was to be the beginning of a series of 27 consecutive flights with no other failure until March 1951—a most impressive record. The failure of

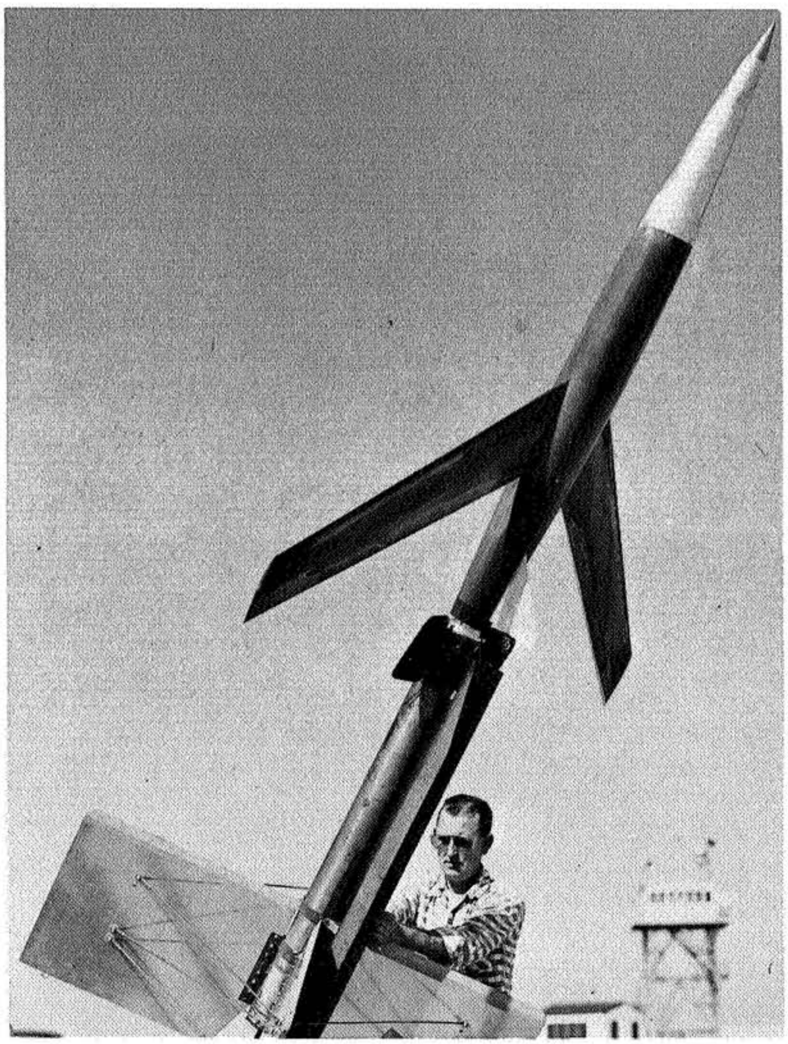


FIGURE 113. View of F25 transonic drag model with basic wing H, mounted on rail launcher with HVAR booster, October 10, 1950. Propulsion technician Nat Johnson connects firing leads.

the first test resulted from failure of an aluminum headcap on the internal rocket motor. The headcap had been substituted for the standard steel cap to reduce weight. The extreme rate of heating inside the burning rocket motor, which caused the failure, was not appreciated beforehand.

The drag coefficient of the basic F25 model without nacelles was 0.015 at subsonic speeds, followed by a transonic drag rise beginning at a Mach number of 0.97 and rising to 0.044 at Mach 1.25. One of the first modifications made to the basic F25 wing was to increase the thickness ratio at the wing root to 16 percent to provide a better structure. This modification lowered the drag-rise Mach number to 0.91 and added approximately 0.003 to the transonic drag coefficients. The next modification to the basic model was to indent the fuselage at the wing juncture. Several theoreticians, including Robert T. Jones, had speculated that greater benefits from sweepback in delaying the drag-rise Mach number for a finite wing-body combination could be obtained by modifying the fuselage at the wing juncture to conform to the streamlines of the sweptback wing. Such a configuration was flown on November 9, 1950. Disappointingly, the drag rise Mach number was unchanged, although a significant drag reduction was obtained—approximately 0.004 over the entire transonic range (ref. 38).

Although this indentation in the fuselage was also called a "coke-bottle" shape, it should not be confused with the Whitcomb "Area-Rule" indentations first investigated by Whitcomb in December 1951 (ref. 39). The reasoning behind the two shapes was quite different. Unfortunately, the significance of the earlier F25 finding was not appreciated at the time.

Highly sweptback wings, particularly those having high aspect ratio, suffered from a lack of structural rigidity. A preliminary study of a wing employing a combination of sweepback of the outer wing panel and sweepforward of the inner panel (an M planform) or vice versa (a W planform) had indicated some structural improvement—a reduced twist due to bending. Rocket-models of such planforms were flown in both the F25 and the E2 program. The E2 models are shown in figures 114(a) and 114(b). Both planforms were found to have higher drag than comparable swept wings, with the W planform having somewhat lower drag than the M planform (ref. 40).

Another modified planform wing was also tested in the F25 program. This model, shown in figure 115, was called an A planform at the time of the test but was later referred to as a composite planform. Originated as a structural improvement over the conventional sweptback wing, it was formed by shearing back the inner 40 percent of the wing from the maximum thickness line and adding a flat

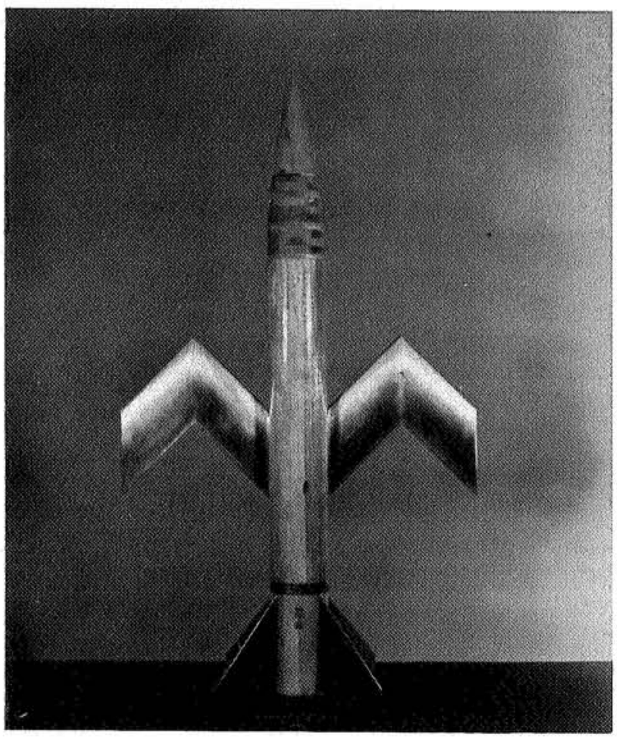


FIGURE 114(a). Typical E2 model with M planform, photographed on July 25, 1949.

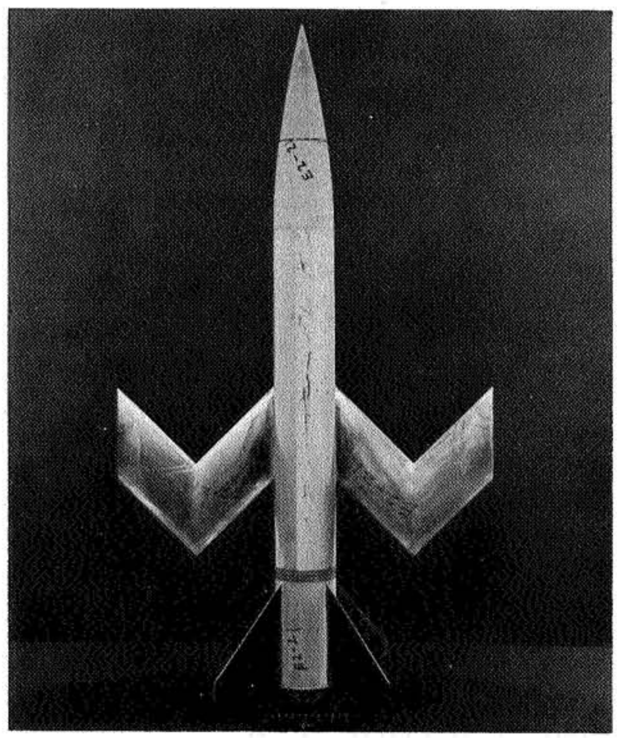


FIGURE 114(b). Typical E2 model with W planform, photographed on July 25, 1949.

middle section of constant thickness. This modification was tried on the basic F25 wing of 9-percent thickness and on two thinner wings of the same planform. One of these had a uniform thickness of 6 percent, while the other varied in thickness from 9 percent at the root to 3 percent at the tip. The A planform modification to the basic 9-percent wing had somewhat lower drag coefficients than the basic wing. Reducing the thickness of the wing, however, had a greater effect. The A modifications to the thinner wings increased the drag somewhat (ref. 41).

Another modification of the wing section of the basic 9-percent wing of the F25 program consisted of making the nose more rounded to provide higher maximum lift coefficients at low speed. This modification also was tested but, unfortunately, had a serious effect on the drag at transonic speeds, increasing the coefficients approximately 0.005 throughout the speed range (ref. 42).

The PARD E2 continued to be used for basic studies of wings suitable for supersonic flight. Dean R. Chapman of the NACA's Ames Laboratory reasoned that blunting the trailing edge of an airfoil might have a favorable effect on the overall supersonic drag. The unanswered question was the magnitude of the pressures acting on the blunt base, which was in separated flow. A number of E2 models were tested to determine this effect, and, for comparison, wings of circular-arc and double-wedge sections also were tested. All wings in this series had maximum thicknesses of 6 percent of the wing chord. The blunt trailing-edge wing had a wedge-shaped section for the first 40 percent of the chord and a slab of constant thickness rearward of this station. A two-channel telemeter provided readings of base pressure on this model. The models were propelled to Mach 1.7 by a two-stage system consisting of a lightweight HVAR booster and an internal 3.25-inch rocket motor. The slab wing had quite a high drag because of unexpectedly high base pressures. The circular-arc wing had the lowest drag below Mach 1; the double-wedge wing was somewhat lower at higher speeds (ref. 43).

A second set of tests was made to obtain additional information regarding base pressures on blunt trailing edges. This time, the wings were modifications to a basic circular-arc airfoil of 4-percent thickness. Four trailing-edge thicknesses were tested: full maximum thickness, 1/3 and 2/3 maximum thickness, and normal trailing-edge. Although base pressures were not measured, the drag values for all the wings with blunt trailing edges indicated that the same base-pressure ratios were acting here that had been measured earlier on the 6-percent wing. These tests proved conclusively that, at least up to Mach numbers approaching 2, blunting the trailing edge offered no promise of reduced drag (ref. 44).

A series of 60-degree delta wings was tested in the E2 program with different double-wedge airfoil sections. Three wings were of 6-percent thickness with different chordwise locations of the point of maximum thickness; and one 3-percent wing was tested with its maximum thickness at midchord. It was found that moving the maximum thickness rearward greatly increased the drag, and even the best location provided higher drag than an NACA 65-006 airfoil used for comparison. The wing with 3-percent thickness naturally had the lowest drag of all (ref. 45).

The effect of taper ratio was determined as part of the E2 program for aspect ratios of 2 and 4. All wings had 50-degree sweepback of the midchord line and 6-percent double-wedge sections. Wing taper ratios were 0, 0.33, and 0.67. The wing drags at supersonic speeds, deduced by subtracting from the total drag the drag of the body and fins tested alone, were in good agreement with supersonic theory, although the differences between the various wings were small (ref. 46).

The speed provided by the booster in a rocket-model flight test depended greatly upon its weight. This fact was as true of the booster fins as of any other component. The drag of the fins also affected the speed. The fins on some of the boosters used at Wallops had external bracing to save weight. To allow an assessment of the merits of different fin arrangements, a series of E2 models was constructed with different externally braced fins, and with a cantilever design. The basic fin was a scaled model of the Deacon fins used in the E15 longitudinal stability program. In the tests, it was found that a fin braced with flat tie rods had approximately the same drag as the cantilever fin. In addition, the braced fin has less weight (ref. 47). This seemed to rule out the cantilever fins, but in reality did not do so, because they were designed for twice the load and could be used safely to a higher Mach number. It did explain, however, why externally braced fins continued to be used on boosters up to low supersonic speeds.

As interest increased in extending airplane and missile speeds beyond Mach 2, the need for large-scale wing-drag data at higher speeds was realized. An exploratory program was begun with special E2 models propelled by Deacon boosters. With the combination of a Deacon booster and an internal

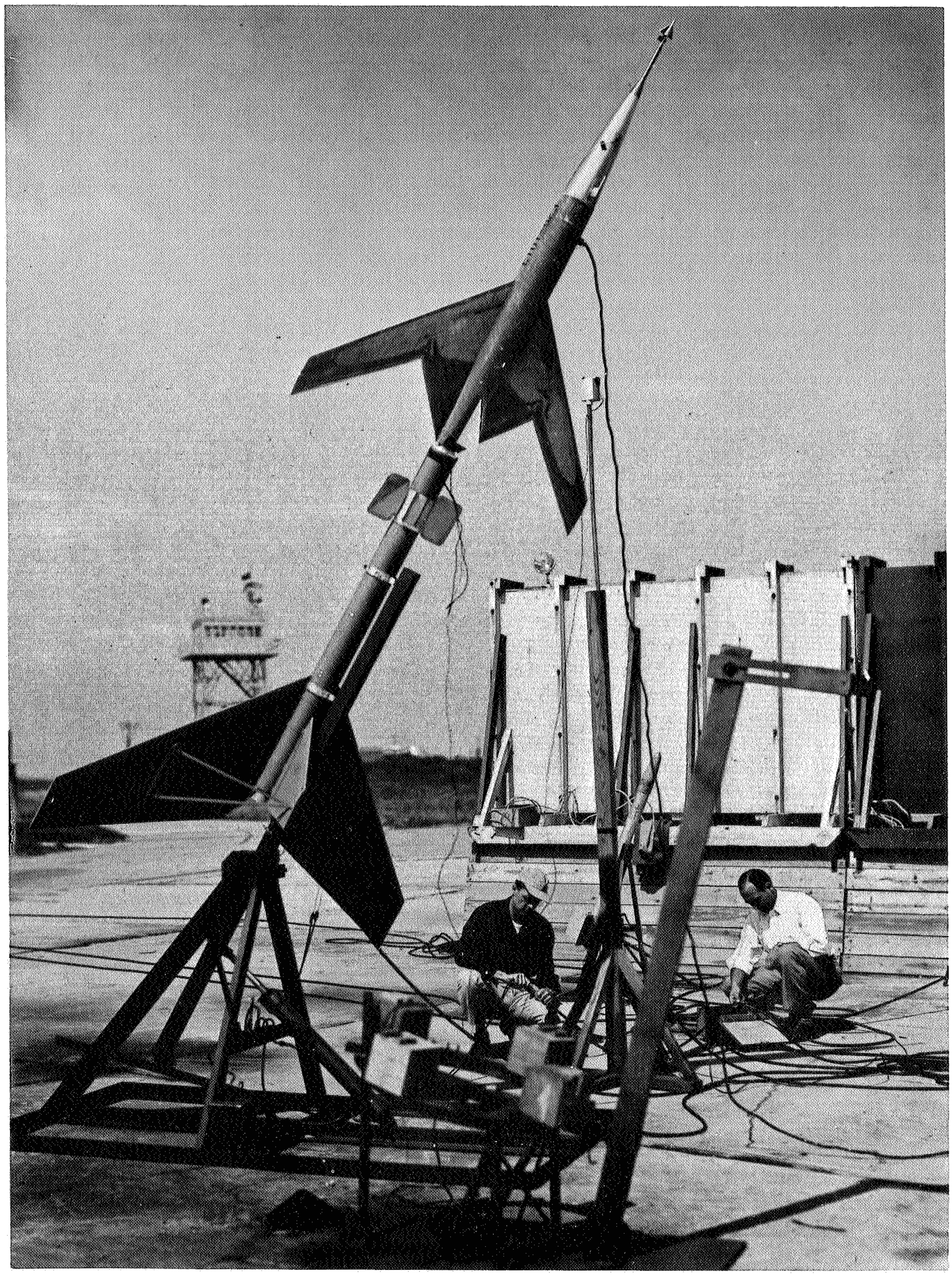


FIGURE 115. Engineers W. B. Pepper and S. Hoffman of PARD examine power leads to F25 model with "A" planform wing. Model is shown with an HPAG booster on the rail launcher at Wallops, August 31, 1949.

3.25-inch rocket motor, speeds to Mach 2.6 were attained. These special models were constructed of aluminum alloy and had upper and lower vertical fins, but no horizontal tail. Two 60-degree delta wings, an untapered wing with 10-degree sweepback, and a tapered wing with 63-degree sweepback were tested. The drag results agreed well with earlier tests at low Mach numbers, and decreased as expected at the higher speeds. Low wing thickness ratios were found to be even more beneficial at the higher speeds (ref. 48).

CONTINUATION OF E5 LATERAL CONTROL PROGRAM

The E5 general research program on lateral-control effectiveness was continued through the 1950–1954 period, with 88 models being launched in 1950 and approximately 30 per year thereafter. The effect of spanwise location of the control received attention, as did the overall subject of aeroelasticity.

Tests were made with two series of untapered wings of aspect ratio 3.7 and NACA 65A009 airfoil section, one with 45-degree sweepback and the other with 0-degree sweep. The wings were tested with trailing-edge ailerons located (1) along the entire span, (2) along the outer half of the wing, and (3) along the inner half of the wing. The effectiveness of the ailerons on the unswept wing varied with spanwise location in a manner to be expected, the full-span aileron being the most effective, and the inner aileron, the least effective. On the sweptback wing, however, an unexpected phenomenon was encountered in that the inboard aileron was more effective than the outboard one. This phenomenon was unexplained at the time (ref. 49).

A more extensive evaluation of spanwise location of ailerons on sweptback wings was made in another series of tests with tapered wings of 35- and 45-degree sweepback. In these tests, it was found that for rigid wings the optimum spanwise location for an aileron per unit length was at the mid-semispan of the wing. Locations farther outboard were even less favorable under realistic aeroelastic conditions (ref. 50).

Locating the aileron outboard of the normal wing tip is an extreme case of spanwise location. Half-delta tip controls had been found to provide almost constant rolling effectiveness over the speed range on delta wings, and low hinge moments could be obtained by proper hinge location. The effectiveness of such ailerons on tapered unswept wings and on 45-degree sweptback wings was therefore investigated. The wings were of 9-percent thickness, whereas the ailerons were of approximately 3-percent thickness (0.125-inch aluminum sheet). The wing-tip ailerons were compared with trailing-edge ailerons of the same area on wings of the same planform. In all cases, the tip ailerons were greatly superior to the trailing-edge ailerons at supersonic speeds although they were less effective at subsonic speeds. The supersonic results agreed well with linear theory as calculated by one of the investigators in the program, Robert O. Piland (ref. 51). The relative merits of flap-type and wing-tip controls were summarized in a paper by David G. Stone (ref. 52).

The rolling effectiveness of controls as measured with rocket models was known to be affected by aeroelasticity. The deflected controls applied a torsion to the wing which acted in a manner to reduce the control effectiveness. The wings in the E5 program were generally constructed of wood with metal plates inlaid in the upper and lower surfaces for strength and avoidance of flutter. The loss of rolling power from torsion in the case of thick wings constructed in this manner was usually not very great; but with thin wings, the loss could be considerable. For example, an unswept wing of 3-percent thickness, made of solid aluminum, was found to suffer a complete reversal of effectiveness at Mach 1, as shown in figure 116. Even with a steel wing, the loss of aileron power was large (ref. 53).

The loss of rolling effectiveness due to aeroelasticity in rocket-model flights at low altitudes was more severe than was expected from full-scale aircraft at their normal high altitude of operation at supersonic speeds. It was necessary, therefore, to identify the structural effects in the model tests in order to evaluate the aerodynamic effects. In application to a particular airplane then, the particular structure of the airplane would be given consideration. Inasmuch as the rocket-model tests were the only source of large-scale control data at transonic speeds, it was necessary to obtain the aeroelastic losses from them. The rocket-model test results with different stiffnesses were used to deduce equivalent aerodynamic twisting moments with which aeroelastic effects could then be computed (ref. 54).

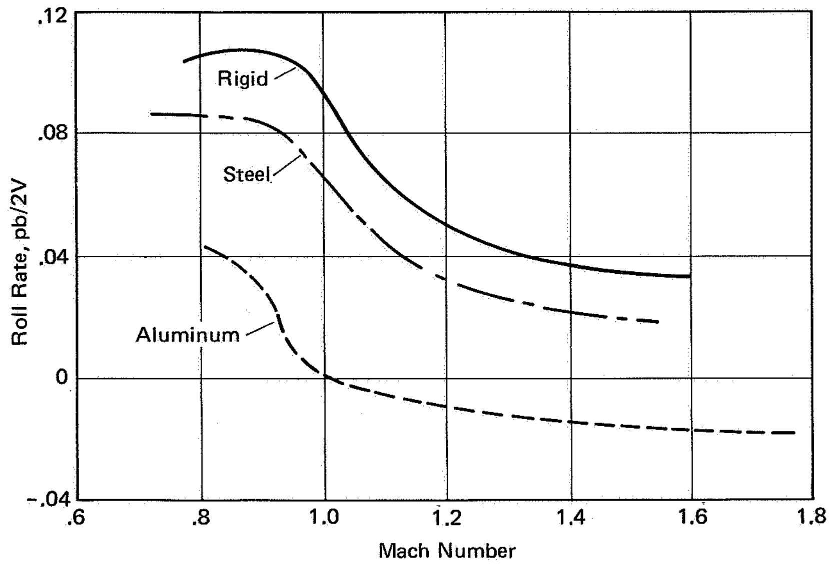


FIGURE 116. Graph showing influence of aeroelasticity in loss of aileron control effectiveness for an unswept wing of aspect ratio 3.7 (NACA 65A003 airfoil section; $\delta a = 5°$).

Tests of a special series of delta wings of different stiffnesses were made to allow evaluation of aeroelasticity for this special shape (ref. 55).

JET VANE CONTROLS

Although all of the rockets flown at Wallops by 1950 had been stabilized and controlled by aerodynamic surfaces, some exploratory research was begun with jet-vane controls, first on a ground-based thrust stand and then with simplified flight models. When a control or vane was deflected within the exhaust jet of a rocket motor, the jet would be deflected and a side force would be developed. Such a side force could then be used to stabilize the model.

The ground-based tests of jet vanes were made in the rocket test area at Langley. The first such test was made of a "paddle" jet vane which was mounted flush with the jet stream in an undeflected state, hinged at its front end, and deflected into the jet as a control. Such a test with a 3.25-inch rocket motor showed that a side force of approximately 9 percent of the thrust could be generated. This was equivalent to deflecting the entire jet 5 degrees. The force required to hold the paddle vane in the jet was high. In the test, the stainless steel vane used was unaffected by the exhaust, and the loss of rocket impulse was negligible (ref. 56).

Another type of jet vane investigated was an all-movable control surface immersed within the rocket exhaust. This type had been used to control the German V-2 rocket, and later was to be used on the first stage of the Scout launch vehicle. One concept of stabilizing a booster rocket was to connect such a vane to an external free-floating aerodynamic vane that would provide the force for actuating the jet vane. Such a system was given a flight trial with an instrumented model at Wallops on January 11, 1950. In this test, a modified HVAR rocket motor was used, and the external fin was interconnected to the jet vane in such a manner as to provide 3-degree motion of the jet vane for 1-degree motion of the external fin. With such an arrangement, the usual large booster fins required on the first stage could be eliminated, with a reduction in drag and an increase in overall performance. The flight test indicated that such a scheme was practical. In a ground test on a thrust stand prior to flight, the jet vanes as used were able to deflect the jet 1.5 degrees (ref. 57).

The success of this exploratory flight led PARD to examine the scheme for use with the larger Deacon motor. In tests on a thrust stand, it was found that fins made of steel would survive the 3.2-second burning period with negligible loss of material. Graphite fins were found to erode excessively during the test and were subject to chipping and breaking in ordinary handling. As before, the vanes were effective in deflecting the jet 1.5 degrees (ref. 58).

This system on a Deacon rocket motor was given several flight trials in the period 1952–1954, but by that time interest had shifted to larger booster rockets and the Deacon system was never put to use. As mentioned earlier, the first such operational system at Wallops was to be on the NASA Scout launch vehicle. The 1952–1954 results were useful in guiding the design of that system.

References

1. Michal, David H., Aeronautical Research Scientist, Memorandum for Chief of Research, Dec. 16, 1949, proposing transfer of free-flight apparatus to Wallops.
2. Thibodaux, J. G., Memorandum for Chief of Research, Aug. 25, 1948, regarding visit to NACA Headquarters and Office of Chief of Ordnance.
3. Krieger, R. L., Memorandum for Director, July 12, 1950, regarding security at Wallops Island.
4. Minutes, NACA Special Committee on Self-Propelled Guided Missiles, Mar. 14, 1945.
5. Hall, James R.; and Sandahl, Carl A.: *The Zero-Lift Drag of Several Configurations of the XAAM–N–2 Pilotless Aircraft.* NACA RM L50C16a.
6. Hopko, Russell N.: *A Flight Investigation Utilizing Rocket-Propelled Test Vehicles of the Damping in Roll and Rolling Effectiveness Including Aeroelastic Effects of Models of the XAAM–N–2 (Sparrow) Missile With Tails Interdigitated.* NACA RM SL51D16.
7. Sandahl, Carl A.; and Hall, James R.: *Free-Flight Investigation of the Longitudinal Stability and Control of a 1-1/8-Scale Model of the XAAM–N–2 (Sparrow) Missile Having Interdigitated Tails.* NACA RM SL51B15.
8. Hall, James R.: *Free-Flight Investigation of Longitudinal Stability and Control of a 1-1/8-Scale Model of the XAAM–N–2 (Sparrow) Missile Having Inline Tails.* NACA RM SL51J17.
9. Gillespie, Warren, Jr.; and Arbic, Richard G.: *Large-Scale Flight Measurements of Zero-Lift Drag at Mach Numbers From 0.90 to 1.95 of a 1/14-Scale Model of the Northrop MX-775B Pilotless Aircraft With Small Body.* NACA RM SL50H18. Reissued as NACA RM L50K28a.
10. Arbic, Richard G.; and Gillespie, Warren, Jr.: *Summary of Rocket-Model Tests at Zero Lift of the Northrop MX–775B Missile Configuration From Mach Numbers of 0.9 to 1.8.* NACA RM SL53J02. Reissued as NACA RM L53J02.
11. Mitcham, Grady L.; and Blanchard, Willard S., Jr.: *Summary of the Aerodynamic Characteristics and Flying Qualities Obtained From Flights of Rocket-Propelled Models of an Airplane Incorporating a Sweptback Inversely Tapered Wing at Transonic and Low-Supersonic Speeds.* NACA RM L50G18a.
12. Strass, H. Kurt; Fields, E. M.; and Schult, E. D.: *Free-Flight Investigation at Transonic and Supersonic Speeds of the Rolling Effectiveness of a Partial-Span Aileron on an Inversely Tapered Sweptback Wing.* NACA RM L50B08.
13. D'Aiutolo, Charles T.; and Mason, Homer P.: *Preliminary Results of the Flight Investigation Between Mach Numbers of 0.80 and 1.36 of a Rocket-Powered Model of a Supersonic Airplane Configuration Having a Tapered Wing With Circular-Arc Sections and 40° Sweepback.* NACA RM L50H29a.
14. D'Aiutolo, Charles T.; and Henning, Allen B.: *Lateral Stability Characteristics at Low Lift Between Mach Numbers of 0.85 and 1.15 of a Rocket-Propelled Model of a Supersonic Airplane Configuration Having a Tapered Wing With Circular-Arc Sections and 40° Sweepback.* NACA RM L55A31.
15. Lundstrom, Reginald R.; and O'Kelly, Burke R.: *Flight Investigation of the Jettisonable-Nose Method of Pilot Escape Using Rocket-Propelled Models.* NACA RM L9D11.
16. Henry, John R.: *Experimental Determination of the Subsonic Performance of a Ramjet Unit Containing Thin Plate Burners.* NACA RM L9B17.
17. Hill, Paul R.; and Gammal, A. A.: *An Analysis of Ducted-Airfoil Ramjets for Supersonic Aircraft.* NACA RM L7I24.
18. Hill, Paul R.: *Parameters Determining Performance of Supersonic Pilotless Airplane Powered by Ram-Compression Power Plants.* NACA ACR L6D17 (Wartime Report L–755).
19. Faget, M. A.: *Flight Tests of a Two-Dimensional Wedge Diffuser at Transonic and Supersonic Speeds.* NACA RM L8E27.
20. Faget, Maxime A.; and Dettwyler, H. Rudolph: *Initial Flight Investigation of a Twin-Engine Supersonic Ramjet.* NACA RM L50H10.
21. Dettwyler, H. Rudolph; and Bond, Aleck C.: *Flight Performance of a Twin-Engine Supersonic Ramjet From 2,300 to 67,200 Feet Altitude.* NACA RM L50L27.
22. Breitweiser, Roland: *Performance of a Ram-Jet Type Combustor With Flame Holders Immersed in the Combustion Zone.* NACA RM E8F21.
23. Faget, Maxime A.; Watson, Raymond S.; and Bartlett, Walter A., Jr.: *Free-Jet Tests of a 6.6-Inch-Diameter Ramjet Engine at Mach Numbers of 1.81 and 2.00.* NACA RM L50L06.
24. Judd, Joseph H.; and Trout, Otto F., Jr.: *Free-Jet Tests of a 1.1-Inch-Diameter Supersonic Ramjet Engine.* NACA RM L5118.
25. Messing, Wesley E.; and Simpkinson, Scott H.: *Free-Flight Performance of 16-Inch-Diameter Supersonic Ramjet Units. II, Five Units Designed for Combustion-Chamber-Inlet Mach Number of 0.16 at Free-Stream Mach Number of 1.60. (Units B–1, B–2, B–3, B–4, and B–5).* NACA RM E50B14.
26. Rabb, Leonard; and North, Warren J.: *Free-Flight Performance of 16-Inch-Diameter Supersonic Ramjet Units. IV, Performance of Ramjet Units Designed For Combustion-Chamber-Inlet Mach Number of 0.21 at Free-Stream Mach Number of 1.6 Over a Range of Flight Conditions.* NACA RM E50L18.
27. Disher, John H.; and Rabinowitz, Leonard: *Free-Flight Performance of 16-Inch-Diameter Supersonic Ramjet Units. III, Four Units Designed for Combustion-Chamber-Inlet Mach Number of 0.245 at Free-Stream Mach Number of 1.8 (Units D–1, D–2, D–3, and D–4).* NACA RM E50D07.

28. Disher, J. H.; and Carlton, W. W.: *The Free-Flight Performance of Several 16-Inch-Diameter Ramjet Units at Free-Stream Mach Numbers of 0.60 to 1.86.* Paper presented at NACA Conference on Supersonic Aerodynamics, Moffett Field, California, Feb. 28 and Mar. 1, 1950.
29. North, W. J.: *Summary of Free-Flight Performance of a Series of Ramjet Engines at Mach Numbers From 0.80 to 2.20.* NACA RM E53K17.
30. Baals, Donald D.; Smith, Norman F.; and Wright, John B.: *The Development and Application of High-Critical Speed Nose Inlets.* NACA ACR L5F30a. Reissued as NACA TR 920, 1948.
31. Ferri, Antonio; and Nucci, Louis M.: *Preliminary Investigation of a New Type of Supersonic Inlet.* NACA RM L6J31. Reissued as NACA TN 2286, 1951; and NACA TR 1104, 1952.
32. Sears, R. I.; and Merlet, C. F.: *Flight Determination of the Drag and Pressure Recovery of an NACA 1–40–250 Nose Inlet at Mach Numbers From 0.9 to 1.8.* NACA RM L50L18. Reissued as NACA TN 3218, July 1955.
33. Sears, Richard I.; and Merlet, C. F.: *Flight Determination of Drag and Pressure Recovery of a Nose Inlet of Parabolic Profile at Mach Numbers From 0.8 to 1.7.* NACA RM L51E02.
34. *Annual Report,* NACA, 1950, p. 16.
35. Stone, David G.: *Wing-Dropping Characteristics of Some Straight and Swept Wings at Transonic Speeds as Determined with Rocket-Powered Models.* NACA RM L50C01.
36. Purser, Paul E.: *Notes on Low-Lift Buffeting and Wing Dropping at Mach Numbers Near 1.* NACA RM L51A30.
37. Gillis, Clarence L.: *Buffeting Information Obtained From Rocket-Propelled Airplane Models Having Thin Unswept Wings.* NACA RM L50H22a.
38. Pepper, William: *The Effect on Zero-Lift Drag of an Indented Fuselage or a Thickened Wing-Root Modification to a 45° Sweptback Wing-Body Configuration as Determined by Flight Tests at Transonic Speeds.* NACA RM L51F15.
39. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Science and Technology in the Exploration of Space, 1915–1960,* NASA, 1961, p. 68.
40. Katz, Ellis; Marley, Edward T.; and Pepper, William B.: *Flight Investigation at Mach Numbers From 0.8 to 1.4 to Determine the Zero-Lift Drag of Wings with "M" and "W" Planforms.* NACA RM L50G31.
41. Pepper, William B., Jr.; and Hoffman, Sherwood: *Transonic Flight Tests to Determine the Effect of Thickness Ratio and Planform Modification on the Zero-Lift Drag of a 45° Sweptback Wing.* NACA RM L52F02a.
42. Pepper, William B., Jr.: *Free-Flight Tests at Mach Numbers From 0.8 to 1.4 to Determine the Effect on Zero-Lift Drag of Increasing the Leading-Edge Bluntness of a 45° Sweptback Wing Having an NACA 65A009 Airfoil.* NACA RM L52F30.
43. Morrow John D.; and Katz, Ellis: *Flight Investigation at Mach Numbers From 0.6 to 1.7 to Determine Drag and Base Pressures on a Blunt-Trailing-Edge Airfoil and Drag of Diamond and Circular-Arc Airfoil at Zero Lift.* NACA RM L50E19a. Reissued as NACA TN 3548, Nov. 1955.
44. Morrow, John D.: *Measurements of the Effect of Trailing-Edge Thickness on the Zero-Lift Drag of Thin Low-Aspect Ratio Wings.* NACA RM L50F26. Reissued as NACA TN 3550, Nov. 1955.
45. Welsh, Clement J.: *Results of a Flight Investigation to Determine the Zero-Lift Drag Characteristics of a 60° Delta Wing With NACA 65–006 Airfoil Section and Various Double-Wedge Sections at Mach Numbers From 0.7 to 1.6.* NACA RM L50F01. Reissued as NACA TN 3650, Apr. 1956.
46. Pittel, Murray: *Flight Tests at Supersonic Speeds to Determine the Effect of Taper on the Zero-Lift Drag of Sweptback Low-Aspect-Ratio Wings.* NACA RM L50F30a. Reissued as NACA TN 3697, June 1956.
47. McFall, John C., Jr.: *Drag Investigation of Some Fin Configurations for Booster Rockets at Mach Numbers Between 0.5 and 1.4.* NACA RM L50J12.
48. Hopko, Russell N.; and Sandahl, Carl A.: *Free-Flight Investigation of the Zero-Lift Drag of Several Wings at Supersonic Mach Numbers Extending to 2.6.* NACA RM L52D29.
49. Strass, H. Kurt: *The Effect of Spanwise Aileron Location on the Rolling Effectiveness of Wings With 0° and 45° Sweep at Subsonic, Transonic, and Supersonic Speeds.* NACA RM L50A27.
50. Schult, Eugene D.; Strass, H. Kurt; and Fields, E. M.: *Free-Flight Measurements of Some Effects of Aileron Span, Chord, and Deflection and of Wing Flexibility of Ailerons on the Rolling Effectiveness of Ailerons on Sweptback Wings at Mach Numbers Between 0.8 and 1.6.* NACA RM L51K16.
51. Sandahl, Carl A.: Strass, H. Kurt; and Piland, Robert O.: *The Rolling Effectiveness of Wing-Tip Ailerons as Determined by Rocket-Powered Test Vehicles and Linear Supersonic Theory.* NACA RM L50F21.
52. Stone, David G.: *Comparison of the Effectiveness and Hinge Moments of All-Movable Delta and Flap-Type Controls on Various Wings.* NACA RM L51C22.
53. Strass, H. Kurt; Fields, E. M.; and Purser, Paul E.: *Experimental Determination of Effect of Structural Rigidity on Rolling Effectiveness of Some Straight and Swept Wings at Mach Numbers From 0.7 to 1.7.* NACA RM L50G14b.
54. Strass, H. Kurt: *Summary of Some Effective Aerodynamic Twisting-Moment Coefficients of Various Wing-Control Configurations at Mach Numbers From 0.6 to 1.7 as Determined From Rocket-Powered Models.* NACA RM L51K20.
55. Marley, Edward T.; and English, Roland D.: *Some Effects of Aeroelasticity at Mach Numbers From 0.7 to 1.6 on the Rolling Effectiveness of Flat-Plate Delta Wings Having 45° Swept Leading Edges and Full-Span Constant-Chord Ailerons.* NACA RM L51L05.
56. Bond, Aleck C.: *Experimental Investigation of a Flat-Plate Paddle Jet Vane Operating on a Rocket Jet.* NACA RM L50I20.
57. Wineman, Andrew R.: *Preliminary Investigation of a Fin-Actuated Jet-Vane Control System for Stabilization of Rocket-Powered Models.* NACA RM L50K17.
58. Gilladett, Leo V.; and Wineman, Andrew R.: *Investigation of Vanes Immersed in the Jet of a Solid-Fuel Rocket Motor.* NACA RM L52F12.

CHAPTER 8

SUPERSONIC BODIES AND HEAT TRANSFER: 1951

WALLOPS PERSONNEL AND OVERALL CHANGES IN MANAGEMENT

By 1950, the number of employees at Wallops had increased to 75, a figure that was to remain almost constant until 1959, when Wallops was made a separate Station under the newly established NASA. The 75 employees were distributed about as follows: Mechanical Service Unit, 45; Administrative Unit, 10; and Research Section, 20. The Research Section handled all flight operations and the Preflight Jet. The number assigned to research varied from day to day as men were borrowed from Mechanical Service to meet changing needs.

Most of the Wallops personnel in December 1950 are shown in figures 117(a) and 117(b). Krieger was one of those absent. The first group, in figure 117(a), contains mostly research and administrative personnel; the second group, in figure 117(b), mostly mechanical service personnel. This arrangement of personnel placed approximately the same number in each group. In daily transportation to and from the island, with two personnel boats in use, this same grouping was also followed. The separation of personnel resulted in injury to just one of the groups in the tragic boat fire to be discussed later in this chapter. The division became such a habit that, when the boats were replaced by a ferry with two passenger cabins, the employees followed this same grouping. Transportation on the island between the boat dock and work areas was provided by two yellow school buses with the same grouping. In the daily operations at the island, however, organization lines were not rigidly drawn—all personnel helped in any way they could to get the job done.

Some changes in overall management were made in the period 1950–1955. PARD, the parent division at Langley, had been organized into four branches in 1949, as discussed in Chapter 6; but at that time not all of the section heads under the branches had been selected. In such cases, the branch head served in that capacity, assuming a dual role.

On August 22, 1950, the following section heads were appointed in the Performance Aerodynamics Branch, which was headed by Paul R. Hill: M. A. Faget, Performance Section; J. G. Thibodaux, Model Propulsion Section; and R. S. Watson, Preflight Jet Section.

On August 30, 1950, C. A. Sandahl was appointed head of Aircraft Components Section of the General Aerodynamics Branch headed by Paul. E. Purser; and on July 1, 1955, W. N. Gardner was appointed head of the Aerodynamics Section of the Stability and Control Branch headed by David G. Stone.

In June 1951, R. R. Gilruth was promoted to the position of Assistant Chief of Research at Langley. Joseph A. Shortal succeeded him as Chief of PARD, and Paul R. Hill became Assistant Chief, PARD. In

FIGURE 117(a). Personnel at Wallops Island, December 1950. Group (a): Front row—James Quillen, Walter Colonna, Elizabeth Pennington, Nathaniel Johnson, Eldred Helton, Philbert Mears, and Franklin Forbes. Second row—William Ferguson, Albert Kellam, James Fenner, Joseph Robbins, William Carey, Patrick Levy, Joseph Smith, John Palmer, and Durwood Dereng. Third row—Don Foster, Frank Townsend, James McConnell, Robert Hallett, Abraham Spinak, John Parks, Tom McComb, Waldorf Roberson, Eugene Menning, Clyde Hargis, and Tom Cutler.

FIGURE 117(b). Personnel Wallops Island, December 1950. Group (b): Front row—Dudley Watkinson, Howard Shreaves, Samuel Watkinson, Harry Bloxom, Robert Holdren, William Daisey, Sam Tyndall, Charles Young, and B. E. Reid, Sr. Second row—Elwood Evans, Granville Watson, George Cutler, Eugene Merritt, Harold Kellam, and Richard McAllen. Third row—Charles Turlington, Doris Bloxom, James Boyce, Brooks Thomas, William Bloxom, Harry Willett, Roy Colonna, and Sanford White. Fourth row—Paul Mears, Ashe Walker, Harvey Thornton, Louis Birch, Robert Watkinson, Luther Watkinson, James Pennington, Frank Finney, John Rumer, Wilson Parks, Walter Melson, Gardner Rew, and William Grant.

his new position, Gilruth was assigned overall supervision of Structures Research Division, Dynamic Loads Division, and PARD. With two additional divisions to supervise, Gilruth now devoted less time to PARD activities although rocket-model testing remained close to his heart. Hill remained Acting Head of Propulsion Aerodynamics Branch until February 25, 1952, when M. A. Faget was named head of that branch. Aleck C. Bond replaced Faget as head of the Performance Section, and D. H. Foland became head of the Preflight Jet Section, replacing Watson, who had resigned from the NACA late in 1951.

When R. L. Krieger moved to Wallops Island in 1948 to become Engineer-in-Charge, he moved his family with him. He lived at first in Onancock, Virginia, but after about a year, moved to a larger house nearer Wallops. The house, which he rented, was a rural dwelling outside Mappsville, Virginia. Shopping facilities, schools, and hospitals were not easily accessible. In fact, when his son required hospitalization, Krieger took him to Salisbury, Maryland, and had to drive more than 40 miles each way daily to visit him. By 1951, Krieger was ready to return to Hampton, not only because of the living conditions on the Eastern Shore, but also because he felt that he could contribute more to the continued development of Wallops by being at Langley. It was there that the flight projects were originated, the yearly budgets were prepared, the models were designed, constructed, and instrumented, and new techniques were developed.

Accordingly, in 1951 Krieger asked to be transferred back to Langley. Shortal was impressed with Krieger's ability in directing Wallops activities and worked out a plan whereby his services could be retained in the same capacity. Krieger's office was moved to the main PARD building at Langley, but he retained the titles of Engineer-in-Charge of Pilotless Aircraft Research Station, and Head, Wallops Island Branch of PARD. The only one with reservations about this move was H. J. E. Reid, Director of Langley. He agreed to it, however, with the provision that G. S. Brown, Resident Engineer in Charge of Construction at Wallops, would be given the additional duties of Acting Engineer-in-Charge of the Station, reporting to Krieger, when Krieger was absent from the Station. Krieger recommended that John C. Palmer be assigned as Head of Research Operations at Wallops, under the Wallops Island Branch of PARD. All of these changes were made effective July 31, 1951. Although Krieger's transfer to Langley was motivated chiefly by personal reasons, the transfer memorandum read "to permit Mr. Robert L. Krieger to assume additional duties." As it turned out, he was to be assigned many additional duties, and the arrangement of directing Wallops activities from Langley was to continue until he was transferred back to the Eastern Shore in 1959, this time as Director of Wallops.

In July 1952, in keeping with the change in title of Engineer-in-Charge of Langley to that of Director, the Chief of Research was now called the Associate Director, and the Assistant Chiefs of Research were called Assistant Directors.

On January 20, 1953, the lines of authority at Wallops were reestablished following the transfer of G. S. Brown to Muroc, California, in late 1952, to take charge of a new construction program at the NACA High-Speed Flight Station. John C. Palmer was selected to serve as Acting Engineer-in-Charge in the absence of Krieger, and William E. Grant was named to so serve in the absence of both Palmer and Krieger.

In March 1954, the Wallops Island Branch was renamed Research Techniques and Operations Branch of PARD, with Krieger continuing as head. PARS, Wallops Island, was continued in this branch with Krieger as Engineer-in-Charge. At the same time, the Operations Section of PARD was transferred from the Division Office to this new branch, with Krieger appointed Acting Head to replace Charles A. Hulcher, who had resigned shortly before.

When Palmer was appointed head of Research Operations at Wallops in 1951, the official status of the group was not clear. The situation was clarified in April 1954, when the unit containing research personnel at Wallops in the Research Techniques and Operations Branch was officially recognized as the Wallops Island Research Section, with J. C. Palmer as head.

A major reorganization at Langley took place in 1954 following the death of Ernest Johnson, Chief of Administrative and Technical Services, on April 19 of that year. Administrative Services and Technical Services were once again separated, with W. Kemble Johnson appointed Chief of Administrative Services, and Percy J. Crain, Chief of Engineering and Technical Services. The Instrument Research Division, formerly a part of Technical Services, was now placed under Research, with Assistant Director H. A. Soulé having cognizance over its activities at the headquarters level.

AERIAL MOSAIC AND GRID SURVEY OF WALLOPS ISLAND

In 1950, the urgent need for an accurate map of Wallops Island was recognized. Since the easiest method of obtaining one was from an aerial survey, preferably an aerial mosaic made from a large number of matched photographs, the first attempt to obtain a mosaic was made through the Langley Air Force Base commander. Failing in this, Langley requested NACA Headquarters to contact U. S. Air Force Headquarters in Washington, D. C. Following the NACA's letter of May 16, 1951, the USAF, on June 4, 1951, requested its Tactical Air Command at Langley to prepare such a mosaic for the NACA. TAC, in turn, ordered its Shaw Air Force Base, South Carolina, to perform the task, and on August 2, 1951, a complete mosaic of Wallops was transmitted to the NACA. A map of the complete island was traced from the mosaic and used as a reference for both NACA and Navy installations on the island.

The 1945 property map of Wallops Island, prepared at Langley, established a local Grid Survey system for identifying locations on the island. Certain reference points in the system, such as the Coast Guard tower on the northern end of the island, were located with respect to existing Coast and Geodetic Survey points, such as the Assateague lighthouse. Later, the Department of Commerce was asked to provide elevations and coordinates of certain additional points on the island. For example, in September 1949, it determined that the elevation of bench mark A299, identified by the NACA as the west stoop of the General Utility Building (hotel), was 10.331 feet, and in April 1950 the exact coordinates of the Chincoteague Air Station water tower were given.

In December 1950, Langley requested NACA Headquarters to obtain the assistance of the U.S. Coast and Geodetic Survey in establishing a verified grid system for Wallops. Following a visit by G. S. Brown of Wallops and M. E. Bowling of NACA Headquarters to Coast and Geodetic Survey headquarters in Washington, D. C., during April 1951, an agreement was reached for making the required survey at a cost of $1,300. The survey was made during the period April 19–22, 1951, and the results were transmitted to Langley on May 8, 1951.

Mean sea-level elevations of five bench marks were determined, and these bench marks, as well as the NACA water tower and the control tower, were located from first-order triangulation in the Virginia State Coordinate system and geographic positions set by the North American Datum of 1927. By this means, Wallops was now accurately correlated with all other positions in this system. The new system replaced the earlier Wallops Grid Survey system for identifying locations on the island, and represented an important step for Wallops as a test range. Distances could now be determined from the State Coordinates to within 0.10 inch, and from geographic positions to within 0.10 foot. The system was especially valuable in establishing baselines for determining flight trajectories by triangulation.

NAVY OPERATIONS AND GRANTING OF USE PERMIT

Despite the many plans of the Navy BuOrd's NAOTS to develop an extensive test facility on Wallops Island, its activities there were never to be very large. With the signing of the agreement of March 11, 1949, between the NACA and BuOrd, which recognized NACA's primary interest in Wallops, and the acquisition of the entire island by the NACA on November 7, 1949, through condemnation proceedings, relations between NACA and Navy personnel on Wallops became very cordial at all levels. In June 1950, Reid, Gilruth, and Krieger met with NAOTS personnel at Chincoteague to discuss certain planned permanent improvements. Langley described a plan to locate a telemeter receiving station and to construct an airstrip on the north end of the island. Captain G. K. Fraser, Commanding Officer, NAOTS, offered no objection and said, in turn, that he planned to improve the road system, which should provide better access between NACA and Navy areas on the island.

Captain Fraser said he would have use for the airstrip and would lend his support to that project. In response, Reid promised to support the Navy's efforts to improve the roads. Fraser also wanted NACA support in developing a fresh-water supply in the Navy area. Despite the fact that the NACA had found good water in its area, the Navy had been unable to do so and filled its needs by hauling water by truck from the NACA system. Although this meeting indicated the willingness of both parties to assist each other in their construction plans, neither side made much progress. Langley was refused permission to construct the airstrip, and Fraser's request for funds for roadway improvement was turned down.

During 1951, it became evident to NAOTS personnel that a written agreement between the NACA and BuOrd, which would allot a definite area of the island to the Navy, was necessary if the NAOTS intended to make their installation there a permanent one. On May 10, 1951, Fraser invited Krieger to the Air Station to discuss such an agreement. NAOTS asked for a use permit covering all of the island east of longitude 75°28′15″, the old lease line. Krieger recommended consideration by higher authority. On October 23, 1951, a meeting was held at the Bureau of Ordnance in Washington, D. C., with representatives from BuOrd, NAOTS, NACA Headquarters, and Langley. The main concern of BuOrd was that the 1949 agreement implied that NAOTS would leave the island after completion of the Kingfisher project, whereas they wanted to remain and conduct aircraft armament firings. BuOrd pointed out that this was necessary because both Dahlgren and Inyokern ranges were saturated. The long runways under construction at Chincoteague would enable BuOrd to use Wallops for testing armament on the new high-speed jet aircraft. When it was finally made clear that BuOrd was not thinking in terms of guided missiles activity but only of guns and bombs, NACA representatives agreed to cooperate.

In November 1951, Krieger recommended to NACA Headquarters that if an official permit were prepared allowing the Navy use of part of Wallops Island, the property line should be made 37°51′54″ latitude instead of the requested line of 75°28′15″ longitude. Kreiger pointed out that his proposed property line would give the Navy jurisdiction over all of the island on which it had installations, except for two temporary observation stations. G-3 and Oboe.

A revocable permit from the NACA allowing the Navy use of Wallops Island north of 37°51′54″ latitude was signed by H. L. Dryden, NACA Director, on January 14, 1952. This was a 90-day revocable permit that allowed the Navy to use a specified part of the island for aircraft armament testing, and required the Navy to obtain approval from the NACA for any new construction on the island. In addition, right-of-way was granted the Navy for access to its stations G-3 and Oboe. The Navy accepted the terms of the permit.[1]

Before the Navy had officially accepted the permit, NAOTS asked permission of the NACA for erection of two 42-foot steel towers for Askania and Mitchell phototheodolites. Langley obtained permission from NACA Headquarters and forwarded it to NAOTS on April 10, 1952.

The next request by NAOTS for approval of a construction plan came on May 2, 1952, when Captain M. P. Bagdanovich, Commander of NAOTS, requested approval from Langley for construction of an aircraft armament ammunition test facility. Guns were to be fired out to sea to a range of 6,000 yards. The request was approved by H. J. E. Reid on May 13, 1952, and the facility was placed in operation a short time later.

At this time, the Navy finally was able to run powerlines from its facilities on the northern end of the island to the NACA line that connected with the local public service company. In 1948, the Navy had requested permission to draw power from the new line which the NACA was installing across the marsh. At that time, the Navy gave its requirements as 30 kw, and the NACA had agreed to provide this much power at no charge. Now, in 1952, the Navy asked for 200 kw. The NACA agreed to supply this amount but specified that the Navy would be billed for its usage each month. The Navy erected their own powerline and connected it to the NACA line through a separate meter near the hotel. On November 29, 1952, power was finally turned on for the Navy line.

D22 AND F36 RAMJET MISSILE TESTS AND PLANS TO USE BANANA RIVER RANGE

The success of the PARD F23 ramjet vehicle in demonstrating efficient flight operation at Mach 3 prompted P. R. Hill and M. A. Faget to propose two new flight programs for evaluating the usefulness of this means of propulsion in guided missiles. The two proposals were for a ramjet ground-to-air interceptor missile and a long-range ramjet ground-to-ground missile.

1. Letter from Navy Bureau of Yards and Docks to Ralph E. Cushman, Procurement Administrator, NACA, March 17, 1952, enclosing executed copies of revocable permit for use of certain land on Wallops Island, Virginia.

The interceptor missile was to be powered with two 6-inch F23-type ramjet engines. As proposed, the twin engines were to be located in one plane on stub fins, while a 65-degree delta wing would be located in the other plane. Small canard fins were added well forward on the body, which was 8 inches in diameter and 14 feet in length. This project was called RJ-6 at first, but redesignated D22, with major emphasis on stability and control problems. The project was established in 1949 under the supervision of the Stability and Control Branch of PARD, with R. R. Lundstrom as project engineer. The D22 models had the same range as other PARD models, and no special range considerations were involved in the tests.

Extensive tests were made of scaled models of the D22 design in the Langley 4-foot Supersonic Tunnel, and one complete full-scale flight test was made. In the flight test on May 11, 1955, the canard fins in both the pitch and yaw planes were arranged to be pulsed between stops, to allow a study of control and stability while the twin ramjet engines were operating. In addition, the model was stabilized in roll. A Nike booster was used. (See figure 118.) Unfortunately, one of the ramjet engines in the model did not ignite. The test results were of little value and were never published. This event ended the D22 program.

The long-range ground-to-ground guided missile proposed by Hill and Faget had two 10-inch ramjet engines, a length of 22 feet, a weight of 800 pounds, a fuselage 14 inches in diameter, and an estimated range of 300 miles. In this proposal, the engines were to be mounted in nacelles in the wing in the horizontal plane, with small stabilizing fins in the vertical plane. Small canard surfaces were to provide longitudinal control. The missile was to be roll-stabilized, programmed to climb to an altitude of 60,000 feet, and then to fly level at Mach 2.25.[2] The flight program to develop this missile was designated F36 and was assigned to A. Gammal as project engineer, in the Propulsion Aerodynamics branch of PARD. The booster proposed for the program was the 3DS-47000 solid-rocket motor that was later to become known at Wallops as the Nike booster.

The need for a test of such a stabilized vehicle with flight at constant altitude was brought out by Gilruth and given approval by Dr. Dryden at the September 20, 1949, meeting of the Ramjet Panel at

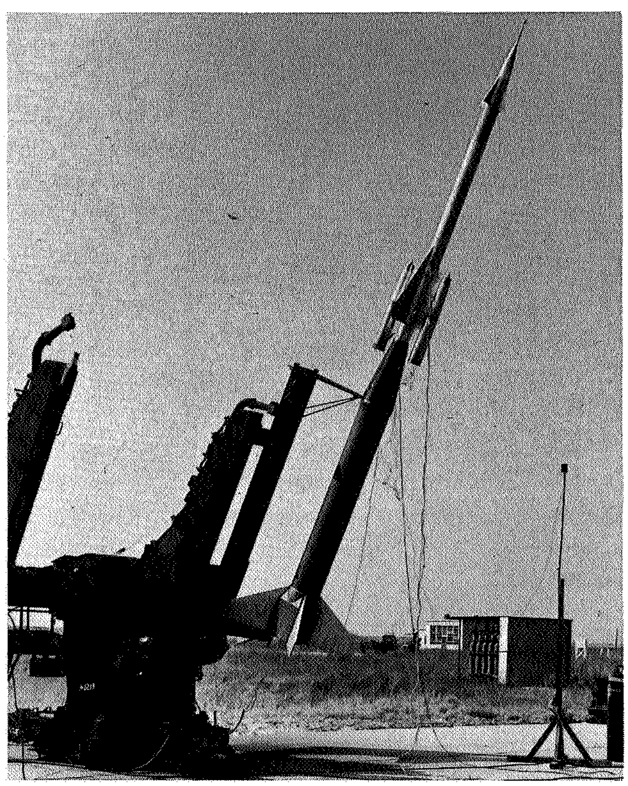


FIGURE 118. View of D22 ramjet-powered interceptor missile and Nike booster on launcher for research firing at Wallops, May 11, 1955.

2. Letter from Langley to the NACA, April 6, 1951, regarding initiation of flight tests of a stabilized ramjet research vehicle.

NACA Headquarters. At the same meeting, Abe Silverstein disclosed that the Lewis Laboratory was also planning a flight-stabilized ramjet model for test at constant altitude. Such flight models would have ranges beyond the limit of existing tracking systems at Wallops. Also under development in a cooperative program between Langley and Lewis were new engines that burned magnesium-boron slurry fuel. With the substitution of these engines, even greater ranges would be reached.

The long range envisioned for the F36 program led Langley to consider launching the models at the Long-Range Proving Ground at Banana River, Florida, later called the Atlantic Missile Range (AMR). The range had launched its first missile on July 24, 1950. E. C. Buckley, Chief of IRD, had made contact with Dr. Arthur Warner, Technical Director at Banana River, regarding the availability of this range for such a test and had found him very receptive. In fact, it was indicated that all the details could be handled directly between Langley and Banana River without other approvals. On May 4, 1951, Langley forwarded additional information to NACA Headquarters regarding the objectives of this long-range program and the extent of support needed from the Long-Range Proving Ground.[3] Approval of the program was given by NACA Headquarters on May 17, 1951.

On August 8, 1951, Robert L. Krieger of PARD and H. H. Youngblood of IRD visited the Long-Range Proving Ground to discuss the proposed firing of NACA ramjets at that range. This was the first additional duty assigned Krieger after his transfer back to Langley on July 31, 1951. The first thing Krieger and Youngblood learned on their visit was that the Long-Range Proving Ground was under the Air Force Missile Test Center (AFMTC) at Patrick Air Force Base, Cocoa, Florida, and was to be incorporated into the new Research and Development Command by August 15, 1951. The NACA would therefore have to make an official request to that command for any assistance. The visitors were exposed to AFMTC's philosophy regarding the need for destruct systems in all flight missiles and the concept of a statement of "user requirements" to be answered by a "range response" regarding what the range could supply.

The firing circuitry, under construction at AFMTC, was discussed with Harold Morris, a former employee of both PARD and IRD at Langley, who had also designed the firing circuit at Wallops. As Krieger expressed it, "Naturally enough, their system is very similar to that at Wallops Island and our models can be fired from their circuits very easily." The Langley visitors also learned that the first three tracking stations were now in use (Cape Canaveral, Jupiter Inlet, and Grand Bahama) and the fourth, at Eleuthera Island, was to be activated in November 1951.

This visit to AFMTC indicated that long-range missiles could be launched from Cape Canaveral if Langley so desired, and the operational problems did not appear to be large. Krieger was somewhat embarrassed by one action taken by the range personnel following his visit. Although the visit was considered to be of an exploratory nature without commitments, Krieger learned later that AFMTC had used this NACA proposed project as the justification for a budget request for additional hangar and office space. On October 1, 1951, Langley requested NACA Headquarters to make an official request for use of the AFMTC range.

As time went by, Langley personnel became less inclined to consider using AFMTC. The ease of operating at Wallops made them reexamine the range situation there. As discussed in Chapter 7, Langley had already turned down a Navy offer to use NAMTC at Point Mugu, California, for long-range firings because of the distance from Langley. The tracking requirements for the long-range ramjet could be met at Wallops by stationing a telemeter receiver on either a boat or airplane downrange and by adding a beacon transponder to the test model. The only hindrance remaining was the Navy's request that the NACA limit its flight operations to a range of 25 miles.

In August 1951, the Air Force relinquished its control over the northern half of area Xray (XRAY NAN) and turned control over to the Commander, NAAS/NAOTS, Chincoteague, Virginia. A new agreement regarding use by the NACA of airspace offshore from Wallops was prepared by the Tactical Air Command, the Fifth Naval District, and NAOTS. The range limitation of 25 miles from Wallops Island, however, remained in effect.[4] A Navy order describing procedures for use of the area assigned to NAOTS was issued by that station on August 27, 1951.

3. Letter from Langley to NACA Headquarters, May 4, 1951, enclosing memo by P. R. Hill regarding Langley flight-test program of stabilized ramjets.
4. Letter from Tactical Air Command, Fifth Naval District, and NAAS/NAOTS to Director, NACA, August 8, 1951, regarding operational use of the Chincoteague and Virginia Capes Offshore Airspace Warning Areas.

In November 1951, Langley asked NACA Headquarters to reopen discussions at a high level with the Navy, to allow the NACA to launch the proposed long-range ramjet vehicle from Wallops to a distance of 200 miles. This time Langley agreed to install a destruct system in the vehicle, which would be activated if the flight deviated from the assigned corridor. The plan was for one long-range flight every six months, starting in July 1952. An explosive destruct system for use at Wallops, which had been flight tested in 1950, indicated that the flight could be terminated at will (ref. 1). A second method also considered for terminating a flight was to deflect the canard control surfaces abruptly to a large angle, causing excessive air loads and structural destruction. A trial flight of such a system was made on August 15, 1951.

By April 1952, no action had yet been taken by NACA Headquarters, and Langley became impatient for a decision on the use of Wallops or Cape Canaveral for the long-range ramjet program. A memorandum was prepared in summary of the situation, with a strong plea for Headquarters to try to convince the Navy that an occasional firing into its training area could be tolerated, and that, in fact, the results of the firings would be of benefit to the Navy. At this time, it was pointed out that either the range would have to be extended beyond 25 miles or future development at Wallops would have to be curtailed, because rocket-model testing for aerodynamic data at higher Mach numbers would naturally result in flights of longer range, and the need for such data was seen to be increasing at a fast rate (ref. 2). No action was taken by Headquarters on this plan.

In the meantime, the F36 ramjet program was making slow progress. The job of designing and constructing this large, complicated, ground-to-ground missile in Langley facilities turned out to be bigger than had been expected. Several 5/14-scale models of the F36 missile were flown during 1952 and 1953 for an evaluation of drag, stability, and trim. Models weighing approximately 70 pounds were flown to Mach 2 with double Deacon boosters. One of the models on its launcher is shown in figure 119. The tests indicated that the design was sound (ref. 3).

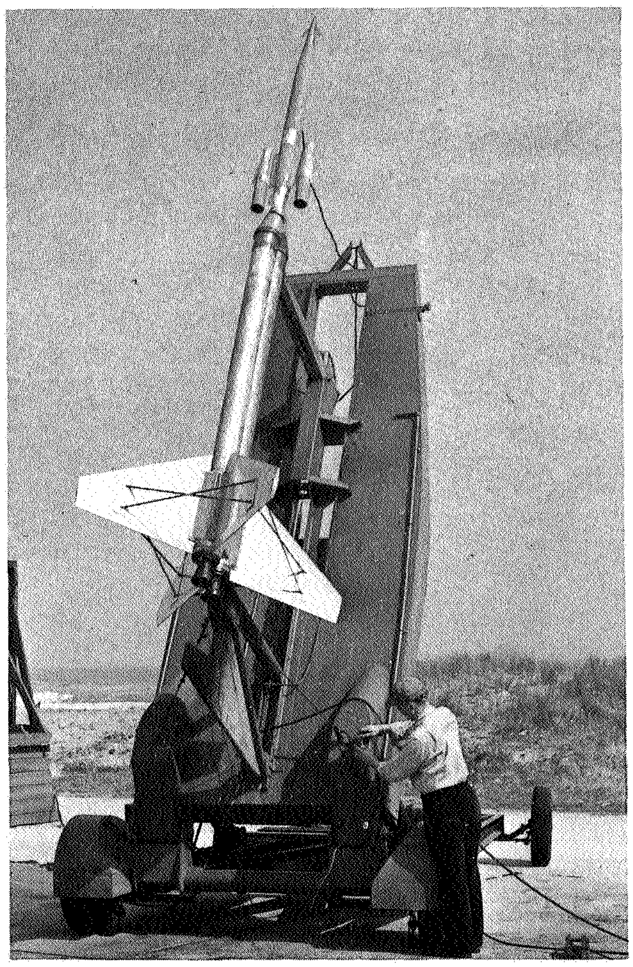


FIGURE 119. Technician Harry Bloxom measures elevation angle of launcher for flight of 5/14-scale model of F36 long-range ramjet vehicle. Model is shown with double Deacon booster, April 10, 1953.

There remained the development of a booster system incorporating the new 3DS-47000 (Nike) rocket motor, development of the 10-inch ramjet engines, a roll-control system, and an altitude-control system. By the beginning of 1954, a "dummy" model with the new booster system had been constructed and instrumented for flight. It was in the shop at PARD awaiting shipment to Wallops for firing when the word came from Gilruth that the entire project had been canceled. Whereas, at the initiation of the project in 1950, Gilruth had enthusiastically supported it, by 1954 nationwide interest in ramjet propulsion had dwindled, the project was far behind its original schedule, and the manpower was needed for the new hypersonic research program. Cancellation of the project therefore appeared to be the wisest move. Project engineer Gammal, who had devoted more than 3 years of dedicated effort to the F36 project, was so upset over this action that he resigned from Langley on February 5, 1954.

With cancellation of the F36 project, justification for an extended range, either at Wallops or at Cape Canaveral, ended.

ASSISTANCE IN TRACKING HIGH-SPEED AIRPLANES

The NACA range at Wallops Island, with its SCR-584 tracking radar, was an ideal site for certain Langley high-speed airplane flight tests. One such test was the calibration of airspeed-measuring devices.

The normal method of determining airspeed was from measurements of total and static pressure, made either with a single head such as a Pitot tube, or with separate measurements of the two pressures. At high speeds, it was difficult to measure static pressure because it was hard to find a place on the airplane that would not be affected by angle of attack or of yaw. Langley had made use of a "trailing bomb"—a streamlined body suspended from the airplane by a wire—for static pressure measurements. This system was not practical, however, in high-speed flight, particularly in dive tests.

In 1949, John A. Zalovcik of Langley developed a radar method of calibrating airspeed installations which was accurate, not only in maneuvers but also at transonic and supersonic speeds (ref 4).

During the 1950–1952 period, such calibration tests by SCR-584 radar were made at Wallops on two separate Lockheed F-80 airplanes, several North American B-45 and F-82 airplanes, and a Republic F-84 airplane. It soon became standard practice to calibrate all high-speed airplanes used in flight research at Langley by flying them over the Wallops range.

In early 1951, the Air Force asked Langley to use flights over the Wallops range to determine the minimum radius of turn possible with the North American B-45 airplane at various speeds and altitudes. Flights of the B-45 were made at Wallops on January 22, 1951, and the plot board records of the maneuvers were transmitted to the Air Force authorities (ref. 5). A second series of similar tests was made on March 9, 1951.

The Langley Flight Research Division instituted a flight research program dealing with the interception problem. The advent of the all-weather radar-guided bomber made it imperative that an automatic all-weather interceptor be developed, and the Langley research was related to this need. As part of the program, a series of intercept flights was made over the Wallops range during the latter part of 1951, with a Grumman F9F-3 airplane as the interceptor and a North American F-51 airplane as the target. Both airplanes were tracked alternately by the SCR-584 radar at Wallops. Complete paths of both airplanes were then obtained by interpolation.

The F9F-3 airplane was equipped with a gyroscopically controlled lead-computing gunsight for lead-pursuit attacks. The flight tests were made with a pilot controlling the interceptor airplane, to study measures he would take in actual situations. The study objective was to furnish an aid in developing fully automatic systems. The radar tracking of the airplanes was quite successful, and the tests provided the researchers with needed information on the types of maneuvers most likely to result in successful interception (ref. 6).

Early in 1952, the Wallops range was used by the Langley Flight Research Division for yet another series of flight tests. This time a Lockheed TV-2 airplane was used in strafing attack runs on a target located on the island proper. Wallops was chosen because of the absence of interference from other aircraft. The problem being investigated resulted from the reduction in damping of lateral oscillations encountered with high-speed military aircraft. Researchers wanted to determine the relationship of this reduced damping to firing accuracy. The TV-2 airplane was equipped with an auxiliary fin below the nose, which could be excited in such a way as to vary the damping of the airplane to simulate a wide range of conditions. Gun firing effectiveness was evaluated from gun-camera pictures made during each strafing attack. In the tests, it was clearly shown that reduced damping increased dispersion and indicated the need for the addition of auxiliary yaw dampers to high-speed service airplanes (ref. 7).

ACCIDENTS AT WALLOPS

At Wallops, everyone was aware of the personal dangers associated with the handling and firing of the solid-rocket motors and explosives used daily. Recognizing the dangers, the personnel treated these devices with respect and operated under strict safety rules that enabled Wallops to experience an enviable safety record. In the period covered by this history (1945 to 1959), there were no fatalities, even though thousands of hazardous devices were used.

During this period, however, there were two serious accidents resulting in personal injury: one in 1951 involving a premature firing of a rocket motor, and the other in 1953, resulting from a gasoline explosion and fire on a personnel boat.

For the sake of completeness, this chapter discusses all the accidents (in the 1945–1959 period) of enough severity to warrant an official investigation. The circumstances are discussed with the thought that perhaps other accidents of a similar nature might be forestalled.

The most serious accident at Wallops involving personal injury experienced with rocket motors was the accidental firing of a Deacon booster motor on August 2, 1951, while Technician Durwood A. Dereng was on the launcher immediately below the model and booster. A model of the MX-775B Northrop Boojum missile was on the launcher and was being checked by Dereng for flight readiness. In figure 120, the project engineer, R. A. Arbic, is shown with the model and in the same position in which Dereng was to be when the accident occurred. (See also figure 102, Chapter 7.)

A few minutes before the firing of an instrumented model, it was customary for a technician to climb the ladder on the launcher and, with a screwdriver, turn a flush-mounted switch in the model, which shifted power from external to internal batteries. If all was well, the external power plug was then pulled. External power was used to warm up the telemeter and to perform preliminary tests. The short-life internal batteries were saved for actual flight use. In a normal case, if everything was working properly after the plug was pulled, the technician would descend the ladder, run to the special shelter, and connect the firing leads to the circuit leading to the firing programmer inside the Control Center. The model was then ready for firing.

On the day of the accident, the launcher had been elevated to 75 degrees, and Dereng was on the ladder beneath the Boojum model awaiting instructions from the Control Center. Joseph W. Smith, the telemeter technician at the telemeter receiver inside the Control Center, was in charge of this part of the countdown. He was in contact with Dereng through a telephone line to the Control Tower, whose operator then relayed any message to Dereng over an outside loudspeaker. On command from Smith, Dereng switched from external to internal power as usual, and pulled the plug. At this, the telemeter ceased operating and Smith asked Dereng to put the plug back in and turn the switch back to external power. The telemeter returned to normal operation. Thinking that perhaps the switch was faulty, Smith asked Dereng to turn the switch off and on several times. After a few seconds, the Deacon rocket motor fired.[5] Unknown to Smith, Dereng had also pulled the power plug and was holding it in his left hand.[6] This information was obtained from Dereng after he had been taken to the hospital following the accident.

5. Statement by Joseph W. Smith, prepared for accident committee, August 2, 1951.
6. Affidavit by H. R. Turner, prepared from conversation with Durwood A. Dereng, August 3, 1951.

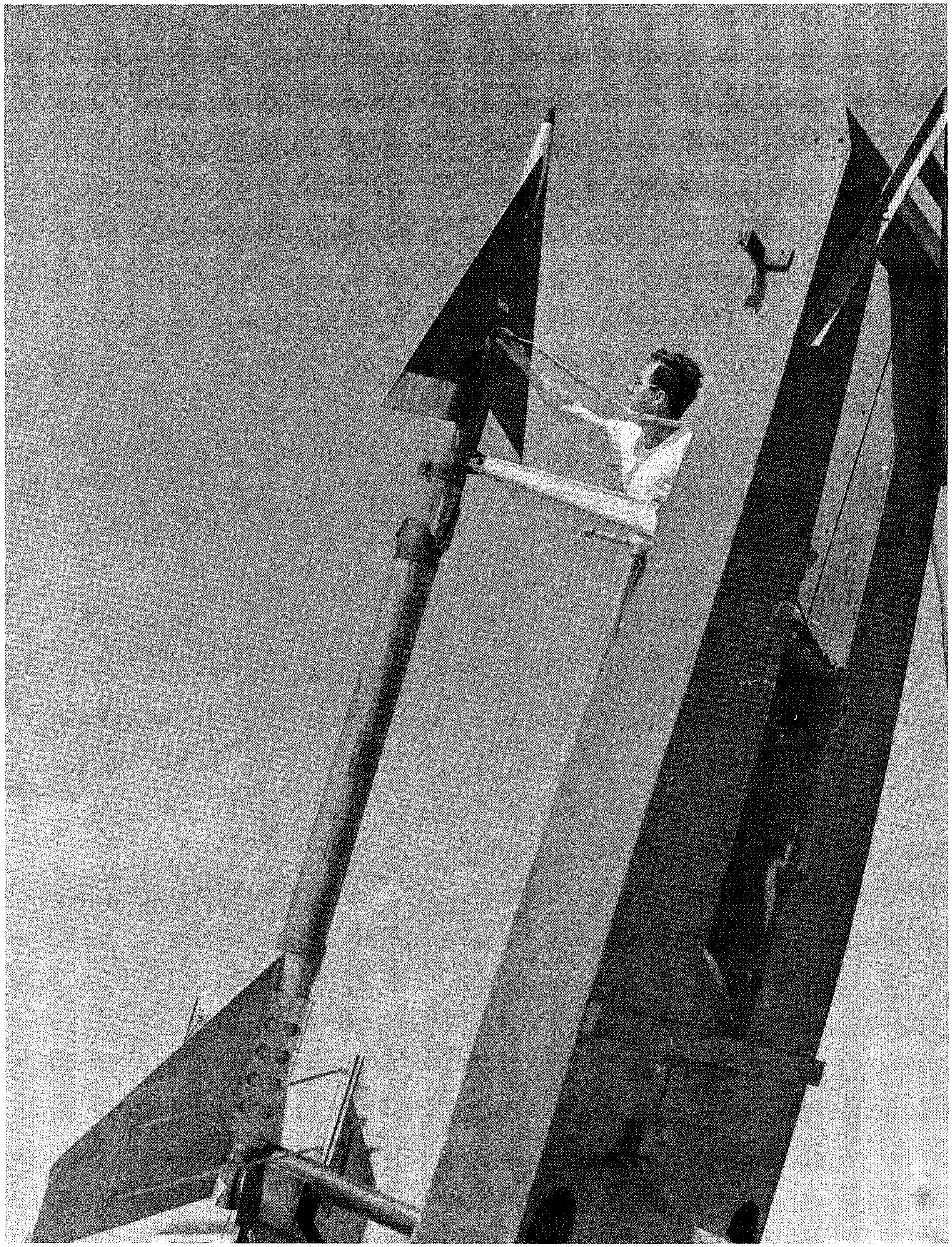


FIGURE 120. Engineer R. A. Arbic examines external-power plug leading to model of Northrop Boojum missile on launcher at Wallops.

When the Deacon fired, the front support arm, which was spring-loaded, slammed down on Dereng's arm, cutting and bruising it and breaking a bone in his left hand. The model and booster took off and passed over Dereng. One of the brace rods on the booster fins struck his right hand, severing most of it from his wrist. By the force of this blow, Dereng was rolled over completely to the other, smooth side of the launcher, down which he slid to the ground.[7] Despite exposure to the noise and flame from the Deacon, Dereng suffered no ill effects from those sources. Apparently, the short time of exposure saved him from that type of damage.

A high-speed boat took Dereng to the Mainland Dock, where he was met by an ambulance from the Chincoteague Naval Air Station. After first-aid treatment at the hospital there, he was flown to the Marine hospital in Norfolk, Virginia, where corrective surgery was performed. Upon discharge from the hospital, he was fitted with an artificial hand, and returned to his job at Wallops.

An accident investigating committee from Langley, with Ray W. Hooker as chairman, was flown to Wallops the afternoon of the accident. The committee began an investigation and appointed a special technical committee, headed by Paul R. Hill, to study possible causes of the accident. After extensive tests in which different assumed conditions at the rocket motor at the time of the accident were simulated, it was found that the firing could have been caused by one of several possibilities, but the exact cause was never determined.

When the committee investigated a simulation of the situation as described by Smith, i.e., the clicking off and on of the switch while the power plug was in the model, no firing was obtained. When the condition described by Dereng, however, was simulated, i.e., the power plug's being pulled out and possibly touching metal, a firing could be obtained under several different conditions. One of the prongs of the power plug had a potential of 350 volts between it and the ground. The ignition of the Deacon normally was initiated by sending current to an electric squib which, upon ignition from an imbedded heated wire, would set off the Deacon igniter and then the Deacon itself. The squib had a metal case that was known to be in electrical contact with the metal case of the Deacon. When 400 volts was applied to the case of a squib in a simulated test, the squib would fire under several different conditions. When the voltage was applied directly between the case and the firing leads, the squib would fire with a current of only 13 milliamps, compared with the 400 milliamps required for the normal heater circuit in the squib. This was a new finding. In addition, the squib would fire if either a large resistor or a small condenser were placed in the circuit. Finally, the squib would fire if a small charged condenser were discharged between the case and the firing leads (refs. 8, 9, and 10). Although it was not possible to determine the exact cause of the accidental firing, the most probable cause appeared to be related to the high-voltage pin in the power plug's being touched to the metal frame and the circuit's being completed through the ground and the firing leads.

The manufacturer of the squibs, Hercules Powder Company, conducted a separate investigation of possible causes of the accident but was unable to find any defect in the squibs, or to locate an exact cause of the accident.

Although the Langley investigation did not find the exact cause of the accidental firing, the tests disclosed that the squibs could be fired in several unexpected ways, and that knowledge prompted some changes in procedure. Whereas, in the past, it had been considered safe merely to short squib leads by twisting them together, now the additional safety measure taken was to connect the leads, the rocket motor case, and the telemeter chassis to a common ground at all times except when in transit. In addition, all squib cases were insulated from the rocket case. The external power supply was moved inside the Control Center and a remote means was used to remove the power plug from the model prior to launch. The internal power switch was also operated remotely. One method is illustrated by figure 121, in which a technician is shown operating the switch with a screwdriver attached to a 10-foot pole. Later, all instrumented models were equipped with a stepping-relay that allowed the operators inside the Control Center to transfer the power at will.

The remote removal of the external power plug was now done by yanking on the connecting cable from a safe distance. Needless to say, one of the first corrective measures taken was to remove the ladder from the mobile launcher. Access to the model now was provided from adjustable mobile

7. Interview with D. A. Dereng at Wallops Island, May 6, 1968.

platforms called aerostands, used around airplanes. Still later, Wallops was to acquire "cherry-picker" platforms for reaching the model.

The committee was concerned that a similar mishap might occur in the telemeter room of the Assembly Shop during checks of a loaded model. The committee recommended, therefore, that a

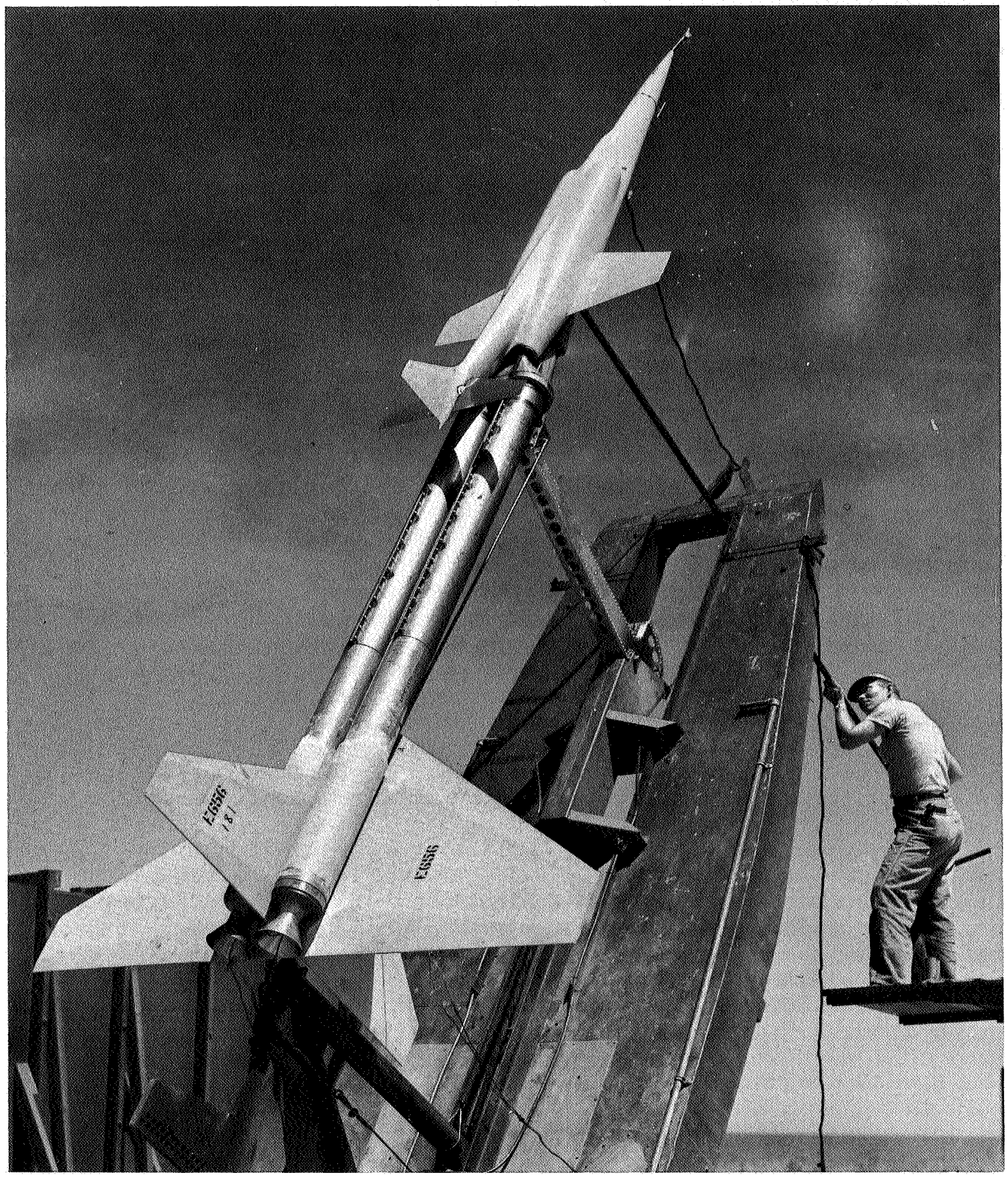


FIGURE 121. Technician George Cutler uses remote 10-foot screwdriver to operate power switch on model of Douglas X–3 research airplane. Model and double Deacon booster are shown on launcher at Wallops, June 13, 1952. A stiffening sleeve encircles each Deacon motor.

device be developed for holding instrumented models containing internal rocket motors while they were being tested in the Assembly Shop. Such a device was installed in the telemeter room of the shop. It consisted of a pipe which could be connected to the rocket motor nozzle, and which could hold the thrust if the motor fired accidentally. The pipe passed through the wall of the building to carry the exhaust outside. A test firing of an HVAR rocket motor in this device was made on October 30, 1951, but it was never to be called upon in actual use.

On July 1, 1953, the most disasterous accident, in terms of the number of people injured, happened when a gasoline explosion and fire occurred on one of the personnel boats while it was loading passengers at the mainland dock. This boat, of the type shown in figure 11, had been converted from a Navy barge into a personnel carrier, with the addition of a cabin. Benches lined the two sides of the cabin, and the gasoline engine was located in the center, under a wood cover.

Safety regulations prohibited passengers from boarding the boat until after the engine had been started. In normal practice, an engine mechanic, usually Sam W. Watkinson, reported 30 minutes early for work and would have the engine running when personnel arrived at the dock at the start of the day. The personnel would sign in at the office on the dock as they arrived, and then board the boat. The research and administrative personnel usually rode one boat, and mechanical service personnel the other. The explosion occurred on the one used by research and administrative personnel. J. E. Robbins, Administrative Officer, was usually the last man aboard because he remained in the office until the last minute, and carried the sign-in sheet with him. The boats were scheduled to leave the dock at 8:00 a.m.

On the ill-fated morning, Watkinson started the engine as usual and, shortly after, personnel started to board the boat as they arrived. After 18 had gone aboard, 13 inside and 5 on the outer decks, the engine stopped. A check revealed that the gasoline tank was empty. After it had been filled, an attempt was made to start the engine. All personnel remained on board since the safety rules did not cover this contingency. The engine failed to start, and Watkinson was called back to get the engine going again. In one attempt to start the engine, it backfired through the carburetor, causing an explosion and setting fire to the entire interior of the cabin. The explosion knocked the men on the decks into the water, and they were unharmed. Four of the men seated inside the cabin near the rear door escaped with minor injury, but the remaining nine people seated near the engine received first- and second-degree burns on their faces, hands, and arms. Watkinson was the most severely burned because, in attempting to start the engine, he had removed the cover and was working directly on the engine. After the personnel left the boat, it was cut loose from the dock to prevent damage there. The boat was pulled ashore later, after being almost completely destroyed by the fire (as shown in figure 122).

All of the injured people were taken to the hospital at Chincoteague Naval Air Station. Of the nine receiving severe burns, eight were transferred to the Marine hospital in Norfolk, Virginia, for extensive treatment. These were Eldred H. Helton, Donald S. Foster, James K. Coleburn, Philbert R.

FIGURE 122. Remains of personnel boat after accidental gasoline explosion and fire that occurred while passengers were boarding at Mainland Dock, July 1, 1953.

Mears, John C. Palmer, Samuel W. Watkinson, Louis T. Birch, and Frank L. Townsend. The ninth, Doris B. Bundick, remained at the Chincoteague hospital. Watkinson, the most severely burned, retired on disability a few months later. All of the others returned to duty, some with severe scarring.

The investigating committee concluded that the cause of the fire was excessive gasoline in the bilge. A leaky gasoline line was suspected, since only 10 trips had been made to the island since the tank was last filled, and normally 14 trips could be made before refilling. Records showed that the carburetor had been removed the day before for repairs. Judging from the location of the flame arrester after the fire, the committee was of the opinion that it had been removed from the carburetor before the accident.

The committee recommended that, in the future, no attempt be made to start such engines if the flame arrester was not in place, and that a better leak detection and ventilating system be installed. In addition, it was recommended that passengers be required to unload before an attempt was made to restart an engine. These recommendations were applied to the remaining personnel boats. The boat destroyed was not replaced because a large ferryboat, powered with Diesel engines, had been procured to replace the LCM boats as well as the personnel boats. The ferry had not been placed in regular service because additional dredging of the channel was required, but it was used intermittently, pending completion of the dredging. (The ferry and associated construction work will be discussed in Chapter 9.) Ironically, the dredge was also an ill-fated vessel for it, too, burned to the waterline at the time the job was nearing completion.

A small fire had occurred on January 20, 1948, on the 104-foot air-sea rescue boat used between Langley and Cape Charles, Virginia (see figure 52). The situation caused the investigating committee of that accident to question the advisability of using gasoline-powered boats of any type. The boat was being used for a special mission at the time of the fire. One LCVP boat and two LCM's, originally obtained from the Navy, had been declared surplus and were being towed from Wallops Island to Langley to be returned to the Navy at Norfolk for survey. The party was about 8 miles off Hog Island, midway between Wallops and Cape Charles on the ocean side, when a short circuit developed in the conduit containing ignition wires leading to two of the three engines. A flash fire occurred around the area but fortunately did not spread to any other part of the boat. After about 2 hours, the damaged wires were spliced, but not before the boat had drifted an additional 8 miles from shore. The boats arrived at the Langley boathouse at 10:45 p.m.

Following this accident, the wiring was replaced by new overhead conduits, because it was believed that the original wiring beneath the deck could have been damaged by salt water. The investigating committee expressed concern over the use of the boat for this mission, and recommended that any towing in the future be arranged by contract. Although no fuel leakage was found, the committee, as an extra precaution with concern for future possibilities, recommended that "a thorough check be made of the tightness of all fuel piping."

On February 15, 1950, another accident occurred on the air-sea rescue boat. On this occasion, the boat was providing assistance to the Air Force in seaplane operations in Chesapeake Bay. Heavy fog was encountered and the boat captain, John Paul, decided to drop anchor. When he thought he had enough cable out, he applied the brake on the drum and the brake band broke. To hold the cable, he put the dog of the winch in the hold position. When he found that the anchor was dragging, he tried to release the dog with the hand crank. The crank handle struck him in the face, bruising his lip and breaking the upper plate of his false teeth. The investigating committee recommended that a power winch be installed.

Wallops experienced several accidental firings of small devices such as pulse rockets and separation mechanisms. Pulse rockets were small rocket motors with right-angle nozzles, typically developing 75 pounds of thrust for 0.08 second. The rockets were used in flight tests to provide a disturbance to a model, so that dynamic stability could be analyzed. In September 1949, such rockets were installed in a "dummy" model of the Douglas X-3 research airplane mounted on a crutch launcher at Wallops. The rockets fired prematurely on the launcher and knocked the model to the ground. It was repaired and flown on September 21, 1949.

On July 9, 1953, two pulse rockets accidentally fired while they were being installed in a model in the rocket loading room of the Assembly Shop. These pulse rockets were to be fired with a longer delay after launching than could be accomplished with the usual time-delay squibs which necessitated the use of a self-contained firing system in the model. As the technician connected the leads to the switch, the pulse rockets fired. Technicians and observers dashed out the door and were able to escape injury. An investigating committee headed by John C. Palmer determined that the technician had wired the battery to the wrong terminals on the switch such that, when the pulse rockets were attached, they were directly connected to the battery, which then fired them. The committee concluded that the immediate cause of the accident was a mistake by the technician; but they found, as contributing factors, the absence of a safety switch, the lack of a wiring diagram, and the lack of a second technician to check the operation (ref. 11). Up to this time, detailed wiring diagrams had not been used. PARD depended upon the rocket technicians' having a complete understanding of all parts of the firing circuits before they began any job. This preparation was considered vital to safety. Later, as the models became more complicated, wiring diagrams were made mandatory.

On April 4, 1955, a circuit design error caused the crash of an airplane being used at Wallops by the contractor in flight tests of the Martin Bullpup air-to-ground guided missile. The NACA was providing assistance in the test, but the air-launched missile was the responsibility of the contractor. The missile was located beneath the right wing of the airplane, a Douglas F3D, and was held to its launcher by a retaining pin. The plan was to retract this pin first and then fire the rocket motor in the missile. At time zero, however, the rocket fired instead of the pin retracting. The pin was supposed to shear in case of such a mishap, but through a design error, it had been made too strong. The 8,000 pounds of thrust of the motor put the airplane into a spin at low altitude. The crew escaped by parachute, but the airplane crashed into the ocean. The missile broke off from the airplane during the violent maneuver and pieces of the rocket motor grain hit the chase plane assisting in the test and became embedded in its fuselage. The contractor "traced the trouble to an 'insidious circuit' which allowed the rocket to fire before a retaining pin had been withdrawn." The crew of the launch plane were rescued from the ocean by a Navy helicopter after about 20 minutes. Both crewmen suffered from exposure in the near-freezing water (43 degrees F). A large number of pieces of aluminum sheetmetal from the wrecked airplane washed ashore after the crash.

A somewhat similar but much less disastrous accident occurred on the launch pad at Wallops on March 28, 1958. A planned second event occurred before the first. A model of the Lockheed Polaris missile nose cone was attached to the front end of a Recruit rocket motor booster by an explosive bolt. Instead of using the normal maypole system for initiating the second event after the booster had moved, the plan scheduled both booster and explosive bolt systems to be ignited at zero time, with a one-second-delay squib in the nose cone attachment. By some freak accident, the Recruit motor had a two-second delay in its ignition. The bolt blew off at one second as planned, and the test model dropped to the ground, followed by ignition of the booster and a good flight of the 'riderless" vehicle. According to the Wallops flight log, the telemeter in the nose cone transmited a good signal during its fall and as it lay on the pad.

Another accidental firing of a self-contained ignition system occurred on November 13, 1958, when a recovery-parachute ejection system fired while contractor representatives from Talco Engineering Company were making adjustments in a Temco Corvus missile in the Assembly Shop at Wallops. Only minor injury resulted.

The most spectacular and heartbreaking accidental firing at Wallops was the premature firing on August 21, 1959, of the escape system on the first Mercury test capsule while it was mounted on its Little Joe booster and was being prepared for launching. By this time, all self-contained systems were powered with Yardney silver-cell batteries that were shorted out at installation and charged a few minutes before launch, after the area had been cleared of personnel.

The Little Joe capsule contained a battery-powered programmer that would initiate planned sequences in the flight, if all went well. The programmer included a rapid-abort sequence and a booster-destruct system, with its own batteries, in order to save the capsule in case of a malfunction. The abort sequence could be activated by radio command from the ground. This sequence would initiate separation of the capsule from the booster, ignite the escape motor, jettison the tower, deploy the drogue chute, and then deploy the main chute, which would lower the capsule into the ocean for recovery. This rapid-abort system was connected to the destruct system with a 1.6-second delay, so that the capsule would have time to get away from the booster before destruction. In case of a radio command to start the rapid-abort system, destruct would follow 1.6 seconds later without further command.

On the fateful morning, while the programmer and destruct batteries were being charged in preparation for launching, the escape rocket suddenly fired and pulled the capsule off the booster and out to sea. Observers watched the capsule in its path through the air, hoping that the main chute would open. This did not happen, however, and the capsule crashed into the ocean. A large number of men from Langley had been working with the Wallops crew around the clock to get this first Mercury flight ready. A large number of Space Task Group personnel also were on hand to witness the test. Disappointment was particularly keen because the Mercury program had experienced delays, and NASA was counting on the usual high reliability of Wallops' solid-rocket motor tests to help restore prestige to the project.

The capsule was recovered from the ocean floor by divers several days later. Examination revealed that the rapid-abort escape system had been activated and all sequences had been followed except the last, which was to have been the firing of an explosive bolt to release the antenna section and deploy the main parachute. Apparently, the batteries were not charged sufficiently to last through this event.

Following the accident, an investigating committee made an analysis of the wiring diagram for the rather complicated electrical circuit with its interconnected systems. The analysis revealed that when the rapid-abort escape system had been interconnected with the destruct system, one of the power leads from the internal battery had been routed to the solenoid coil (that armed the destruct system) along a path that also led to the power terminal of the rapid-abort plug (ref. 12). The error was clearly in the design of the system, and was corrected for subsequent firings by relocating a single wire.

The error was not detected during a dress rehearsal dry run during which the various events were simulated by the firing of match squibs. Examination after the run showed that all squibs had fired, but the fact that some had fired early was not detected. An electrical check of the systems in a different test revealed continuity between the terminals of the rapid-abort system and those of the delay-destruct arming bars. This was a clue to the impending trouble and was questioned until it was found to be in accordance with the wiring diagram. It was concluded that it would not endanger the destruct system, but the fact that it would lead to a premature firing of the rapid-abort escape system during battery charging was not appreciated.

Stringent procedures to prevent future occurrences were strongly recommended by the investigating committee. At Langley, the major change made was in regard to responsibility for electrical circuits on the larger flight projects. Divided responsibility between Engineering Services and IRD was replaced by a responsibility given to the Langley Electrical Engineering Division not only for the design but also for the installation and checking of electrical circuits.

Despite the almost daily flights of airplanes between Langley and Wallops, there was only one accident of any consequence and this resulted in no serious injuries. On November 3, 1954, the Grumman JRF-5 amphibian was making a normal flight from Langley to Wallops Island with James B. Whitten as pilot. Immediately after the amphibian had touched down on the creek just back of the island, a strong gusty crosswind from the right rolled and turned the plane off its course and caused it to crash into the island dock. This was the fourth JRF-5 amphibian used by Langley and the 896th trip made to Wallops with this type of airplane.

Although the airplane was badly damaged, as shown in figure 123, all passengers and the crew evacuated through the door and over the wing to the dock. Whitten received a bruise on his right arm, and one passenger, M. W. McGoogan, received a bloody nose from striking the seat ahead of him.

The investigating committee concluded that the accident was caused by the fact that, without the pilot's knowledge, the wind velocity had increased considerably above the nominal safe value of 25 knots previously established for crosswind landings (ref. 13).

NACA MANAGEMENT CONTROL INFORMATION SYSTEM

During the first 30 years of the existence of NACA Headquarters, its control over research conducted at the several NACA laboratories was rather informal. Individual researchers were allowed considerable freedom in conducting experimental and theoretical investigations of their own, with only local

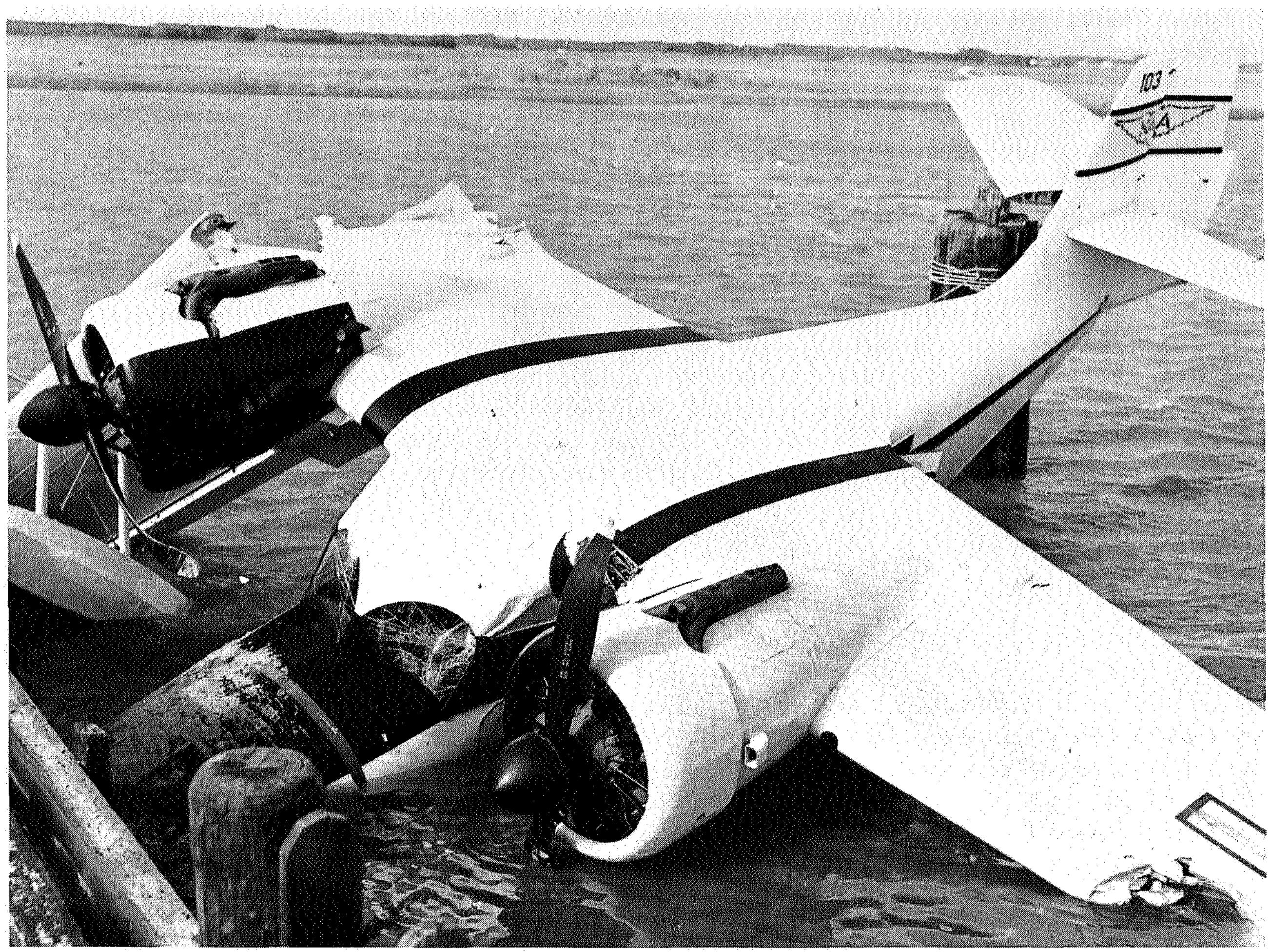


FIGURE 123. Grumman JRF–5 amphibian after accidental crash into Wallops Island Dock during landing run, November 3, 1954.

laboratory approval, provided that they were generally related to certain specified areas of need. Such investigations were charged to rather broad, general Research Authorizations (RA's) issued by Headquarters, and the number of RA's for general research was kept intentionally small. A separate RA, however, was issued for each specific request for assistance by a military service, as a means for giving approval and formalizing the work. In the preceding chapters of this history, these early RA's—simple chronological numbers—have been given for most projects.

By 1951, the NACA had grown to such an extent that Headquarters decided tighter control of all research was desirable. In addition, the need for relating all work to specific advisory committees and their subcommittees was appreciated. To meet these needs, the old RA system was abolished on June 25, 1951, and was replaced by the Management Information Control System (MCIS) (ref. 14). Under this system, a new series of RA's was issued with an identifying number coded to show the laboratory and committee involved. Since any work on a research project was charged to an RA through appropriate job orders, it was now possible to analyze research effort in terms of the committee structure.

Under this new system, a separate RA was issued for each specific military request as before; but, in addition, a separate RA was now required for the smallest unit of a project. Since each RA required NACA Headquarters approval, Langley no longer had the freedom of operation it had enjoyed for so long. Adoption of the new system marked the beginning of an ever-increasing flow of paper between Headquarters and the laboratory.

Because of the large number of RA's now required to define the general research, no attempt to reference them will be made in the following chapters. The RA issued for a specific work request, however, will still be referenced as a source of initiation of such a project.

The coding structure of the new system is shown by a typical RA. For example, in RA A22L14, A signifies that the work is related to the Aerodynamics Committee. The first 2 shows that the work comes under the Stability and Control Subcommittee, while the second 2 indicates some specific phase of the subcommittee's interest. L represents Langley, and 14 indicates the fourteenth RA issued under this subcommittee.

The other three committees were identified in a similar manner—P for Committee on Powerplants for Aircraft, C for Committee on Aircraft Construction, and O for Committee on Operating Problems. Each of these committees had from three to eight subcommittees. Although most of the research at Wallops came under the Committee on Aerodynamics, the ramjet engine research was conducted under the Powerplants committee, and the Aircraft Construction Committee had cognizance over research on flutter, loads, structures, and materials. While this new system might appear to give the committees and subcommittees more control over Langley research, actually the relationship between the laboratory and the committees remained unchanged. Sometimes it was difficult to select the appropriate committee or code letter for the RA covering some of the research at Wallops because of the dual objectives of the tests, particularly those involving complete airplane models.

NORTHROP SNARK SUBSONIC STRATEGIC GUIDED MISSILE

A rocket-model program involving 1/14-scale models of the Northrop Boojum (MX-775B) supersonic strategic guided missile has been discussed in Chapter 7. Northrop was developing the Snark (MX-775A) subsonic strategic missile at the same time, and early in 1950 the need for rocket-model tests of the Snark was recognized as well. Although the Snark was essentially a subsonic missile, one flight plan called for the missile to attain transonic speeds in a final dive on its target from high altitude. On March 23, 1950, the Air Force requested a free-flight program by the rocket-model technique, and the NACA issued RA 1564 on April 17, 1950, to cover the investigation.

The purpose of the investigation was "to determine the drag, roll, and pitch characteristics at transonic and low supersonic velocities." From four to six 1/12-scale models were authorized, to be built by Northrop Aircraft Inc. Actually, the models were 1/10-scale and eight models were tested, two of which were of the fuselage alone.

The first model was launched on November 15, 1950, and the last on June 4, 1954. All flights were successful. The later firings were made during the period of flight development of the full-scale missile at Cape Canaveral, and for these firings the models were modified to incorporate changes proposed for the actual missile.

The Snark was to be the nation's first intercontinental strategic missile, and it served as an interim weapon while ballistic missiles were under development. The Snark first attained its design range of 5,000 miles on October 31, 1957, and became operational in April 1959. It was 69 feet long, had a wing span of 42 feet, weighed 60,000 pounds, and was powered by a Pratt and Whitney J57 turbojet engine. Two Aerojet 130,000-pound-thrust solid-rocket motors were used as boosters to make launching from a zero-length launcher possible. The Snark contained a stellar-monitored inertial navigation system and could enter the target area from any direction at either low or high altitude (refs. 15, 16, and 17).

The 1/10-scale rocket models, which weighed 80 pounds, were propelled to a Mach number of 1.39 by single Deacon boosters. To avoid structural divergence of the model-booster combination with this rather long model, the Deacon motor case was stiffened by the addition of a steel sleeve around the aluminum case. The sleeve can be seen in figure 124, a photograph of the first Snark model. In the two tests of the fuselage alone (plus three stabilizing fins), a 65-inch HVAR was used as a booster.

As can be seen in figure 124, the Snark missile was a tailless design, a trademark of Northrop in this period. The missile consisted of a fuselage of fineness ratio 13, a 45-degree sweptback wing of 6 percent thickness streamwise and an aspect ratio of 5.5, and a single vertical tail.

The first test was to determine the drag. The complete model contained a six-channel telemeter that transmitted measurements of accelerations and pressures. The model used to evaluate fuselage drag contained a four-channel telemeter. The first test showed that the Snark was a reasonably good transonic design in that no abrupt changes in trim were noted and the drag rise Mach number was 0.96.

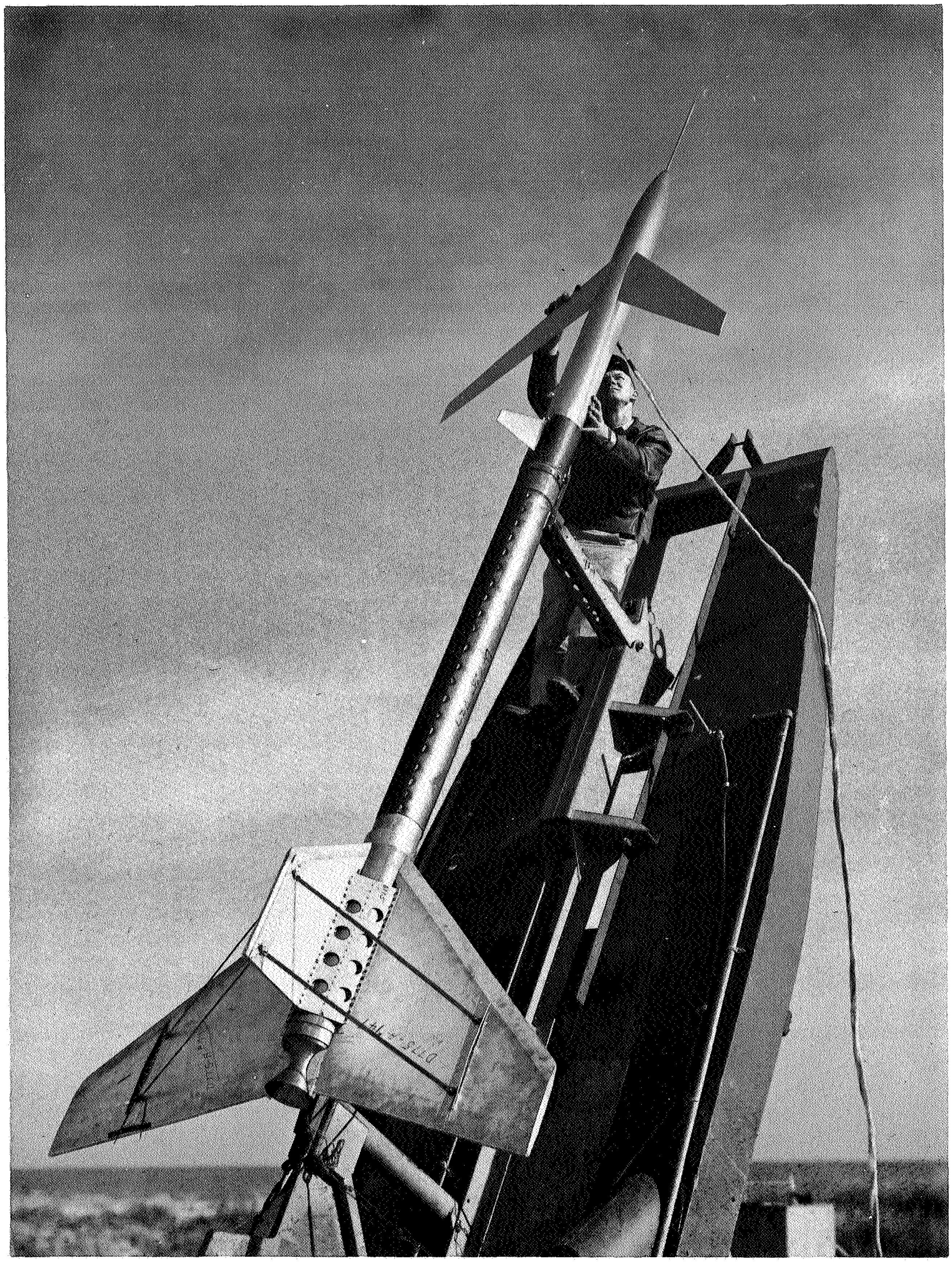


FIGURE 124. Technician D. A. Dereng examines power plug in 1/10-scale model of Northrop Snark missile at Wallops, November 15, 1950. The Deacon booster shown with the model has a steel sleeve encircling the motor case.

The drag coefficient at the highest speed reached (Mach 1.39) was 0.034, of which 55 percent was contributed by the fuselage (ref. 18).

Following this first test, the fineness ratio of the nose of the fuselage was increased from 3 to 4 to reduce the fuselage drag. (The overall fineness ratio was increased from 13 to 14.) All of the remaining models had this modification. On the average, this change reduced the drag coefficient by about 0.002.

The next series of models was flown to study longitudinal stability. Five pulse rockets, producing 475 pounds of thrust each for 0.04 second, were mounted in the fuselage behind the wing and were exhausted upward. The disturbances in pitch caused by these pulse rockets allowed an evaluation of static and dynamic longitudinal stability as well as the drag under lifting conditions. An angle-of-attack indicator was mounted on a sting protruding from the nose of the model. As a byproduct, lateral oscillations were also induced, from which the directional stability was evaluated. The firing of these large pulse rockets in earlier tests had disrupted the telemeter. As a part of the calibration procedure for the present tests, the model was supported by shock cords in the laboratory, and a pulse rocket was fired while the telemeter was operating. This time, the telemeter was not affected because its chassis was now attached with special shock-absorbing mounts.

Two models were flown in this series, one with a solid aluminum wing and the other with a steel wing. The wings of different stiffness were flown to allow corrections to be made for aeroelasticity, so that the true aerodynamic characteristics for a rigid wing might be determined. With the aluminum wing, it was found that the static stability was greatly increased by aeroelastic effects, the aerodynamic center being some 15 percent of the wing chord farther forward in the test than the corrected value for a rigid wing. Corrections for the aluminum wing were made from static loadings of the wing to determine structural influence coefficients in conjunction with a modified strip theory (ref. 19). The test with a steel wing showed only a 6-percent shift in aerodynamic center, compared with the rigid condition (ref. 20).

During development trials of the full-scale missile, a pitch-up tendency at even moderate lift coefficients was found to interfere with its mission. Such a pitch-up characteristic was to be expected from this 45-degree sweptback wing of aspect ratio 5.5, according to a correlation made by J. A. Shortal and B. Maggin in 1946 (ref. 21). Several modifications to the wing were made as part of an attempt to overcome this fault. Two of the modifications were tested in the rocket-model program. The first consisted of the addition of leading-edge chord extensions on the outer wing panel, and inboard trailing-edge flaps. The outer extensions were drooped 7 degrees, and the inboard flaps were deflected 5 degrees downward. This was one of many arrangements studied in a wind-tunnel program whose aim was to develop additional lift under trimmed conditions without going to a high angle of attack, and thereby to avoid the pitch-up region. This modification was also the one made on the actual missile.

Two rocket models with this modification were tested, one with a solid aluminum wing (ref. 22), and the other with a solid steel wing (ref. 23). In these tests, a combination angle-of-attack and angle-of-sideslip vane, developed by IRD at Langley (ref. 24), was used. Again, pulse rockets were used to disturb the models in pitch. The tests verified that increased lift could be obtained at low angles of attack with this modification, and the increase in drag coefficient at supersonic speeds was not excessive (from 0.034 to 0.041); but rather severe vibrations were encountered, which were believed to be due to flow separation over the modified wing. The data were not corrected for aeroelastic effects, but the structural influence coefficients were determined and made available to the manufacturer.

DOUGLAS X–3 RESEARCH AIRPLANE

Tests of six rocket models of the first design of the Douglas X-3 (XS-3) airplane have been described in Chapter 6. The models were flown at Wallops between August 1947 and April 1948. Following a complete redesign of the airplane, six additional models were constructed. Five of these were flown at Wallops between January 1950 and December 1953. The sixth was used in a wind-tunnel program at Langley.

In this new version of the airplane, the center section of the fuselage consisted principally of two side-by-side nacelles with individual inlets and exits, mounted on the wing behind the pilot's canopy. A rather massive tailboom emerged from between these siamese nacelles to support a conventional tail at the rear. The fuselage ahead of the engines was long and sharply pointed. In fact, the airplane was sometimes referred to as the "flying stiletto." The wing was unswept, had a taper ratio of 0.4, an aspect ratio of 3, and a modified hexagonal section, of 4.5-percent thickness. This was a Mach 2 design, but the intended J46 turbojet engines were never developed. With two J34 engines, the maximum speed attained in flight was a Mach number of 1.21, and this was in a dive.

The rocket models of this final design of the X-3 airplane were constructed by Douglas Aircraft Company of cast magnesium and aluminum alloy. Prior to the first test of one of these models, a dummy wooden model was constructed at Langley for tests of the Deacon booster system. Because of the unconventional tail-boom design, a special adapter was required to transmit the thrust and bending loads. It consisted of two plugs which fitted into the jet exits, and an integral, shovel-type fitting which was attached to the bottom of the fuselage ahead of the exits. This can be seen in figure 125, which is a photograph of the first regular model tested. The flight of the dummy on September 21, 1949, indicated that the booster was satisfactory. The 130-pound model reached a Mach number of 1.34 (ref. 25).

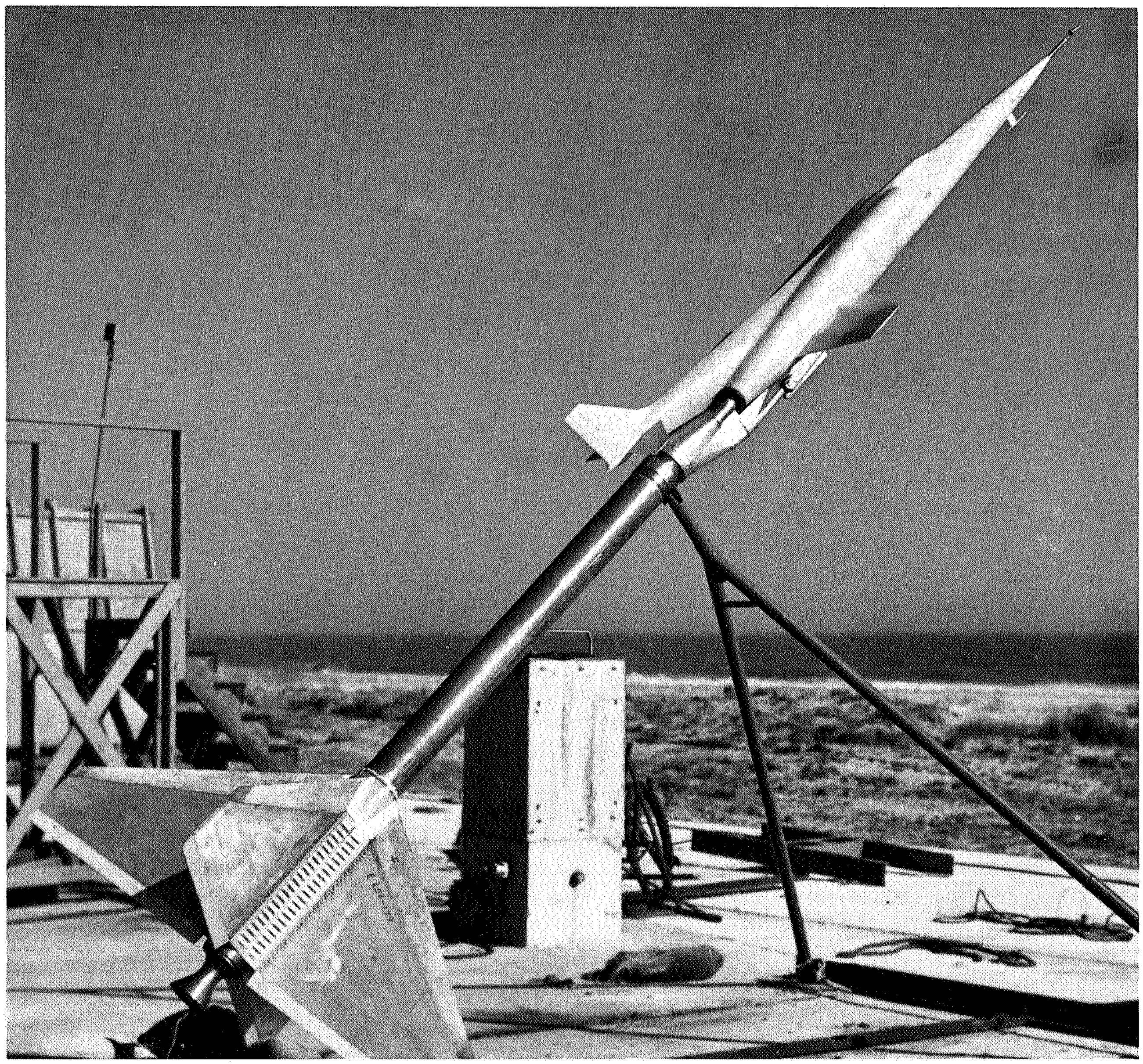


FIGURE 125. View of 0.16-scale model of Douglas X–3 research airplane, mounted with Deacon booster on crutch launcher at Wallops, January 25, 1950.

The first regular model, launched on January 25, 1950, contained a system for pulsing the all-movable horizontal tail between stops in a square-wave pattern to allow a determination of longitudinal stability between a 0-degree and 3-degree angle of attack. The dual air inlets and ducts were open and were designed for the correct mass flow, appropriate to powered flight. A seven-channel telemeter transmitted total pressure; static pressure; normal, transverse, and longitudinal accelerations; angle of attack; and horizontal tail position. From these measurements, the following aerodynamic characteristics were determined over the Mach number range of 0.65 to 1.25: lift-curve slope, total drag at different lift conditions, static longitudinal stability, pitch damping, horizontal tail effectiveness, and directional stability. The model was stable throughout the speed range and showed only a small transonic trim change. The drag coefficient was about 0.030 at subsonic speeds and 0.072 at supersonic speeds, with the drag rise beginning at a Mach number of 0.92 (ref. 26).

The second model of the X-3 was flown on November 16, 1950, and differed from the first model only in the horizontal tail settings. With this model, the tail was pulsed over a higher deflection range to cover high angle of attack operation. At transonic and low supersonic speeds, the results were in agreement with those obtained with the first model except that higher angles of attack were covered and some high-angle buffet was noted. A very surprising and unsatisfactory condition was encountered after the model slowed to a Mach number of 0.70. At this speed, when the tail was deflected to the high-lift condition, the model pitched up beyond the stall and executed a violent rolling oscillation which resembled a "falling-leaf" maneuver. This was followed a few seconds later by a continuous rolling motion while at a high angle of attack. The condition persisted, despite deflection of the control to the low-lift setting, until the Mach number was reduced to 0.25. This was considered to be a dangerous situation for the actual airplane (ref. 27).

An extensive wind-tunnel investigation of this high-angle instability was made in the Langley 300 MPH 7-foot by 10-foot Tunnel (ref. 28) and in the Langley Spin Tunnel (refs. 29 and 30). Following the investigation, the horizontal tail of the airplane was increased in area by 40 percent, and its aspect ratio was increased from 3.0 to 4.3. The remaining rocket models were fitted with this larger tail.

The third rocket-model test, on June 25, 1951, was unsuccessful because of structural failure of the booster fins. As a result, plans were made to test the remaining models at higher speeds, using double Deacon boosters. A 1/2-scale model of a tandem double Deacon design had been flight-tested on December 7, 1950, and next a full-sized dummy was prepared for test. This was flown on January 23, 1952, but the adapter failed. The fourth regular model was flown with a strengthened version of this booster, shown in figure 121. With this booster, a Mach number of 1.43 was reached with the 160-pound model. The flight was not made until June 13, 1952, but it was in time to provide confidence for the first flight of the airplane on October 20, 1952. The rocket-model test indicated that the new tail had corrected the high-angle instability in pitch and provided the same type of general aerodynamic data obtained earlier. As expected, the drag was somewhat higher with the larger tail (ref. 31).

An attempt was made to obtain even higher speeds by using a "piggy-back" arrangement of two Deacon motors as a booster, as shown in figure 126. Although the takeoff of this dummy model was spectacular and appeared to be successful, the telemeter failed after launch.

For the flight of the last model in this program, the researchers returned to a single Deacon booster. By this time (December 16, 1953), a new series of externally braced booster fins had been developed. These fins were made from aluminum-core honeycomb panels. The flight was successful, but a Mach number of only 1.1 was reached. The purpose of the test was to investigate lateral stability. Six pulse rockets, developing 75 pounds of thrust each for 0.08 second, provided disturbances in the yaw plane. Lateral stability derivatives were determined by a vector analysis procedure that yielded good results. The only anomaly in the findings was a sustained "snaking" oscillation in yaw of about 1-degree amplitude at Mach 0.7, which persisted after an initially damped oscillation (ref. 32).

Flight tests of the full-scale airplane at the NACA High-Speed Flight Station did not show this snaking oscillation but did show a pitch-up tendency at high angles of attack, although it could be controlled by the pilot. "Comparisons showed that flight data, rocket-model data, and wind-tunnel data exhibited similar trends and good quantitative agreement" (ref. 33).

Two additional rocket-model tests were related to the X-3 program in that the X-3 wing was used. The first of these was associated with the E17 large-scale drag program. The wing in this case was

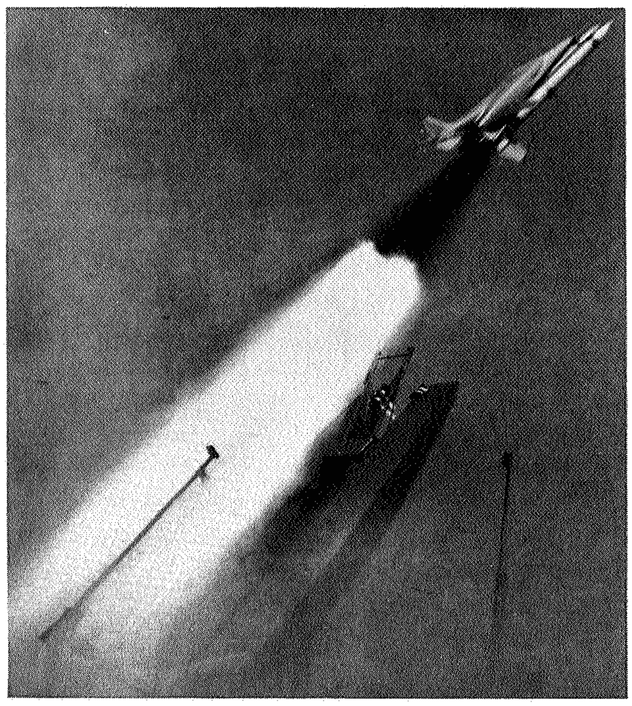


FIGURE 126. Launch of Douglas X–3 research airplane model at Wallops on June 15, 1953. An underslung double Deacon booster was used.

almost twice the size of the one on the complete model, and the data were, therefore, more nearly applicable to the full-scale airplane. Despite the large size, a single Deacon motor mounted internally was able to propel the model to a Mach number of 1.6. The wing drag was estimated from the test by subtracting body drag from the total. This 4.5-percent-thick, unswept, tapered wing with sharp leading and trailing edges had a subsonic drag coefficient of 0.010, which increased sharply to 0.027 at Mach 0.98 and then decreased to 0.013 at a Mach number of 1.6. The low supersonic drag agreed well with theory (ref. 34).

The second supplementary test of an X-3 wing dealt with rolling effectiveness of the ailerons as determined by the E5 technique. Two tests were made, one with a steel wing and the other with an aluminum wing. There was little difference between the results for the two wings, indicating small aeroelastic effects. In either case, the rolling effectiveness dropped rapidly at supersonic speeds, being only 20 percent of the subsonic value at a Mach number of 1.95, but in good agreement with theory (ref. 35).

ADDITIONAL TESTS OF CONVAIR XF–92 AIRPLANE

The first tests of rocket models of the Convair XF-92 airplane have been discussed in Chapter 6. Two additional flight tests were made in 1950, one with a faired nose and the other with a large nose inlet. With the model having the faired nose, a double Deacon booster was used to obtain higher speeds than those obtained earlier with a single Deacon. The pulsed control technique was used, the primary purpose of the test being to obtain drag under lifting conditions, although longitudinal stability characteristics were also secured. Figure 127 shows the model on the mobile launcher at Wallops. The nose shape more nearly represented the XF-92A airplane with its small nose inlet than it did the original XF-92 design. Despite the very large cantilevered fins required on this booster, a Mach number of 1.70 was attained. Some buffet was noted at high lift in the transonic range, and extensive drag data due to lift were obtained. Otherwise, the results agreed with those of earlier tests at the same Mach number, but extended the data to higher speeds (ref. 36).

In the second test, another attempt was made to obtain data with a model representing the original XF-92 airplane with its large, external-compression, nose inlet. The purpose of this test was to obtain drag and inlet characteristics. Prior to the flight test, a calibration of the flow inside the duct was made in the Preflight Jet at Wallops, at Mach numbers of 0.71 and 1.4. In figure 128, the model is shown

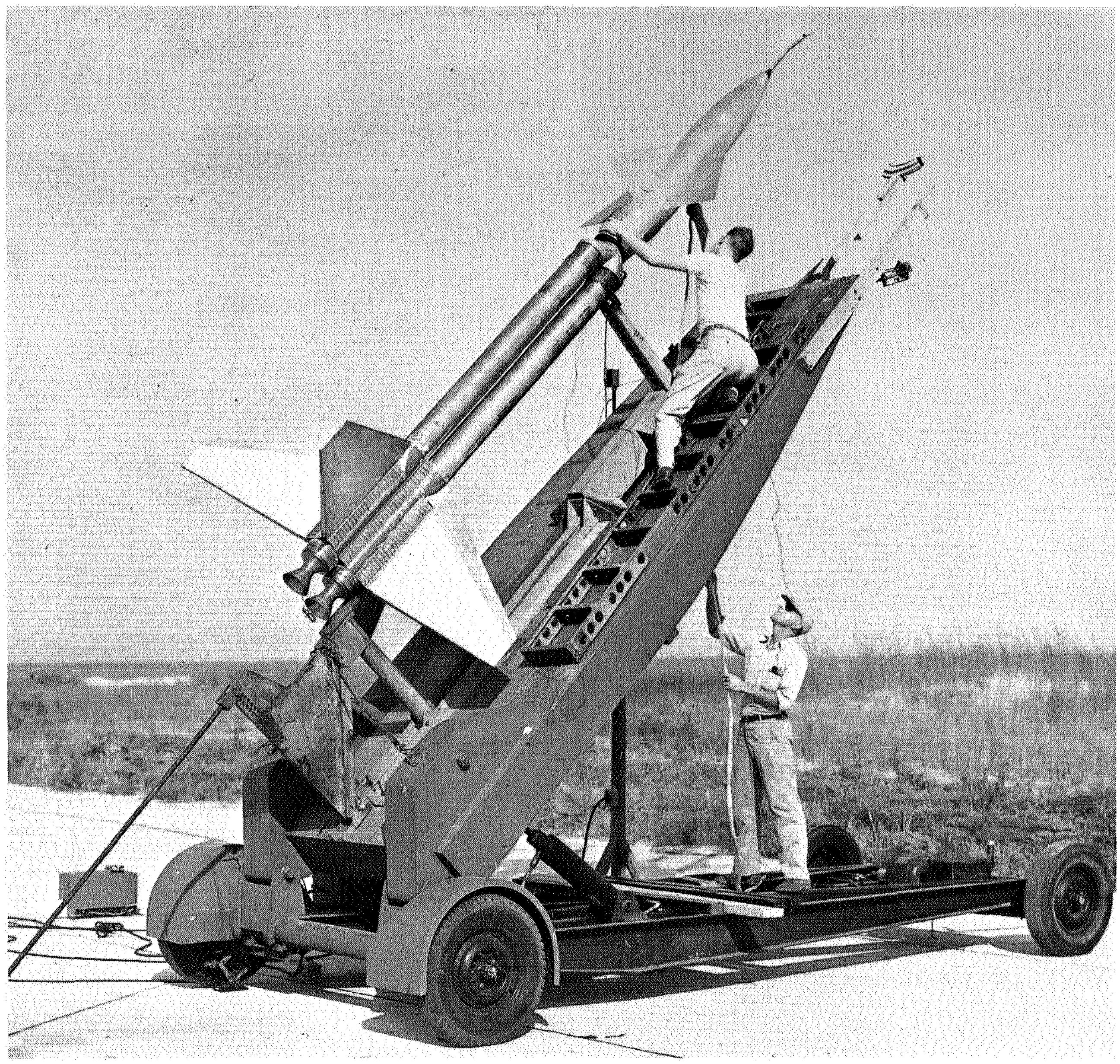


FIGURE 127. Engineer J. E. Stevens prepares to remove external power plug from model of Convair XF−92 airplane, as technician Joe Smith holds cable. The model is shown with its double Deacon booster on launcher at Wallops, August 31, 1950.

mounted in the 12-inch Mach-1.4 open jet. The 27-inch nozzle was used for the tests at Mach 0.71. In the flight test, the model was launched from the mobile launcher and was propelled by a single Deacon booster to a Mach number of 1.45. The total drag of this model was considerably higher than that of the model with a faired nose, even after internal drag had been deducted. The pressure recovery of the inlet varied from 94 percent at subsonic speeds to 91 percent at the highest speed (ref. 37).

SUPERSONIC BODY-DRAG RESEARCH INCLUDING JET EFFECTS ON THE BASE DRAG

After the specifications for low-drag wings for operation at supersonic speeds had been well defined by PARD rocket-model programs at Wallops, attention was centered on obtaining a better understanding of body drag, including various shape effects. In addition, the effect on base and afterbody pressures of a jet exhausting from the rear of the body was given detailed consideration. The greater part of the

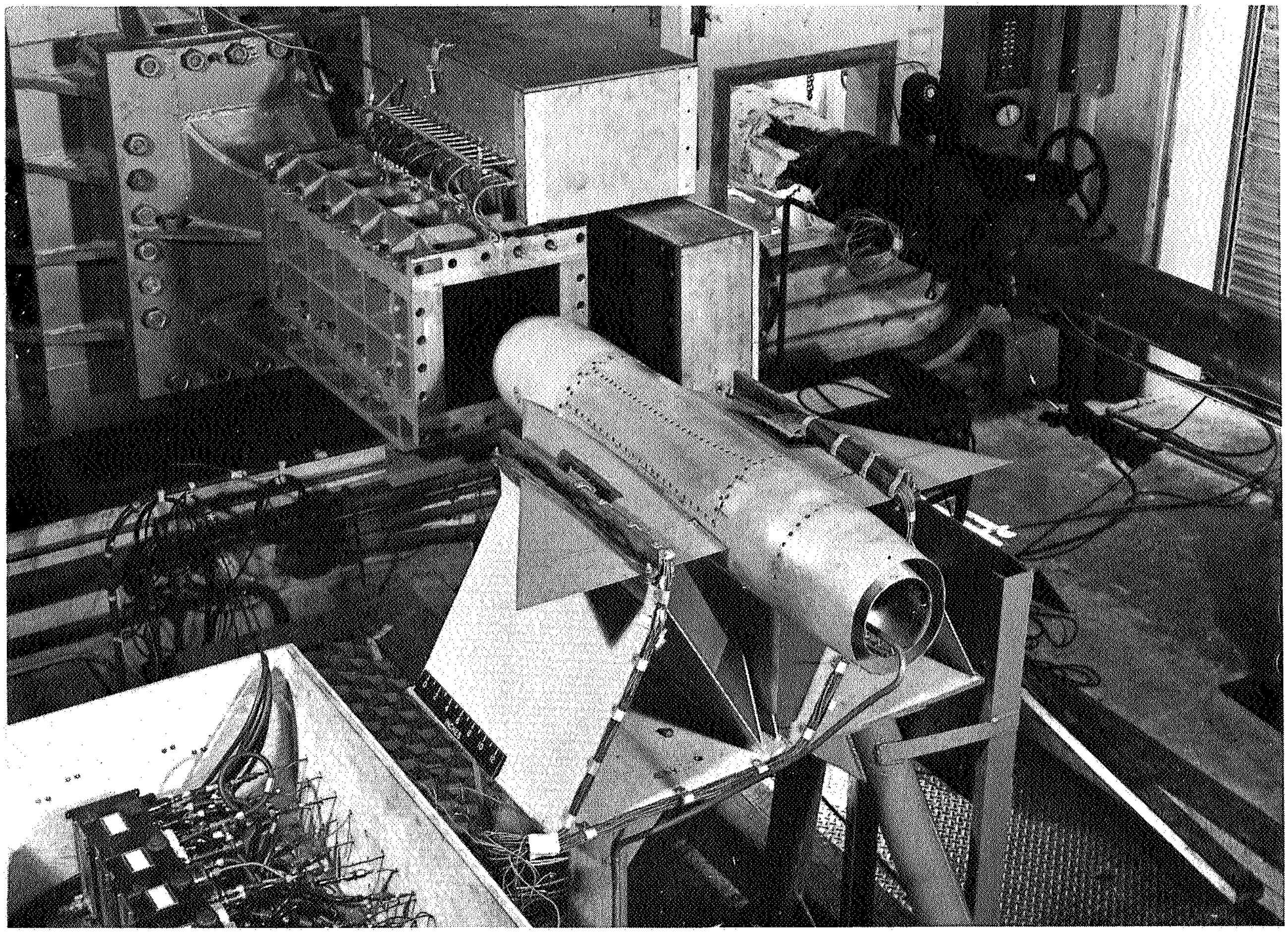


FIGURE 128. View of 1/8.25-scale model of Convair XF–92 airplane, mounted in 12-inch Mach 1.4 open jet at Wallops for inlet and duct calibration, September 27, 1949.

research on bodies was conducted with the basic E2 vehicle, but some exploratory work was done with Helium-Gun models, designated E30.

One of the basic parameters governing body drag at supersonic speeds was fineness ratio, which was analogous to the reciprocal of thickness ratio for wings. Although fuselages with a fineness ratio of 6 were commonly used along with the equivalent 16-percent-thick wings in subsonic aircraft design, when wing thicknesses were reduced to approximately 5 percent for supersonic aircraft, designers were reluctant to increase the fuselage fineness ratio to the corresponding value of 20. In most cases, therefore, the fuselage became the principal source of drag at supersonic speeds. Increasing fineness reduces the slope of the surface of a body and consequently reduces the pressure drag, a major source of drag at such speeds.

An earlier E2 body-drag program, discussed in Chapter 5, provided designers with aerodynamic data on parabolic bodies with fineness ratios of 6 to 12.5. These results showed that drag for a given volume was decreasing at the highest fineness ratio tested. As an extension of this program, parabolic bodies of fineness ratio 17.78 and 24.5 were now tested. Both bodies had their maximum diameter at the optimum location of 0.6 length determined in the earlier program, and both bodies had a small blunt base to accommodate the exit nozzle of the internal rocket motor. Three stabilizing fins were employed. The models were propelled to a Mach number of 1.5 by a two-stage rocket system, consisting of a lightweight HVAR booster and a 65-inch HVAR internal sustainer with a blast tube. In figure 129, the test model of fineness ratio 24.5 is shown being fitted to its booster on the rail launcher at Wallops.

Figure 130 shows the results of the tests for a typical Mach number of 1.4. Drag coefficients are plotted against fineness ratio with the data from the previous tests also shown for comparison. The data are presented two ways: as coefficients based on frontal area, C_{D_A}, and as coefficients based on volume raised to 2/3 power, $C_{D_{V^{2/3}}}$. Optimum conditions for a given frontal area or volume are thereby

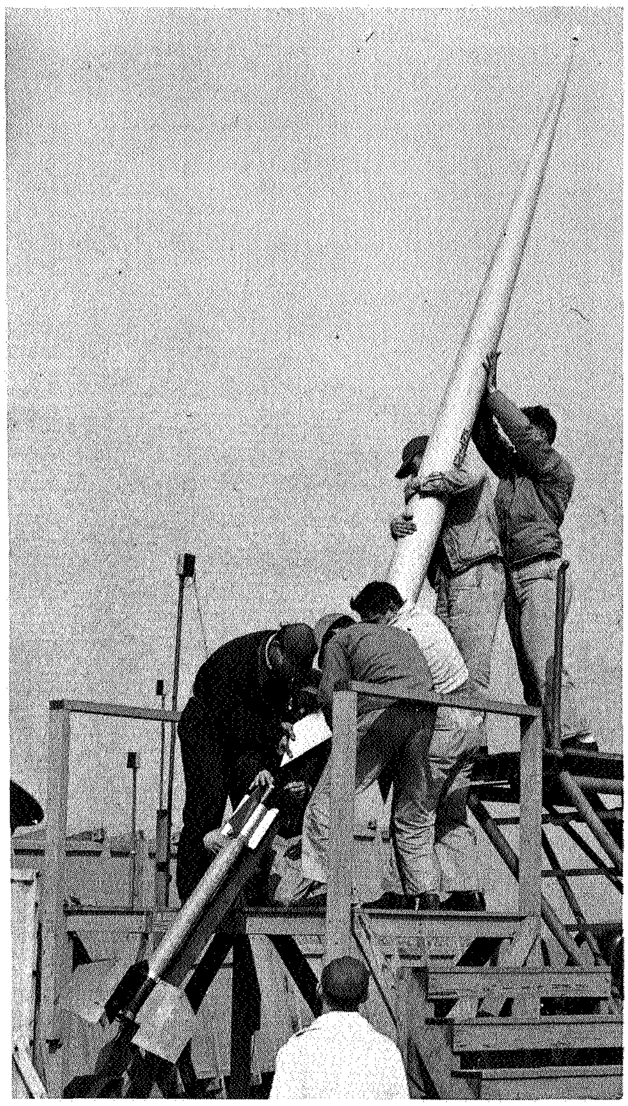
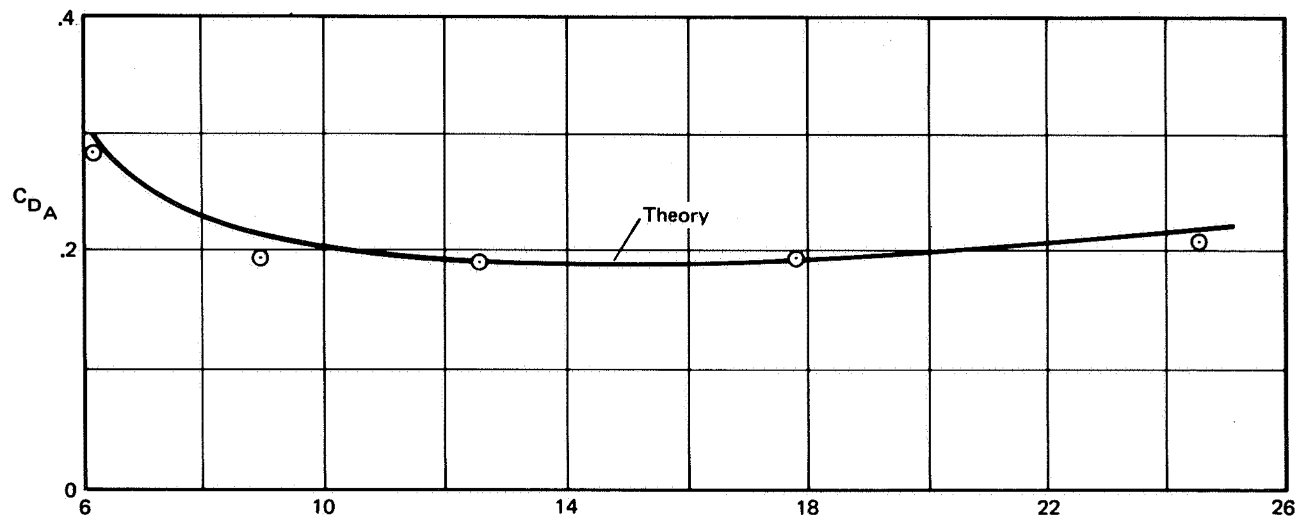


FIGURE 129. Work crew prepares to connect E2 parabolic body of fineness ratio 24.5 to its booster on the rail launcher at Wallops, May 18, 1950.

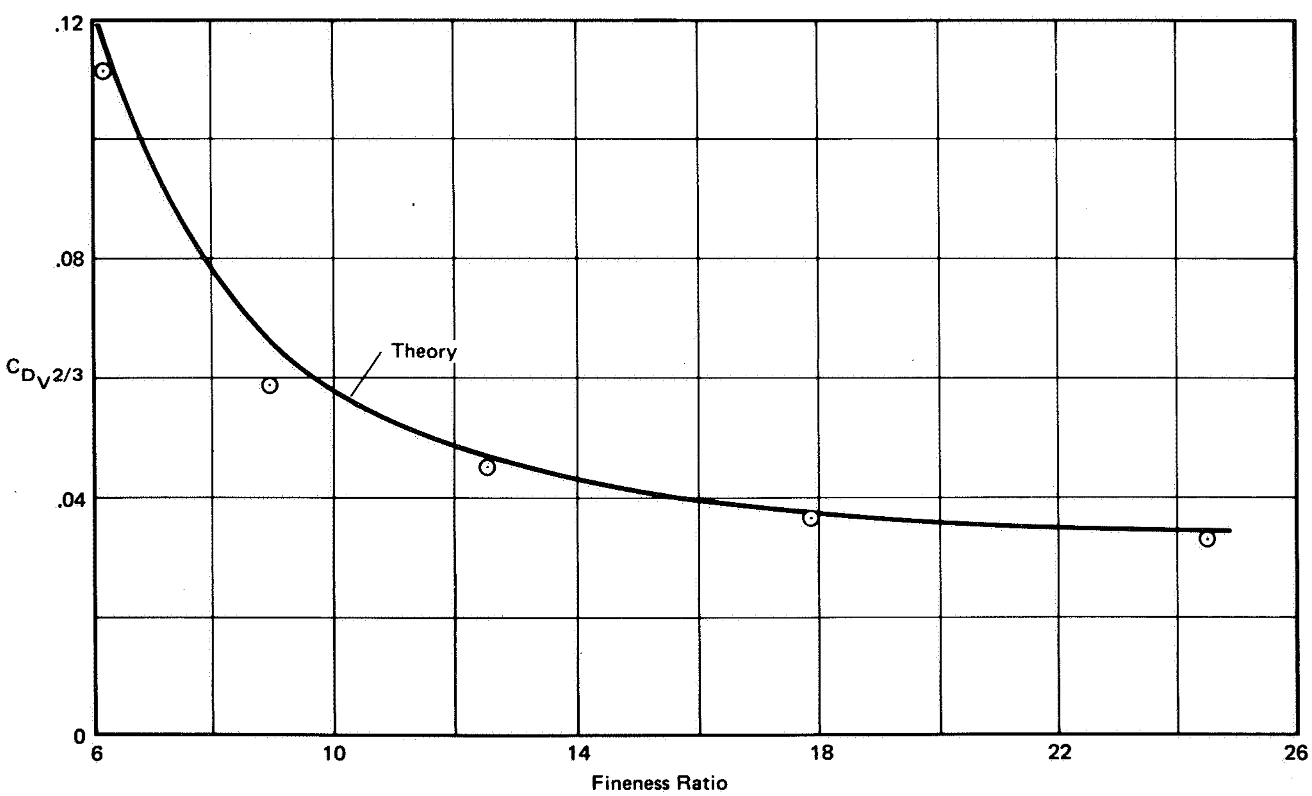
shown. For a given frontal area, it can be seen in figure 130 (a) that the optimum fineness ratio was found to be about 15, with a drag coefficient of 0.19. Of this value, 0.05 was attributed to the three stabilizing fins, leaving a net drag coefficient for the optimum body of 0.14. This was believed to be about the lowest drag coefficient attainable for parabolic bodies, a noteworthy finding of the rocket-model program.

Designing a body for a given frontal area assumes that certain equipment, such as engines and landing gear, dictate a minimum diameter. If, however, volume was the only consideration in the design of a fuselage, the optimum fineness ratio was found to be quite different. As shown in figure 130 (b), by the drag coefficients based on volume$^{2/3}$, the optimum fineness ratio was greater than the highest tested (24.5). This finding was significant in its indication that designers need not hesitate to consider extremely long fuselages if the general layout of the aircraft will allow it. Note also that the drag of a body for a given volume with a fineness ratio of 24.5 was only one-third that of a body of fineness ratio 6. Figure 130 also shows that the experimental results were in good agreement with theory (ref. 38).

Two high-fineness-ratio bodies of cone-cylinder design were also tested. Although the conical sections of these bodies had a low slope (4 degrees), the fact that cylindrical sections had been inserted between the cones to obtain the high fineness ratios, caused them to have higher drag than the corresponding parabolic bodies, by approximately 14 percent.



(a) Drag coefficients based on frontal area



(b) Drag coefficients based on volume$^{2/3}$

FIGURE 130. Graphs of data from Wallops rocket-model tests showing effect of fineness ratio on drag of optimum parabolic bodies at Mach 1.4. Maximum diameter at 0.60 of total length.

Although the program just described allowed the selection of minimum-drag bodies having parabolic shape, these bodies did not necessarily have the shape with lowest drag. Several other nose shapes had been developed theoretically as optimum. PARD researchers Robert L. Nelson and William E. Stoney, Jr., set about to determine experimentally if other shapes would, in fact, have lower drag. A large number of models were launched from the Helium Gun at Wallops for this purpose. In order to magnify the effects of detail shape, a nose fineness ratio of 3 was selected for the tests.

Comparisons were made of a simple cone; the parabolic shape discussed earlier, which had its vertex at the point of maximum diameter; a new parabolic shape having its vertex at the nose and defined by $X^{1/2}$; the hypersonic optimum $X^{3/4}$ nose; the von Kármán nose; and the L-V Haack nose. The tests showed that for speeds up to Mach 2, the $X^{1/2}$ nose was the best choice for overall performance. This shape had a positive slope at the point of maximum diameter, a characteristic which was in accord with new theoretical concepts at Langley. Attempts to capitalize on this new shape by applying it to bodies of high fineness ratio, however, were unsuccessful. In fact, such bodies had higher drag than the earlier minimum-drag parabolic shapes. The researchers believed that the positive slope of the $X^{1/2}$ nose at its junction with the remainder of the body must have caused unfavorable interference (refs. 39 and 40).

Nelson and Stoney were successful in correlating the large collection of data on drag of bodies in the transonic range. They showed that the drag-rise Mach number was related to the fineness ratio of the shortest body component, and that the Mach number for peak drag coefficient was dependent upon the nose fineness ratio and shape. They developed a factor with which the pressure drag of bodies of various shapes could be correlated. They emphasized, however, that high fineness ratio was a major element in providing low drag.

The effect of afterbody shape on the drag of bodies was also investigated by the E30 Helium Gun technique. In this program, the forebody had a parabolic shape of fineness ratio 7.13, while the afterbodies tested had fineness ratios of 1.78, 3.50, and 5.00, respectively, making the overall fineness ratios of the bodies 8.91, 10.63, and 12.13. For each fineness ratio, the base area was varied from no base to a full cylindrical shape. The models had diameters of 1.5 inches and were propelled to a Mach number of approximately 1.3 in the Helium Gun. Varying the bluntness of the base was of interest because most practical fuselages had a base to accommodate the propulsive jet exit.

The tests showed that with large bases, approaching a cylindrical afterbody, fineness ratio had practically no effect. For large afterbody fineness ratios, 5 or greater, the minimum drag was obtained with a pointed afterbody. For smaller fineness ratios, however, it was found that some blunting of the base was beneficial, the critical parameter being the slope of the resulting afterbody. A 4.5-degree slope yielded the minimum drag (ref. 41).

Design rules for afterbody design, as established by these tests, were straightforward. If a body was not to have a jet exit, a pointed afterbody of high fineness ratio was indicated; whereas, if the body required a flat base for a jet exit, the afterbody should be sloped forward at an angle no greater than 4.5 degrees, starting at the edge of the exit. These rules were based on power-off tests and assumed no effect of an operating jet on base and afterbody pressures. Later tests were to evaluate this condition.

With the E2 rocket models, it was possible through telemetry to determine the pressures acting on typical bases. This was done for a series of parabolic bodies of fineness ratios from 6.04 to 24.5. In these tests, the ratio of base diameter to maximum diameter was 0.44. The base drag of these configurations was found to be less than 10 percent of the total (ref. 42).

Additional pressure measurements were made on one of the parabolic bodies of the earlier series to find an explanation for the much lower experimental drag of the body, compared with theory. The body was one having a sharply converging afterbody defined by a fineness ratio of 8.91, with the maximum diameter at 0.80 the length, and with a ratio of base diameter to maximum diameter amounting to 0.44. While this shape was of little practical interest because of its high pressure drag, it was of interest from a research standpoint in providing an insight into flow behavior over such bodies through the transonic speed range. The tests indicated that the large differences between theory and experiment were caused by a shock on the afterbody which made the pressures more positive (ref. 43).

Another test with a body that was identical in structure, but contained an internal rocket motor, provided data on the influence of an operating jet on base pressures. A large positive jet effect was found at supersonic speeds for a point just ahead of the base (ref. 44). The jet in this case was from a 3.25-inch rocket motor, and the exit static pressure greatly exceeded external static pressure.

The finding of a positive or thrusting effect of an operating jet on the body ahead of it opened the way for a continuing program on jet effects. Existing data obtained in other programs were analyzed for this particular effect. Interest was centered on the effect of the jet on pressures on the annular area surrounding the jet, for, if positive pressures could be realized on this portion of the base, then the earlier conclusion about the advantage of cutting the base back outside the jet exit might not be valid. One such analysis (ref. 45) indicated that jet effects on base pressure were of sufficient importance that such effects must be considered in the design of supersonic aircraft and missiles. A later analysis by Warren Gillespie, Jr., showed that there were many factors influencing jet effects, and that more extensive research was required to clarify the effects (ref. 46).

In the evaluation of body drag, the effect of the stabilizing fins was open to some question. Attempts were made to determine the fin drag by reducing the fin thickness, or by reducing the number of fins in steps, and extrapolating to no fins. The best scheme, however, was proposed by Roger G. Hart: to fly a body with no fins, providing stability by an extremely far forward center of gravity. By loading the nose with lead and mercury, and constructing the aft portion with a thin balsa shell, designers obtained a center of gravity just behind the nose. A special steel thrust tube attached to the front end of the booster pushed against a special plate inside the model and slid away from it after burnout of the booster. The body flown successfully in this manner was the standard ogive-cylinder shape used in the first E2, E5, and D13 programs (ref. 47).

Attempts to reduce the drag of parabolic bodies by modifying the nose have been discussed earlier. In some cases, practical considerations dictated the design, and the purpose of the flight test was to determine the penalties resulting from the changes. One such case was nose design for guided missiles. Frequently, the target seeker mounted in the nose precluded the use of a nose of high fineness ratio and, in fact, a hemisphere might be dictated. In order to provide drag data on such modifications to the nose of an otherwise low-drag body, a series of rocket-model tests were made of the parabolic body of fineness ratio 8.91, with its maximum diameter at 40 percent of its length, and with different nose radii varying from a point to a hemisphere whose radius equaled the maximum radius of the body. Rounding the nose with a radius 0.274 times the maximum body radius had no appreciable effect on the supersonic drag, but with a full hemisphere the drag was more than tripled (ref. 48).

The E2 technique was used to provide basic drag data on circular cylinders at right angles to the flight direction. Cylinders of fineness ratio 15, 30, and 60, respectively, were tested as spanwise extensions to short-span wings with endplates on a standard E2 body. Tests were conducted at Mach numbers from 0.5 to 1.3, as shown in figure 131. The results correlated well with previous Langley wind-tunnel tests conducted by John Stack and W. F. Lindsay. The drag of the cylinders, based on cylinder frontal area, was nearly 2.0 at transonic speeds (ref. 49).

Another part of the body-drag rocket-model program involved evaluation of the effects on drag produced by such practical considerations in missile construction as surface roughness, rivets, and joints. It was found that, at high Reynolds numbers, a small amount of roughness could be tolerated although roughness represented by 60-mesh sand caused a 20-percent increase in drag (ref. 50). Rivets and lap joints were found to cause an appreciable increase in drag at all Mach numbers (ref. 51).

Rocket-model tests also were used to determine the increases in drag associated with adding a pilot's canopy to a parabolic body of fineness ratio 8.91. The additional drag was approximately 15 percent when the canopy was simply added to the basic body (ref. 52).

A different concept for canopy design was investigated in May 1950 at the suggestion of Douglas Aircraft representative, Harold T. Luskin, during one of his many visits to Langley in connection with the X-3 research airplane test program. This was the concept of the sunken canopy proposed for the X-3 airplane, which followed the concept of equivalent body of revolution. The canopy was formed by distorting the body in the area of the canopy while retaining a smooth longitudinal distribution of cross-sectional area. Two models were flown to investigate the concept. One had the distorted shape with the sunken canopy, while the others was the equivalent body of revolution. The drag values were found to be approximately the same through the transonic range (ref. 53). An additional check of the concept was obtained through a third test of a body having an elliptical cross section but the same area

FIGURE 131. Technician William Ferguson adjusts Deacon booster adapter on E2 model at Wallops, May 7, 1951. Model was used in basic research on drag of cylinders.

distribution as the standard body. Again, the drag measurements were found to be approximately equal. These were the first verifications of the equivalent body concept at transonic speeds.

The sunken canopy design proposed for the X-3 airplane was the outgrowth of linearized-theory calculations by Ernest W. Graham of Douglas. His analysis indicated that the pressure drag of a slender body in axial supersonic flow was dependent on the rate of change of cross-sectional area regardless of the cross-sectional shape (ref. 54). The same conclusion had been reached independently by W. D. Hayes of North American (ref. 55). The applicability of this conclusion to a wing-body combination was not appreciated until later when Whitcomb discovered it in tests in the Langley 8-foot Transonic Tunnel. According to Graham, "I don't think anybody realized how effective this idea could be for wing-body combinations in transonic flow until Whitcomb carried out his wind-tunnel tests."[8]

NACELLE DRAG AT SUPERSONIC SPEEDS

On the larger airplanes, such as bombers and transports, the engines were usually housed in external nacelles attached to the wings. On long-range fighter aircraft, extra fuel was carried in external wing tanks. The body-drag program was useful in dictating the shape of the isolated store or nacelle, but mutual interference of the wing, fuselage, and bodies in the transonic region was not yet known. A rocket-model program using E2 models was flown at Wallops to define the problem for external wing tanks on the wing of a typical fighter aircraft, and a much more extensive program for nacelles on a typical large aircraft design was conducted with a series of F25 models. In both series, the location of the nacelle or external store was the only variable between successive flights.

In the E2 program, the standard ogive-cylinder fuselage with four stabilizing fins was used in conjunction with an untapered wing having a 34-degree sweepback, an aspect ratio of 2.7, and a streamwise thickness ratio of 7.5 percent. The wing tanks had a fineness ratio of 7.44 and were bodies of revolution with circular-arc profiles, slightly rounded at the nose. A 3.25-inch rocket motor contained within the model propelled it to a Mach number of 1.2. The tanks were tested in five different locations: two fore and aft locations at the wing tips, two fore and aft locations at the 40-percent semispan station, and an underslung, pylon-mounted tank at the 40-percent station. In the tests, the inboard tank symmetrically mounted on the wing with the end of the tank flush with the trailing edge of the wing added only about one-half the drag calculated for the isolated tank, while the pylon-mounted tank added about four times the drag of the isolated tank. The tanks in the other locations added about one and one-half times the isolated value (ref. 56).

The initiation of the F25 wing and nacelle drag program has been discussed in Chapter 7, and the results of tests without nacelles have been given. In this program, wing H of the Transonic Airplane Program was used. This wing, having an aspect ratio of 6.0, a taper ratio of 0.6, a sweepback of 45 degrees, and a wing thickness ratio of 9 percent, was located on a fuselage of fineness ratio 10, with the leading edge of the wing at the maximum diameter of the fuselage. There was no horizontal tail, but a vertical tail was used for directional stability. The arrangement was generally similar to the Snark missile discussed earlier in this chapter. The nacelles added to this wing had a fineness ratio of 9.66, including a cylindrical section, and were designed for a Series 1 subsonic inlet, although in the initial tests the inlet was closed with a conical plug. Each model was propelled by a two-stage rocket system consisting of a lightweight HVAR booster and a 3.25-inch sustainer motor. The model was launched from a rail launcher, as shown in figure 132.

In the first series of tests, the nacelles were located at the 40-percent semispan station and were varied chordwise for two vertical locations: (1) symmetrically enclosing the wing; and (2) mounted beneath the wing with the upper surfaces flush. The symmetrical nacelle in the rearmost position was the best, although all locations showed high interference drag. The drag increments were from two to four times the drag of the isolated nacelle (ref. 57). The drag was increased still further when the nacelles were mounted on a sweptforward pylon at a distance below the wing approximately equal to the diameter of one nacelle. The increased drag occurred particularly between Mach numbers of 0.9 and 1.0 (ref. 58).

8. Letter from Ernest W. Graham to Joseph A. Shortal, January 16, 1968.

In the next series of tests, the nacelles were located chordwise in the best position just determined, and now were varied spanwise from 18 percent of the semispan out to the wing tip. This was done with the nacelles mounted symmetrically around the wing (ref. 59), and with them underslung (ref. 60). The tests showed that the 40- and 60-percent semispan locations were the worst, the 18- and 25-percent locations added drag about equal to that of the isolated nacelles, and locations near the wing tip added almost no drag at all.

Additional tests made with the tip nacelles varied chordwise showed that rearward locations were the best. In fact, in one location the nacelle actually reduced the total drag at Mach 1.0 (ref. 61). This

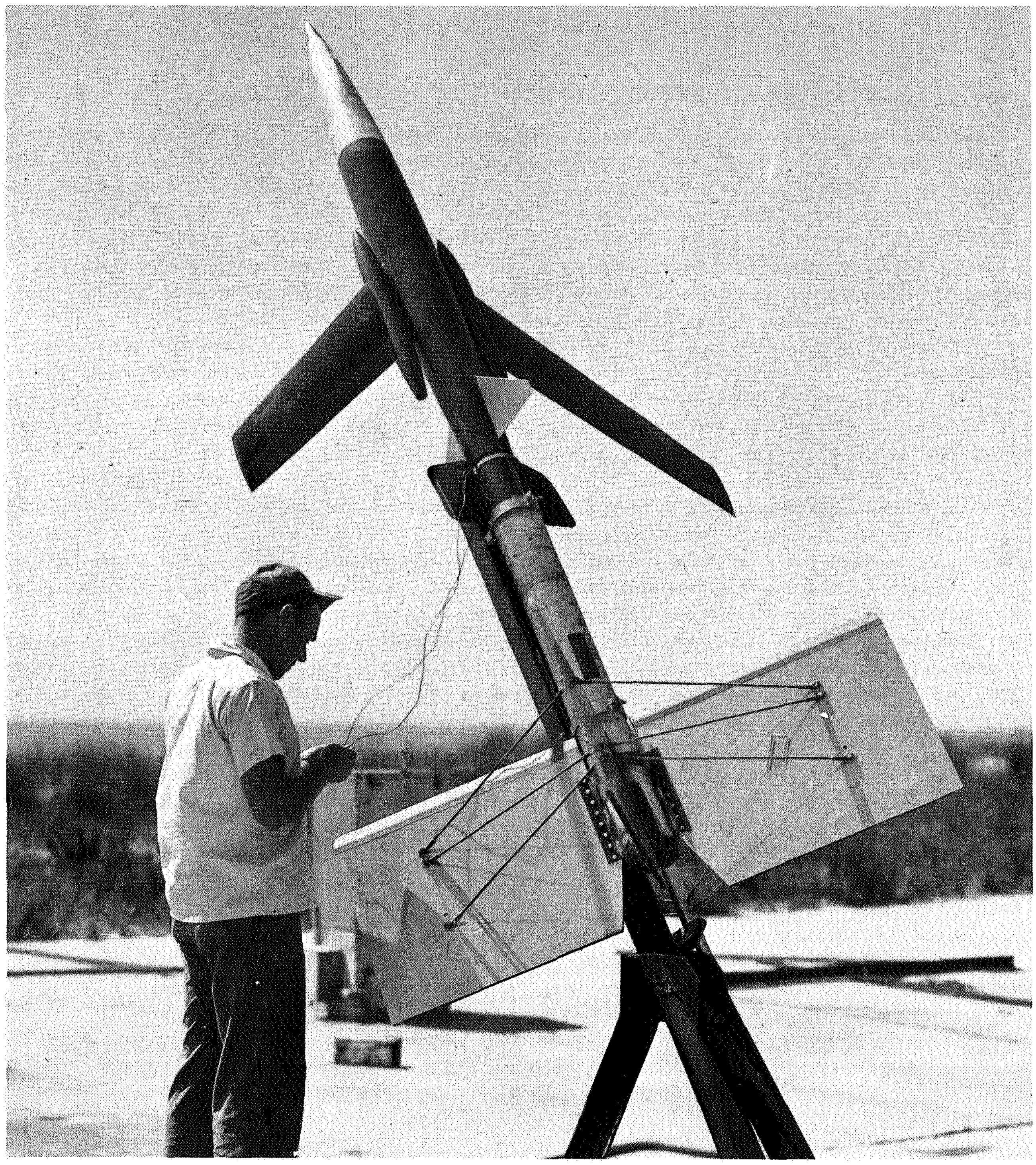


FIGURE 132. Technician Harry Bloxom connects firing leads on F25 model with inboard nacelles. Model is shown at Wallops on July 18, 1950.

finding is shown in figure 133. The explanation for this unexpected phenomenon was found in the area rule as indicated by the distribution of cross-sectional area, also shown in the figure. That the cross-sectional area distribution was the key to the drag of wing-body combinations near the speed of sound was discovered in this period by R. T. Whitcomb in the Langley 8-foot Transonic Wind-Tunnel research (ref. 62).

In the sketches in figure 133, the different components are identified by shading. The open area is the fuselage, the crosshatched area is the wing, and the solid area indicates the nacelles. The shape of the area curve and the area itself are both significant. Note that the wing in its aft location on the fuselage adds less area than it would if located forward; but note especially that the nacelles add nothing to the maximum total area and, in fact, tend to act as a fairing to the base, increasing the

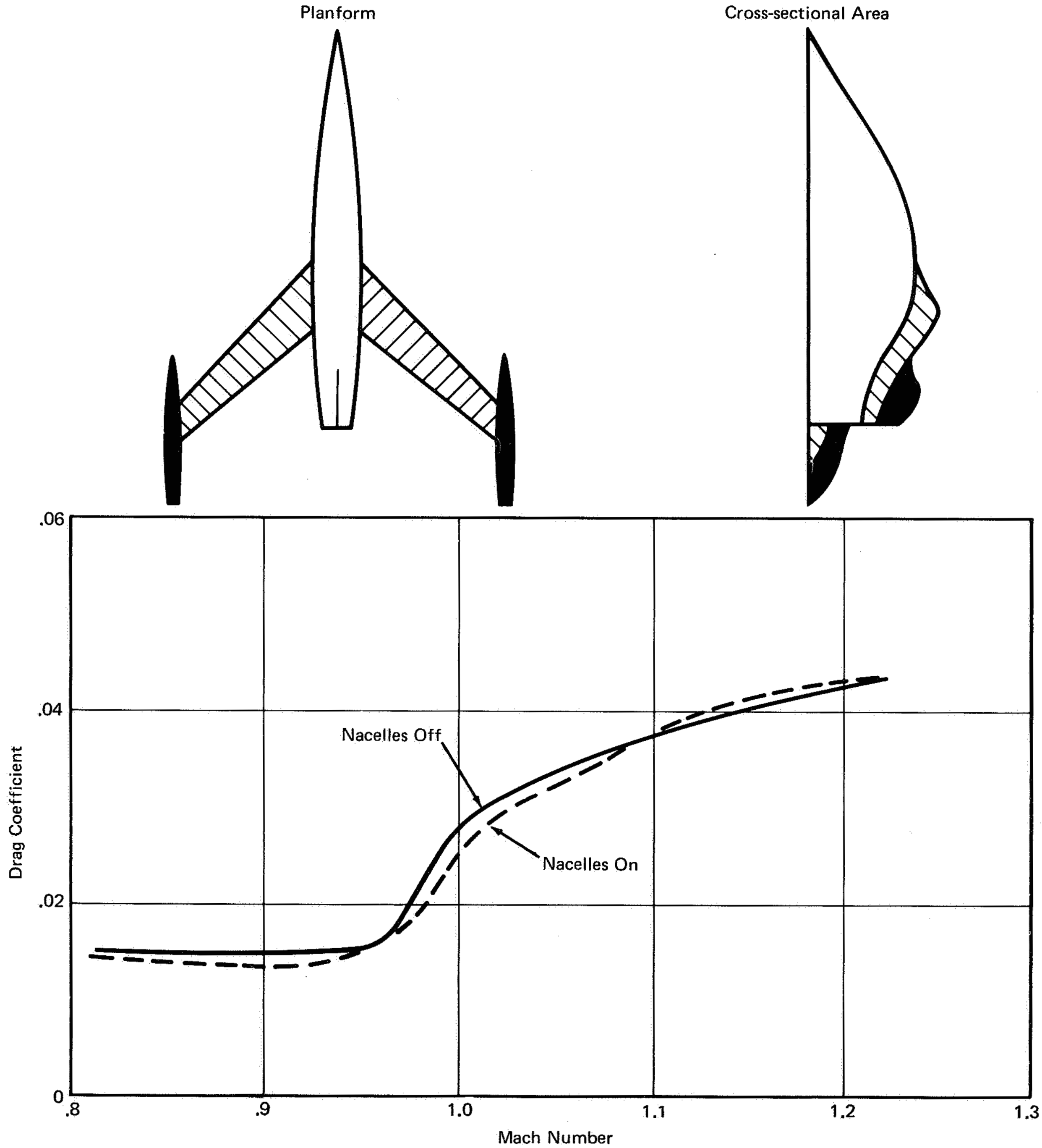


FIGURE 133. Results from Wallops rocket-model tests showing effect of wing-tip nacelles on drag of a sweptback wing and body combination.

effective fineness ratio. The finding that such a nacelle added nothing to the total drag is, therefore, not surprising.

In order to extend the applicability of the results to other fuselage shapes, three flight tests were made with the afterbody boattail of the basic fuselage changed to a cylinder of constant diameter, extending rearward 13 inches. In these three tests, the nacelles were located alternately at 18, 40, and 96 percent of the semispan. The tests showed that the change in the fuselage increased the total drag for all conditions because of the larger base. The added drag from the wing-tip nacelle was greater with the modified fuselage, indicating that there had been a favorable interference acting between the tip nacelles and the original boattailed base. In contrast, the added drag from the nacelles in the other two locations was not quite as severe with the cylindrical afterbody. All of these findings were in qualitative agreement with the area rule (ref. 63).

The tests so far had been made with closed nacelles, for simplicity. Now a test was made with an open nacelle mounted at the wing tip. The fuselage was restored to its original boattail shape. Before flight, the internal flow characteristics of the inlet and duct system were determined by tests in the Preflight Jet at Wallops, at Mach numbers from 0.80 to 1.75. In the flight test, the total drag was found to be about the same as that found earlier with the closed nacelle (ref. 64). A similar comparison of open and faired nacelles was made with the nacelles mounted inboard close against the sides of the fuselage. Again, the open nacelle was calibrated by Preflight Jet tests. In the flight test, there was little difference between the open and closed nacelles, but both showed a large unfavorable interference at Mach 1.0. Again, this finding was explained by the area rule (ref. 65).

A special study of the effectiveness of the wing-tip location was made with the wing span reduced by 35 percent, making the aspect ratio 3.55 instead of 6.0. Again, the nacelle showed favorable interference; the drag added by the nacelle was about one-half that of an isolated nacelle (ref. 66).

As an extension of the transonic nacelle program, consideration was given to the requirements for supersonic flight for similar configurations. It was determined that approximately twice the thrust assumed in the original design would be required. This meant that the number of engines would have to be doubled, or larger engines would have to be used. Several arrangements satisfying this requirement were flight tested. Nacelles having double the volume of the original designs were tested at inboard and at wing-tip locations. Four nacelles were tested two ways: one was located inboard and one at the tip on each wing, and then a siamese arrangement of two side-by-side nacelles was tested at an inboard location. Both inboard arrangements of double-sized nacelles produced high drag. There was little choice between the other two arrangements, both of which added more drag than would be expected from the nacelles alone. All results were in accordance with the area rule (ref. 67).

Investigation also was made of the drag penalties associated with adding nacelles to a delta-wing interceptor configuration having supersonic capabilities. A 60-degree delta wing with 3-percent thickness was selected. The nacelles were open and represented large ramjet engines located at the 66-percent semispan station. Both high-wing and midwing arrangements were tested. The nacelles were symmetrically mounted on the mid-wing, and underslung on the high-wing models. The flight tests were made at speeds up to Mach 2.0. In this extension of the F25 program to higher speeds, a Deacon booster and an internal 3.25-inch rocket motor were used. Calibrations of the open nacelles were made in the Preflight Jet, and a special model of the nacelle alone was flown by the Helium Gun method. The midwing arrangement gave the lowest drag in flight although the cross-sectional area distribution of the two configurations was about the same, indicating the existence of some local secondary interference. The drag added by the nacelles in either arrangement was about equal to that of the nacelles alone (ref. 68).

RM–10 BODY DRAG AND HEAT-TRANSFER PROGRAM

The need for a flight test vehicle with which the pressure or wave drag could be separated from the friction or viscous drag was appreciated by R. R. Gilruth in the early days of Wallops. He assigned to W. J. O'Sullivan, Jr., the job of designing a body with which this could readily be done. O'Sullivan selected a paraboloid of high fineness ratio for the body, after learning from R. T. Jones of Langley that such a shape was amenable to theoretical calculation of pressure distribution. This was a different shape from the one designed by John Stack for the freely falling body program and adopted as the standard body in the Transonic Airplane program at Langley, and it was some time before O'Sullivan could convince Gilruth of the merit of the parabolic shape. After Gilruth approved it, however, and a flight program at subsonic, transonic, and supersonic speeds had been initiated, the wind-tunnel people at Langley and, later, at the other NACA laboratories decided to test scale models of it. It then became a standard body for the calibration of supersonic facilities.[9]

The standard body with four large, sweptback, untapered fins was designated RM-10 by PARD. Although it was redesignated F10 in PARD's new numbering system, the RM-10 designation persisted for this model.

The NATO Advisory Group for Aeronautical Research and Development (AGARD) adopted the RM-10 as a standard correlation model and gave it the designation AGARD Model 1. It was also adopted as the basic shape for the fuselage of the North American Navaho intercontinental supersonic guided missile.

The body was derived from a body of fineness ratio 15 with its maximum diameter at midlength. The tail end of the body was cut back to provide a blunt base for the jet exit of an internal Deacon rocket motor. This reduced the fineness ratio to 12.2 and moved the maximum diameter to 60 percent of the new length. The body was 12 inches in diameter and 146.5 inches in length.

Several different flight programs based on the RM-10 were conducted by PARD at Wallops. In the first tests, which have been discussed in Chapter 4, a version 65 inches long was flown with only three stabilizing fins. All of the later models had the standard four-fin arrangement. A series of 1/2-scale models was tested under the direction of H. Herbert Jackson. These models, designated E10, contained an internal 3.25-inch rocket motor, and were boosted by a similar 3.25-inch motor, by a lightweight HVAR, or by a Deacon, to cover a range of speeds and Reynolds numbers. The full-scale RM-10 program was directed by C. B. Rumsey and L. T. Chauvin. The models were flown with the internal Deacon alone, or with either single or double Deacon boosters in addition.

Figure 134 shows one of the full-size RM-10 models on the mobile launcher with a double Deacon booster. Note that the fins extended some distance behind the base of the body. Twenty-four full-size models were flown between 1948 and 1955, with only three failures. A structural failure spoiled the first launch on October 16, 1948; a telemeter malfunction marred a flight in 1950; and in 1952 a short circuit prevented the internal rocket from igniting. All in all, this was a fine reliability record.

The first flight tests of 1/2-scale and full-size models yielded drag data over a Mach number range of 0.9 to 3.3, and over a Reynolds number range of 20 to 200 million. The results showed no effect of Reynolds number on drag, but indicated the expected reduction from Mach number effects. The 1/2-scale models had somewhat lower total drag coefficients, attributed to an unexplained lower base drag (ref. 69).

A special flight test was made by Robert O. Piland with a 1/6-scale RM-10 model to obtain drag at low Reynolds numbers for comparison with tunnel data. In addition, the Mach number was extended to 4.0. The 1/6-scale model was mounted on a drag balance on a sting, in front of a Deacon rocket motor. In addition, a double Deacon booster was used to reach Mach 4.0. Good agreement was obtained between total drag and base drag for this model and earlier tests in the 8-foot by 6-foot and 4-foot by 4-foot tunnels, for the same Reynolds numbers and Mach numbers (ref. 70). Base pressures for this finless body agreed with theory as well as with tunnel measurements.

To explore the subject of base and afterbody pressures further and to provide more information on the effect of an operating jet on such pressures, two full-scale RM-10 models were flown with extensive pressure instrumentation (ref. 71). The pressures over the body agreed with linearized theory except in the extreme rearward locations near the fins. The total drag and base drag agreed with the earlier large-scale measurements. With the jet operating, large effects were obtained on the pressures over the base and afterbody near the fins. The effect was to reduce the drag by approximately 15 percent. Thrust was measured on the base at Mach numbers below 1.8.

Skin friction was also explored extensively with RM-10 models. For a low-drag body at supersonic speeds, skin-friction drag can be as much as one-half the total drag if the flow is turbulent. Experimental data were needed to establish the condition of the boundary layer as well as to establish

9. Interview with W. J. O'Sullivan, NASA Langley Research Center, September 5, 1968.

FIGURE 134. Technician Durwood Dereng measures elevation of double Deacon booster prior to launch of RM–10 research model at Wallops, February 6, 1951.

the level of the friction drag itself. The RM-10 model was used, both in the tunnels and in flight to provide the experimental values. In most of the tests, the friction drag was determined from a total-pressure survey made close to the surface with a special rake. (See figure 135). An integration of the pressure losses so measured was an indication of the summation of friction losses over the body back to the measurement station. In the tunnel tests, the rake was located at the base of the model and, therefore, gave the total friction drag. In flights with the full-scale models, survey rakes were located at points 58 and 85 percent of the body length back of the nose.

The full-scale RM-10 models gave measurements of skin friction, based on surface area, of the order of 0.0022 at Mach 1.5 and 0.0016 at Mach 3.4, for varying Reynolds numbers and heating conditions (ref. 72). The best available method for prediction of such friction values was that of E. R. Van Driest for a flat plate in compressible flow with heat transfer (ref. 73). The measured values were approximately 13 percent greater than those predicted by this theory.

In one RM-10 flight, the Deacon sustainer was changed to a long-burning jato rocket, 14AS1000, which allowed the measurement of skin friction for a condition in which the Reynolds number and the heating condition remained practically constant as the Mach number was increasing (ref. 74). The skin friction measured under these conditions now agreed with Van Driest's theory.

In an attempt to verify Reynolds' analogy relating skin friction to heat transfer, the local heat transfer data were integrated to obtain average heat transfer for comparison with average skin friction. Results yielded agreement within 8 percent.

Additional flights of RM-10 models over a range of conditions finally made possible the establishment of an empirical expression for skin friction which took into account heating conditions and Reynolds number over a Mach number range of 1.0 to 3.7 (ref. 75). The correlation made use of measurements of skin friction in incompressible flow obtained by towing a full-scale RM-10 model in the NACA Tank at Langley (ref. 76).

It was now possible to compare the skin friction data from the flight tests with data from the tunnel tests. When the flight data were taken for conditions of zero heating, which corresponded to the tunnel tests, excellent agreement was obtained for a given Reynolds number and Mach number. All of the flight data indicated that the flow in the boundary layer was turbulent over 95 percent of the body under practically all conditions. This was so because transition occurred within a foot of the nose and, for this relatively sharp body, only a small area was ahead of the transition point.

To test the validity of the assumption that, for high fineness ratios, body profile had little effect on skin friction, flight testing was done at Wallops with a body of approximately the same size as the full-scale RM-10 model but of cylindrical shape and having an ogival nose. This was actually one of the fuselages from the Sparrow missile program described in Chapter 7. Again, good agreement was obtained with Van Driest's theory, thereby proving its independence of body shape (ref. 77).

From the inception of the RM-10 program, it was planned to measure skin temperatures in flight because of the known influence of temperature of the boundary layer on skin friction. The effect of heating conditions on skin friction has already been discussed, as well as the correlation of skin friction and aerodynamic heating through Reynolds analogy. The measurement of heat transfer, per se,

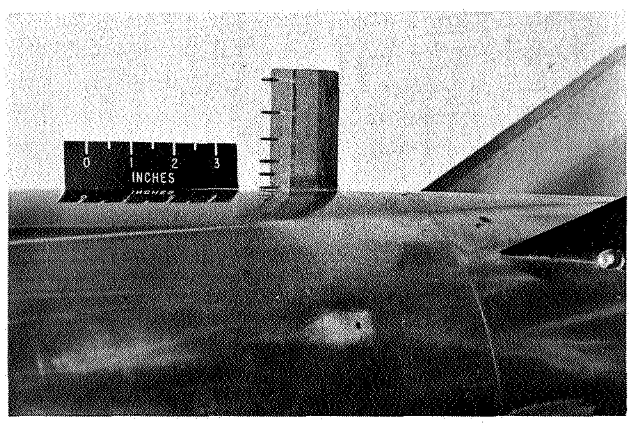


FIGURE 135. Boundary-layer total-pressure survey rake used on surface of RM-10 flight model to determine skin friction. Photograph taken February 6, 1950.

assumed greater importance from structural considerations as flight speeds were increased. In addition, North American representative H. A. Storms, during several visits to PARD, expressed his interest in heat-transfer measurements on the RM-10 at higher Mach numbers, for application to the design of the Navaho missile. A number of full-scale RM-10 models were flown over a wide range of Reynolds numbers and Mach numbers, with extensive heat-transfer instrumentation.

In the heat-transfer tests, the temperature of the skin of the model was measured by resistance-type thermometers cemented to the inner surface of the skin. These thermometers consisted of platinum wires 0.0002 inch in diameter which, with the associated telemeter, were developed especially for this program by C. L. Fricke and F. B. Smith of IRD (ref. 78).

The full-scale RM-10 models were ideally suited for a heat-transfer investigation because they were made of essentially monocoque construction with 0.08-inch magnesium skin. Internal structure was kept to a minimum by maintaining sea-level pressure within the model during flight.

In the construction of the full-size RM-10 models, full advantage was taken of new procedures developed by Langley engineering and shop personnel for fabricating magnesium products. The main body was essentially an unsupported shell spun to close tolerances on a spinning die by a process developed at Langley. The spinning of sheetmetal, which was more of an art than a simple machining operation, required the skillful application of proper amounts of tool pressure and heat, and a generous supply of laundry soap. The spinning lathe at Langley was the almost exclusive domain of technician George H. Veneris, who had the feel and strength required as well as the patience to flow the metal with precision. The rough shell previously had been rolled from a sheet of magnesium and welded along a longitudinal seam, which could not be detected after the spinning was completed. The tailcone was spun from a somewhat thicker magnesium sheet in a similar manner and then the four stabilizing fins, which were magnesium castings, were welded directly to the surface of the cone.

Magnesium was used extensively in rocket-model construction because its low density allowed the use of thicker shells, which had greater elastic stability and which could be formed with the smoothness and precision required for research models. The resulting models were exceedingly lightweight. For example, the complete RM-10 model structure, which was over 12 feet long, weighed only 70 pounds. The techniques developed at Langley were generously shared with industry, and their engineers and technicians visited the shops at Langley on many occasions. One frequent visitor was Calvin H. Corey, Washington manager, Brooks and Perkins, Inc. Many of the special tools used at Langley, such as the spinning lathe, were later produced by regular commercial manufacturers. The various uses of magnesium in rocket models were described by C. C. Johnson, head of pilotless aircraft design at Langley, in an article in the Brooks and Perkins company magazine in November 1950. An account of developing the RM-10 model was an important part of this article (ref. 79).

The first heat-transfer measurements were made to a Mach number of 2.4, with only a Deacon internal rocket motor (ref. 80). Later tests were made to a Mach number of 3.6 by adding a double Deacon booster (ref. 81). The heat-transfer measurements in flight indicated that the flow was turbulent at all measurement stations, and that the heat transfer was a strong function of Reynolds number. It was learned that the correlation found by Allan P. Colburn in 1933 (ref. 82) between Nusselts number, Reynolds number, and Prandtl number for flat plates in turbulent subsonic flow, was quite valid at supersonic speeds.

To obtain some indication of the heating problem of a pilot's canopy for an aircraft application, one flight test was made with a thin metal canopy added to the RM-10 body. Temperature and pressures were measured over the canopy in flight to a Mach number of 3.0. Heat transfer over the windshield area was found to be quite high, but it could be correlated with flat plate results by proper consideration of the flow conditions around the canopy (ref. 83).

The temperature distribution through the boundary layer in flight had been assumed to follow the theory of Crocco (ref. 84). In one flight test, the total temperature distribution within the boundary layer was measured at a station 125 inches back of the nose of an RM-10 full-scale model. The arrangement of the total number of temperature probes is shown in figure 136. The total temperature probe was developed by Langley IRD and consisted of a chromel-alumel thermocouple junction surrounded by an inconel radiation shield within an open tube having a restricted exit. Excellent agreement was obtained with theory of Crocco (ref. 85).

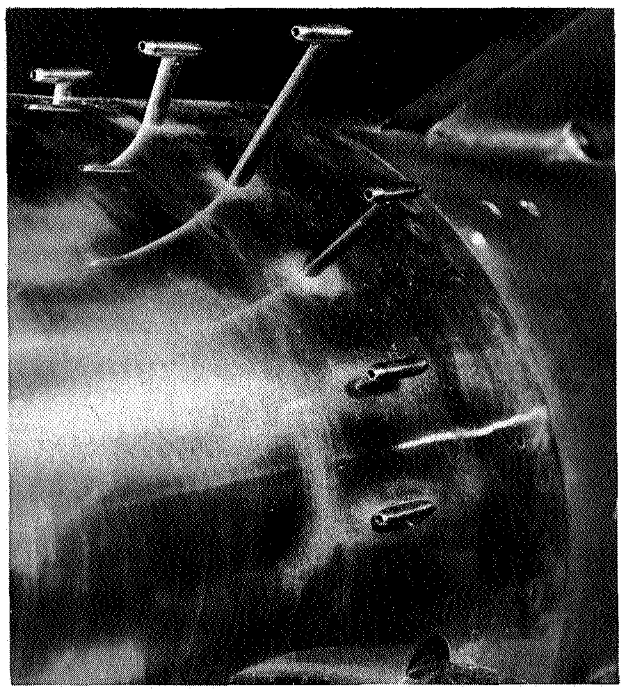


FIGURE 136. Total-temperature probes mounted above surface of RM–10 flight model for use in heat-transfer investigation. Photograph taken March 25, 1954.

CONTINUATION OF LARGE-SCALE WING-DRAG PROGRAMS

During the 1950–1954 period, research investigations of drag of wing and body combinations at high Reynolds numbers were continued with E17 rocket models and with freely falling bodies.

The initiation of the E17 program, which began in 1949, has been discussed in Chapter 6. These models, like the RM-10 models, contained a Deacon internal rocket motor that provided a Mach number of about 1.6. The main variable in the program was the wing. The body, which was 13 inches in diameter and 130 inches in length, initially had the same shape as the freely falling standard body and that of the transonic airplane program. Early in the program, this shape was replaced by a parabolic shape because of its lower drag. The maximum diameter of this body was located at the 40-percent station, and the wings were located just behind this point. Thirty-one E17 models were flown between April 1949 and March 1954. The test with wing C of the transonic program has been discussed in Chapter 6, and tests with the wing of the X-3 research airplane have been discussed earlier in the present chapter. Most of the remaining models will be discussed at this point.

The E17 models were constructed principally of wood. It was found during the tests that the orange lacquer finish used on all PARD wood models was affected by aerodynamic heating if used at Mach numbers in excess of 1.5. The lacquer would blister and cause higher drags. Clear lacquer was used in some cases and a red finish, termed Phenoplast, was also used successfully. Later, the models were finished with a mixture of zinc stearate and thin plastic glue. The E17 models were not affected by this phenomenon as much as the higher speed E2 models, but their surfaces were finished in accordance with findings of the E2 program.

The E2 technique for determining drag by means of the Doppler radar required revision for the E17 models. Because of the long burning time of the Deacon motor, the flight path was no longer a straight line, and corrections for flight-path curvature, determined by the SCR-584 radar, had to be made. In addition, it was found that corrections for wind speed made to the velocity measured by Doppler radar were large enough to affect the results. All of the tests through 1951 were recomputed with these corrections and were summarized in a single report (ref. 86).

One of the first tests made with the new parabolic body was with wing C, for comparison with the earlier test on the transonic body. A favorable interference effect was noted near Mach 1, but beyond 1.2 little difference was found.

NACA researchers did not give up easily on wings of high aspect ratio for transonic flight, because of their favorable lift-to-drag ratios. A wing of aspect ratio 8 was flown successfully in this program, but for structural reasons its thickness had to be 12 percent of the wing chord. The maximum Mach number reached was only 1.1, and the drag was very high. The drag coefficient was 0.058 compared with 0.026 for wing C.

The basic X-3 wing discussed earlier had a hexagonal section. A second model having this planform was flown with an NACA 65-series section for comparison. The more rounded 65-series wing showed lower drag at transonic speeds, but beyond Mach 1.4 the sharp-edged hexagonal section was superior.

The most spectacular planform in the E17 program was the large 60-degree delta wing which figure 137 shows on the launcher at Wallops. This particular model, flown on September 8, 1950, had a wing with a thickness of 6 percent. The first delta wing, however, tested on February 21, 1950, had a thickness of 3 percent. The wing area of both models was 33 times the cross-sectional area of the body. For the thinner wing, the wing-plus-interference drag found in the test was approximately 0.005 at subsonic speeds and 0.006 at supersonic speeds, with a peak value of 0.010 at Mach 1. Except for the peak rise, these coefficients were very little more than would be expected for skin friction alone for turbulent flow. The drag for the complete model was a maximum of only 0.0130. Such low drag values were a great encouragement to the Air Force to continue sponsorship of delta-wing aircraft, the Convair F-102 and F-106 interceptors, in particular. On the other hand, C. L. Johnson, Lockheed Aircraft Corporation, was skeptical of these low-drag results and cautioned NACA Headquarters that some "unscrupulous manufacturer" might propose an airplane and sell it with the aid of these data.

The study of 60-degree delta planforms was continued with tests of a wing of the same percentage of thickness, but one-half the area. Although the total drag coefficient was higher, as expected, the wing-plus-interference drag coefficients were about the same as those of the larger wing. Two tests were made with the larger size delta wing, with thicknesses of 4 and 6 percent, respectively. The drag increased by the expected amount. The 4-percent wing was generally similar to the wing of the Republic XF-103

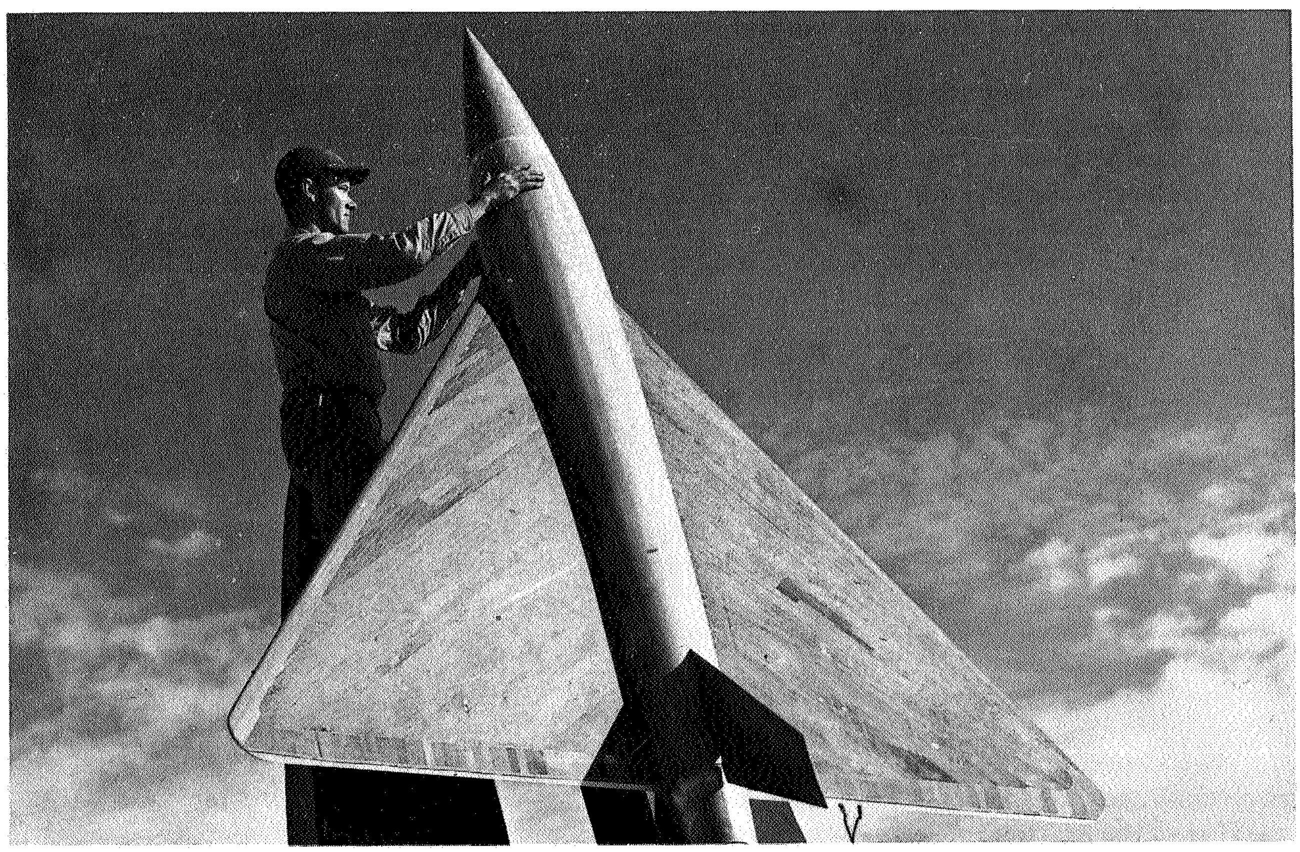


FIGURE 137. Technician Durwood Dereng prepares to pull the external-power plug from an E17 drag-research model at Wallops, September 8, 1950.

airplane. A wing having a 65-degree sweepback of the leading edge is shown in figure 138. The wing, similar to that of the Bell X-5 variable-sweep research airplane in its rearmost sweep position, showed about the same drag coefficient as a 60-degree delta wing of the same thickness ratio. A wing of diamond planform, but otherwise identical to the small 3-percent 60-degree delta wing, had about the same transonic drag as the delta wing; but at supersonic speeds the wing-plus-interference drag was about 50 percent greater for the diamond planform (ref. 87).

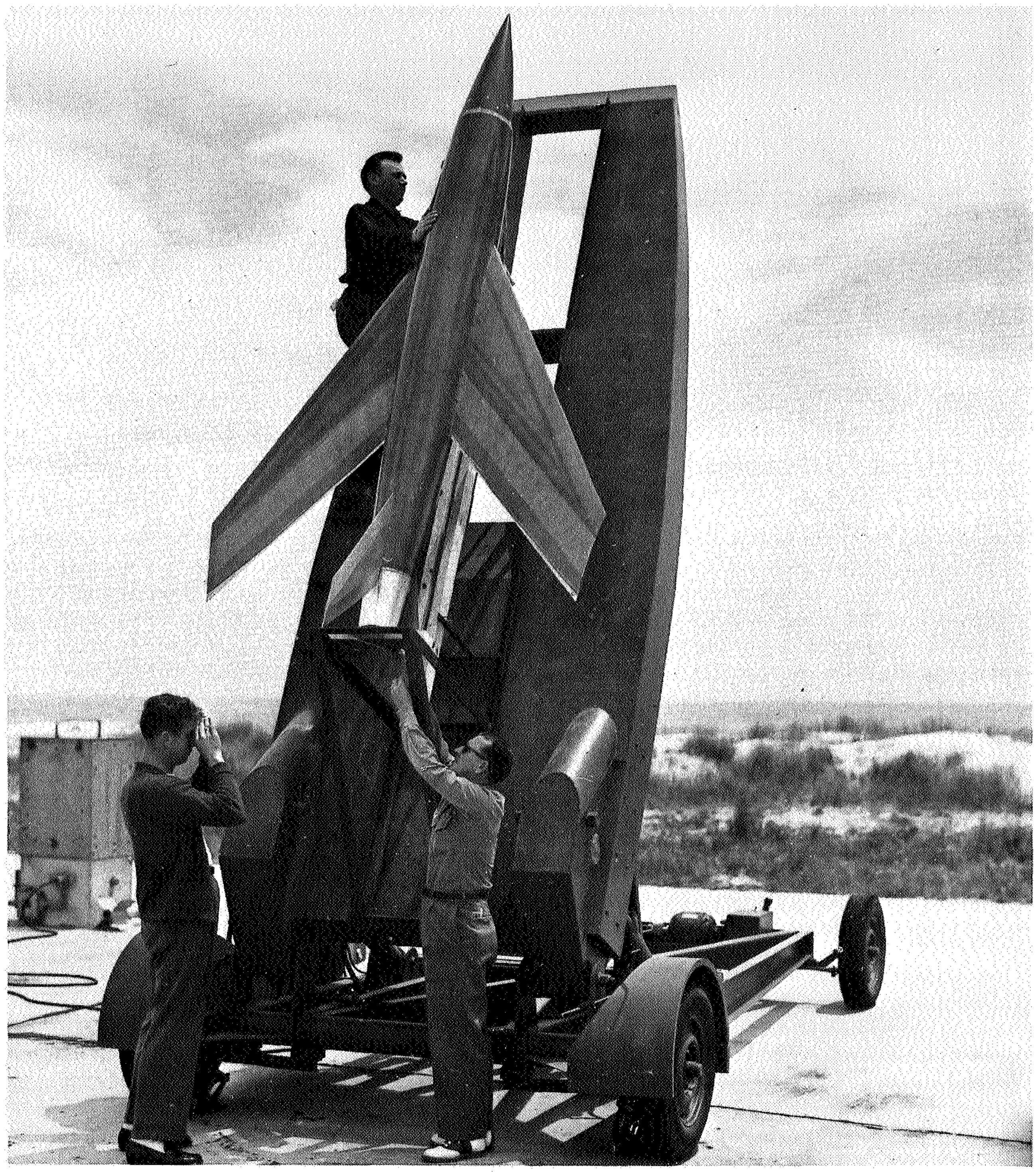


FIGURE 138. From left, technicians William Ferguson, Harry Bloxom, and Nat Johnson make final arrangements for launching E17 drag-research model with Bell X–5 research airplane wing in sweptback position. Photograph taken May 17, 1951.

The drag of two large wing-body configurations was measured in this period at Wallops as part of the freely falling body program of the Langley Flight Research Division. Although the speeds were limited to the transonic range, the results were of interest because of the large Reynolds numbers. One of the configurations had a highly tapered wing with 45-degree sweepback, an aspect ratio of 3.75, and 2-percent thickness in the streamwise direction. The wing was mounted in an aft position on the standard transonic body. Figure 139 shows the model on its transport dolly. This wing was about the thinnest to be tested at Wallops. In the program, the wing drag was measured directly by means of an internal balance. The wing-drag coefficients, so measured, were 0.005 at subsonic speeds and 0.0085 at Mach 1.0 (ref. 88).

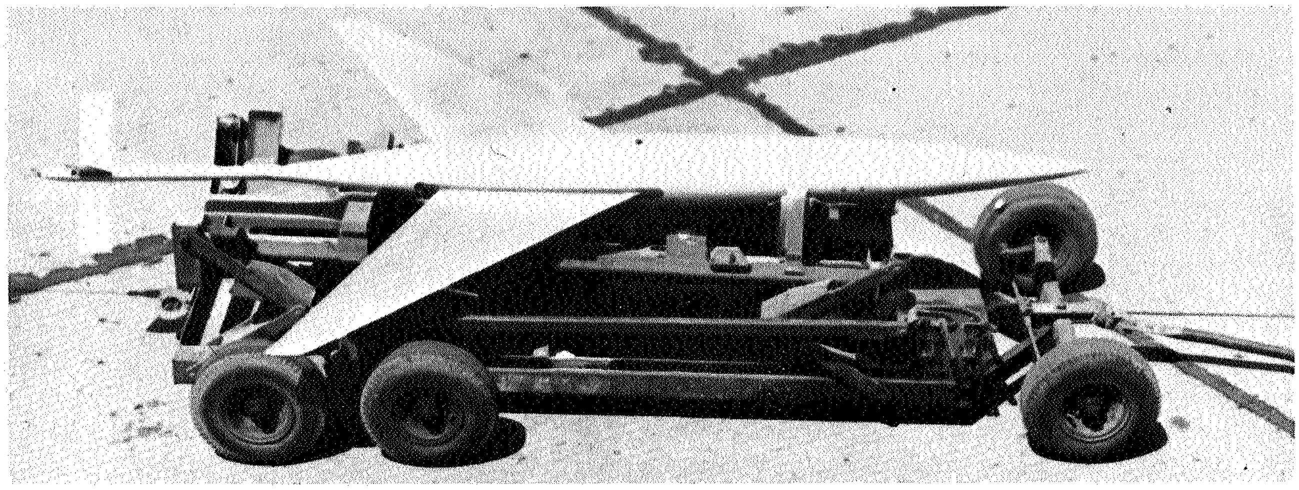


FIGURE 139. Freely falling body with highly tapered, sweptback wing is shown ready for loading on airplane for drop test at Wallops, June 14, 1949.

Early in the freely falling body program, a large difference in drag had been found between a swept wing located aft on a body, and one located in a forward position, as has been discussed in Chapter 4. This finding influenced the design of wing-body combinations to be tested by Langley for several years, but the large difference found could not be duplicated in other facilities. Finally, the Flight Research Division decided to repeat the test of the wing in the aft position and to measure pressures on the body, in an attempt to locate the source of the low drag. This time, the extremely low drag found earlier could not be duplicated, and it was concluded that the earlier test had been in error. The drag of the wing in the aft position was now only slightly lower than that of the forward wing. Furthermore, from this new finding it was concluded that the increase in drag measured when a large fillet was added to the wing in the aft position (as discussed earlier in Chapter 5) was not real. Instead, the new data indicated no effect on drag of adding the fillet (ref. 89).

LONGITUDINAL STABILITY AND DRAG OF AIRPLANE CONFIGURATIONS

Continuing efforts at Wallops included the E7 and E15 general research rocket-model programs and the freely falling body program dealing with longitudinal stability and drag characteristics of wing, body, and tail arrangements suitable for transonic flight. The E7 models usually had streamlined fuselages and fixed tails and some were disturbed in flight with pulse rockets. The E15 models, in general, were built around a standard ogive-cylinder body, and their horizontal tail surfaces were usually pulsed continually during flight. The first models in this program have been discussed in Chapter 6.

The E15 program was concerned principally with wing and horizontal tail effects on drag due to lift, and with longitudinal stability, rather than with development of overall low-drag configurations. Some of the wings were scaled models of those on existing or planned supersonic airplanes. Information on buffeting was also obtained from the program.

Three E15 models were flown with wings of the same planform as that of the Douglas X-3 research airplane, and the results were compared with those from a model flown with no wing. Two of the X-3 wings were of hexagonal section and differred only in construction material. One was built of solid steel and the other of solid aluminum. These models had the usual six-channel telemeter. Only a Deacon booster was used with either a crutch or mobile launcher (ref. 90). The third X-3 wing was made of solid aluminum, but its section was of the more conventional NACA 65A series (ref. 91). All were of 4.5-percent thickness. The model with the 65A series wing section had a second vertical tail added to the bottom of the fuselage for symmetry in the directional plane, to avoid the problem of coupling motions experienced in some earlier tests. In addition, a 10-channel telemeter was used, and the wing was mounted on a balance to measure normal loads. The finding that there was no consistent effect of structural material indicated zero aeroelastic effects for this planform. The only effect of wing section was on drag, the sharp-edged airfoils having higher drag in the transonic region. Data were obtained on lift and drag over a range of angles of attack, wing loads, pitching moment, damping-in-pitch, and control effectiveness. No evidence of leading-edge suction was found for any of these thin wings.

The results from three of the E15 models were combined with a comprehensive description of the method of analysis used in the program (ref. 92).

One E15 model was flown with a scaled wing of the Bell X-1 research airplane for comparison with the full-scale airplane results. Again, a lower vertical tail was installed to minimize coupling effects. A nine-channel telemeter was used to transmit measurements of two normal accelerations, two transverse accelerations, longitudinal acceleration, control deflection, angle of attack, total pressure, and static pressure. Severe buffeting was encountered in the low transonic speed range, accompanied by a sharp reduction in lift-curve slope, which agreed with full-scale results (ref. 93). Some leading-edge suction was noted on this thick wing. At a Mach number of 0.7, the amount was about one-half of the maximum theoretically possible value, and decreased to near zero at a Mach number of 1.1.

An E15 model also was used to test a wing scaled from that of the Bell X-5 research airplane in its rearmost position of 60-degree sweepback of the leading edge (ref. 94). In this case, it was found that leading-edge suction reduced the drag due to lift by as much as 30 percent of the values that would have been obtained with no leading-edge suction.

The effects of changes in horizontal tail arrangement on a possible transonic airplane design were investigated with a series of E7 rocket models. Wing C of the transonic program was mounted in a midwing position on a parabolic body of revolution of fineness ratio 8.91, and successive models were flown with different tails. One of these, shown in figure 140, had an unswept horizontal tail. A Deacon booster with cantilever fins and a shovel-type adapter was used for all models. Lift, drag, trim, and stability were investigated over an angle-of-attack range, induced by a series of pulse rockets. In addition to the unswept tail, two sweptback tails were tested, one on the fuselage centerline, and the other mounted atop the vertical tail. For comparison, two models were flown with the horizontal tail removed, one with a symmetrical fuselage, and the other with the fuselage curved upward somewhat at the rear to provide greater ground clearance. It was found that all configurations were stable, and exhibited a trim change near Mach 1. There was a 20-percent loss in lift-curve slope due to aeroelastic effects on the wing (refs. 95, 96, and 97).

The freely falling body technique was used to test an airplane model similar to this configuration except for the fact that the sweptback tail was mounted about halfway up the vertical tail, as shown in figure 141. This configuration was also known as the transonic airplane model which was tested extensively in Langley wind-tunnel facilities. Fair agreement with the tunnel tests was obtained for the static longitudinal aerodynamic characteristics, both showing a large rearward shift in aerodynamic center at transonic speeds. The free-fall model provided dynamic stability characteristics in the same manner as did the E15 rocket models, except that in the free-fall test the lift coefficients were confined to values below 0.26 (ref. 98).

Wing C was also tested on the E15 basic body. A solid steel wing and a solid aluminum wing were tested to allow evaluation of aeroelastic effects. Structural influence coefficients were obtained from laboratory tests of the aluminum wing, and a form of strip-theory anaysis was used to calculate the effects of aeroelasticity. Good agreement was obtained in flight. As the Mach number slowed to 0.92, the models experienced a violent pitch-up which was related to the combination of the sweptback wing

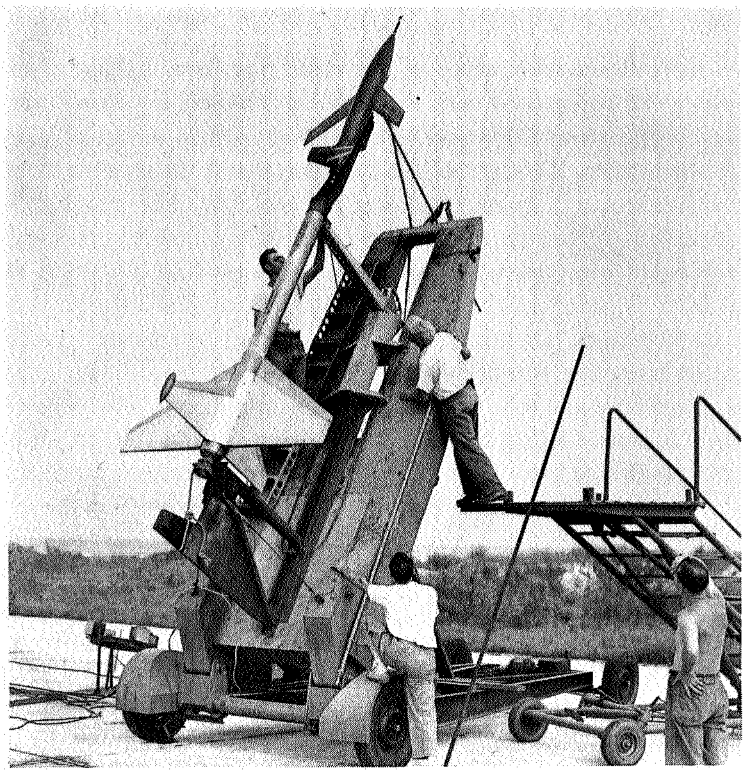


FIGURE 140. Technicians make a last-minute check of front support of Deacon booster in preparation for launching an E7 stability and drag research model, September 5, 1951.

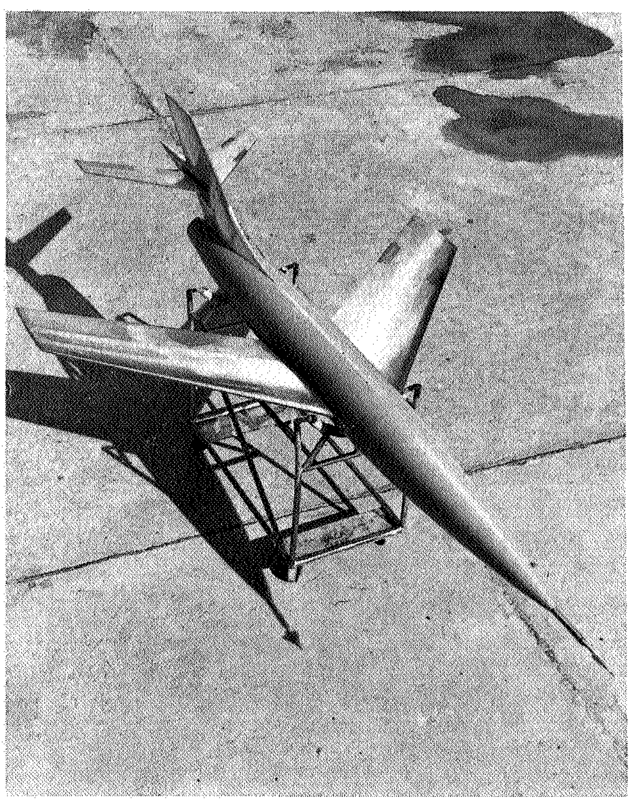


FIGURE 141. Transonic airplane model used in free-fall test at Wallops for stability and drag research at transonic speeds, March 20, 1951.

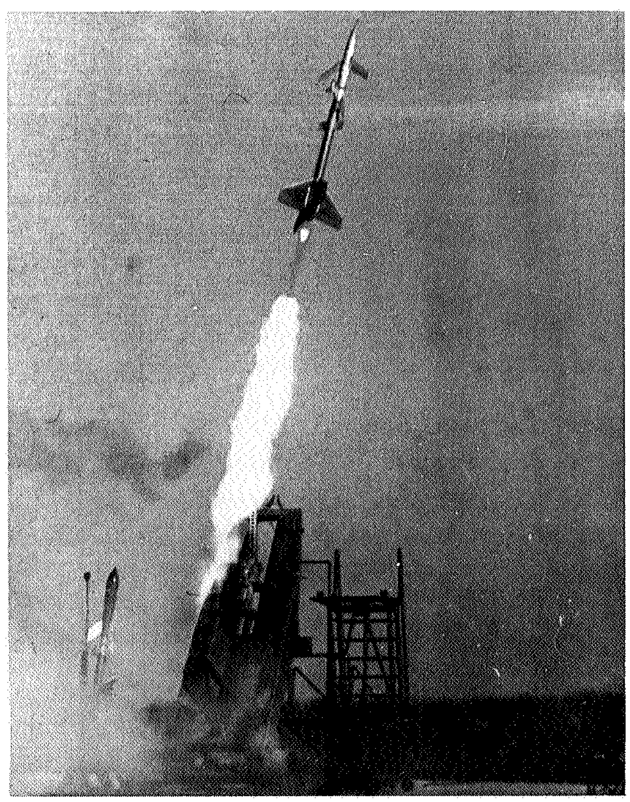


FIGURE 142. Launch of E15 research model with wing C and unswept tail, August 17, 1951. A Deacon booster was used in the launch.

and the high horizontal tail. Further evaluation of flight data below that Mach number was impossible (ref. 99). Figure 142 shows this model at takeoff.

The low drag characteristics obtained in the freely falling body program with a sweptback wing located aft of the maximum diameter of the fuselage inspired Charles W. Mathews to design a tail-first airplane configuration. It seemed logical to locate the horizontal control surface forward as a canard, when the wing was so far rearward. Such an arrangement was tested for longitudinal stability and drag, as a freely falling body. In this test, an autopilot controlled the canard surface to maintain a normal acceleration of 0.5 g, which was equivalent to level flight for the corresponding full-scale airplane. In addition, a rate gyro was installed to maintain a constant roll rate of 0.10 revolution per second. This roll rate was selected to avoid the catastrophic coupling effects of roll and pitch encountered earlier with a model of the X-1 airplane. The tests indicated good stability, control, and drag characteristics at the low angles of attack of the tests, and appeared to confirm the faith of the designer in this arrangement for a transonic airplane (ref. 100). Unfortunately, however, the serious pitch-up phenomena found from other tests at high angles of attack, and characteristic of this wing planform, were to prevent the design from ever reaching full-scale development.

A 60-degree delta wing having a 3-percent thickness ratio was tested on the E15 rocket-model standard body and tail (ref. 101). Over a range of Mach numbers from 0.9 to 1.37, there was little change in lift or stability, and no abrupt trim changes. There was, however, some indication of loss of longitudinal stability at high angles of attack at a Mach number of 0.9, which resulted in a pitch-up to an angle of attack of 20 degrees. This loss in stability was attributed to the high location of the horizontal tail with respect to the wing.

A modified delta wing was also tested on the E15 standard body and tail. This wing was a scaled model of the wing designed for the Republic XF-103 airplane. The trailing edge of the wing had a 15-degree sweepback and a more rounded nose section, which was obtained by reshaping the nose and increasing the thickness ratio to 3.7 percent at the root and 6 percent at the tip. Somewhat higher lift slopes were obtained, and the drag due to lift was somewhat lower than that for the unmodified 60-degree delta wing. No indication of pitch-up at high lift was found (ref. 102).

NOTES ON LATERAL STABILITY OF AIRPLANES FROM ROCKET-MODEL TESTS

Although the E15 rocket model general research program was providing aerodynamicists with both static and dynamic longitudinal stability characteristics of configurations representative of supersonic airplanes, there was no comparable general research program for lateral stability. Methods for determining the more complicated lateral stability factors for a complete model were not to be developed until later in this period. In the meantime, one of the lateral stability factors, damping-in-roll, was the subject of a general research program for wings; and a second factor, static directional stability, was obtained as a byproduct whenever directional oscillations were encountered.

Paul E. Purser and Jesse L. Mitchell recognized the lack of experimental data on directional stability of airplanes in the transonic speed range. After examining the records from different rocket-model flights of complete airplane configurations, they were able to evaluate directional stability from 13 such flights. The results were made available in a combined report for the use of airplane designers (ref. 103).

In contemplating this lack of experimental data, Purser conceived a method for evaluating the contribution of dihedral of the wings to the rolling moment due to sideslip. Purser reasoned that the effect of dihedral in a sideslip was similar to that of incremental wing incidence. The E5 program on the rolling effectiveness of various lateral controls had yielded values of rolling moment obtained from setting the right and left wing panels at equal but opposite angles, and a method for estimating these values from damping-in-roll had been established. Now they could be converted to rolling moment produced by dihedral. The fact that reasonable agreement was obtained between values calculated from these considerations and available theory at supersonic speeds inspired confidence in the use of the experimentally derived data in the transonic region, for which no theory existed (ref. 104).

AERODYNAMIC DAMPING-IN-ROLL RESEARCH: D13 AND E14

An earlier account has been given (in Chapter 6) of the initiation of a rocket-model program to use the D13 technique for measuring aerodynamic damping-in-roll of wings and bodies in combination. This technique utilized the torque from canted nozzles of an internal rocket motor as the driving moment and required only a spinsonde and the Doppler radar to evaluate the data. The technique was used in the 1949–1952 period to provide damping-in-roll data for a wide range of wing shapes. A total of 120 such models were launched at Wallops with a success rate of approximately 82 percent. The failures were practically all due to instrumentation: two-thirds, to inadequate spinsonde record; and one-third, to loss of Doppler signal.

The damping-in-roll obtained with a double-wedge section on an unswept wing of aspect ratio 4.5 was found to agree with theory at supersonic speeds, but showed a more erratic variation with Mach number in the transonic speed range than that obtained with an NACA 65-006 section. At supersonic speeds, the wing with the 65-006 section gave results about 20 percent lower than theory (ref. 105). In another series of tests, this disagreement with theory was indicated to be an effect of thickness for unswept wings, for, when the thickness was increased from 6 percent to 12 percent, the disagreement increased from 20 percent to almost 30 percent (ref. 106).

The effect of wing-planform taper was found to have little effect until the wing was tapered almost to a point, and then a 25-percent reduction in damping was obtained with either unswept or 45-degree sweptback wings (ref. 107). The delta wing is a special case of a sweptback wing tapered to a point but having an unswept trailing edge. The damping of such wings was found to decrease progressively as the sweep of the leading edge was increased from 45 degrees to 70 degrees. Although the damping was lowest with the 70-degree delta wing, the experimental data agreed more closely with theory (ref. 108).

One series of models had three wings scaled from the research airplanes X-2, X-3, and D-558-II; four from wings in the Langley transonic wing series; and the Jones wing (a highly sweptback wing designed by Robert T. Jones of Ames). These wings were selected because of their applicability for transonic aircraft. The results followed the same trends found in the general series tested (ref. 109).

At the conclusion of the D13 program, David G. Stone, PARD branch head, collected and summarized all of the data (ref. 110). He attempted to explain the disagreement with theory by consideration of aeroelastic effects, but found that most of the wings tested were too stiff to be affected by aeroelasticity. The exceptions were those with high aspect ratios and sweepback in combination. He pointed out, however, that in actual practice, aeroelasticity must be considered, because practical aircraft would be relatively less stiff than the wings tested. Most of the models had wings of stiffness equivalent to those of solid aluminum—a most unlikely full-scale structure except for some types of missiles.

The E14 program, a second method for measuring damping-in-roll with rocket models, was also in use during the same period as the D13 method. The program was under the direction of William M. Bland, Jr. A typical E14 model, shown in figure 143, consisted of a rocket motor for propulsion, with four fins to provide stability. The fins were set at an angle of incidence to provide a rolling velocity. A rolling-moment balance in the nose cone attached to the rocket motor measured the aerodynamic resistance to rolling or the damping-in-roll of small test models sting-mounted in front of the nose. With this system, wings alone, wings and bodies in combination, or complete missiles, could be tested. A one-channel telemeter transmitted the rolling moment while rolling velocity was determined by a spinsonde. The forward velocity was determined by the Doppler radar. The telemeter antenna in the stabilizing fins performed the function of the usual spinsonde. The rocket motor was a 5-inch HVAR which provided a maximum velocity of nearly 2,000 feet per second in slightly less than one second. Note, in figure 143, that the vehicle rested on the tips of its four fins on a simple launcher set for a 70-degree launch elevation. The vehicle was held to the launcher by a break-link which released the model when the thrust built up. It was restrained from tipping over by a simple wood support that was removed just before launch. The test wings were machined from steel plate and had spans of approximately 10 inches. The first instrumented model was flown in October 1948. By 1954, when the program was phased out, 36 models of this type had been flown.

FIGURE 143. Rocket technician Nat Johnson adjusts break-link on E14 damping-in-roll vehicle prepared for test of a 45-degree delta wing, August 30, 1950.

Early in this program, identical shapes were tested by both the E14 and D13 methods. The model selected had three wings mounted on the standard ogive-cylinder body. The wings were unswept and untapered, with an aspect ratio of 3.71, and NACA 65A009 sections. Agreement between the two test methods was excellent (ref. 111).

The damping-in-roll, as measured by E14 models, showed about the same effects of wing shape as did the D13 models and, in addition, showed that the fuselage had practically no effect on the damping when the body diameter was less than 20 percent of the wing span (refs. 112 and 113). Increasing the diameter of the body to 40 percent of the wing span reduced the damping by approximately 15 percent. Increasing it further to 60 percent gave a reduction of 40 percent. These percentage reductions were in good agreement with theory (ref. 114).

Aeroelastic effects on a delta wing were determined by testing a solid steel wing and one of solid magnesium, each having a thickness of 3 percent and being mounted on a body of small diameter. To accentuate the effects as well as to provide data at higher Mach numbers, a 3.25-inch rocket motor was added as a booster, and a short rail launcher was used. Data were obtained to a Mach number of 2.2. The data for the magnesium wing were about 30 percent lower than those for the steel wing at supersonic speeds. Extrapolating the results to a rigid condition gave values at supersonic speeds in excellent agreement with theory (ref. 115).

References

1. Lundstrom, R. R.; and O'Kelley, B. R.: "Results of Tests Conducted on a Destructor for Limiting the Range of Research Missiles," Memorandum for Files, Langley PARD, Oct. 11, 1950.
2. Shortal, Joseph A., Memorandum for Chief of Research, May 2, 1952, regarding test site for long-range ramjet.
3. Gammal, Abraham A.; and Kennedy, Thomas L.: *Flight Investigation to Determine Lift and Drag Characteristics of a Canard Ramjet Missile Configuration in the Mach Number Range of 0.8 to 2.0.* NACA RM L54D28.
4. Zalovcik, John A.: *A Radar Method of Calibrating Airspeed Installations on Airplanes in Maneuvers at High Altitudes and at Transonic and Supersonic Speeds.* NACA TN 1979, Nov. 1949. Reissued as NACA TR 985, 1950.
5. Fuhrmeister, P. F., Head, Radar Unit, Memorandum of Jan. 30, 1951, regarding B−45 turn tests.
6. Cheatham, Donald C.; Mathews, Charles W.; and Harper, John A.: *A Study of Visual Interception Attacks on a Nonmaneuvering Airplane Target.* NACA RM L53E01.
7. Kuehnel, Helmut A.; Beckhardt, Arnold R.; and Champine, Robert A.: *A Flight Investigation of the Effects of Varied Lateral Damping on the Effectiveness of a Fighter Airplane as a Gun Platform.* NACA RM L53F08a. Reissued as NACA TN 4199, Jan. 1958.
8. Memorandum for Director, investigation report of accidental missile firing at Wallops Island, Virginia, August 2, 1951. Ray W. Hooker, chairman, investigating committee.
9. Memorandum for Langley Executive Safety Committee, containing findings and recommendations of Special Technical Committee relating to accidental rocket firing August 2, 1951.
10. Anonymous, Notes on Accidental Firing of Rocket-Propelled Model at Wallops Island.
11. Memorandum for Files, September 15, 1953, investigation report of accidental firing of pulse rocket at Wallops Island, July 9, 1953; John C. Palmer, chairman, investigating committee.
12. Special Accident Investigating Committee, *Report of Little Joe No. One Misfire on August 21, 1959, at NASA Wallops Station.* Abraham D. Spinak, committee chairman.
13. Report of Committee Investigation of Accident Involving JRF-5 Amphibian at Wallops Island, Va., on November 3, 1954; J. V. Becker, committee chairman.
14. Thompson, Floyd L., Chief of Research, Memorandum for Research Division Chiefs, Branch Heads, and Section Heads, June 15, 1951, regarding NACA Management Control Information System.
15. *Guided Missiles Volume and Directory,* Government Data Publications, 1962.
16. "USAF's First Twenty Years." *Air Force and Space Digest,* Sept. 1957, p. 84.
17. *Aviation Week.* Sept. 15, 1958, p. 50.
18. Gillespie, Warren, Jr.; and Arbic, Richard G.: *Large-Scale Flight Measurements of Zero-Lift Drag at Mach Numbers From 0.87 to 1.39 of 1/10-Scale Models of the Northrop MX−775A Missile.* NACA RM SL51K07.
19. Gillespie, Warren, Jr.; and Arbic, Richard G.: *Flight Determination of the Longitudinal Stability of a 1/10-Scale Rocket-Powered Model of the Northrop MX−775A Missile at Low-Lift Coefficients and Mach Numbers From 0.89 to 1.34.* NACA RM SL52I12.
20. Arbic, Richard G.; and Gillespie, Warren, Jr.: *Free-Flight Longitudinal Stability Investigation Including Some Effects of Wing Elasticity From Mach Numbers of 0.85 to 1.34 of a Tailless Missile Configuration Having a 45° Sweptback Wing of Aspect Ratio 5.5.* NACA RM L53F18.
21. Shortal, Joseph A.; and Maggin, Bernard: *Effect of Sweepback and Aspect Ratio on Longitudinal Stability Characteristics of Wings at Low Speeds.* NACA TN 1093, July 1946.
22. Arbic, Richard G.: *Free-Flight Investigation of the Low-Lift Transonic Aerodynamic Characteristics of a 1/10-Scale Model of the Northrop MX−775A With an Aluminum-Alloy Wing Having Leading-Edge Extensions and Inboard Trailing-Edge Flaps.* NACA RM SL54E10.
23. Arbic, Richard G.: *Transonic Free-Flight Investigation of the Longitudinal Aerodynamic Characteristics of a 1/10-Scale Steel-Wing Model of the Northrop MX−775A Missile With Leading-Edge Extensions, Inboard Trailing-Edge Flaps, and a Speed Brake on the Vertical Tail.* NACA RM SL55B07.

24. Ikard, Wallace L.: *An Air-Flow Direction Pickup Suitable For Telemetering Use on Pilotless Aircraft.* NACA RM L53K16. Reissued as NACA TN 3799, Oct. 1956.
25. Mitchell, Jesse L.; and Peck, Robert F.: *Results of the Flight Test of a Dummy of the MX−656 Rocket-Propelled Models.* NACA RM SL50A07.
26. Mitchell, Jesse L.; and Peck, Robert F.: *An Investigation of the Longitudinal Characteristics of the X−3 Configuration Using Rocket-Propelled Models. Preliminary Results at Mach Numbers From 0.65 to 1.25.* NACA RM L50J03.
27. Peck, Robert F.; and Mitchell, Jesse L.: *An Investigation of the Longitudinal Characteristics of the X−3 Configuration With Wing and Horizontal Tail Surfaces of Aspect Ratio 3.0 By Means of Rocket-Propelled Models. Results at High-Lift Coefficients.* NACA RM L51G10.
28. McKee, John W.; and Riebe, John M.: *An Investigation of a 0.16-Scale Model of the Douglas X−3 Airplane to Determine Means of Improving the Low-Speed Longitudinal Stability and Control Characteristics.* NACA RM L52H01.
29. Burk, Sanger M., Jr.; and Hultz, Burton E.: *Static Longitudinal Stability and Dynamic Characteristics at High Angles of Attack and at Low Reynolds Numbers of a Model of the X−3 Supersonic Research Airplane.* NACA L50L19.
30. Hultz, Burton E.: *Free-Spinning Tunnel Investigation of a 1/20-Scale Model of the Douglas X−3 Airplane.* NACA RM L51K12.
31. Peck, Robert F.; and Hollinger, James A.: *A Rocket-Model Investigation of the Longitudinal Stability, Lift, and Drag Characteristics of the Douglas X−3 Configuration With Horizontal Tail of Aspect Ratio 4.33.* NACA RM L53F19a.
32. Mitchell, Jesse L.; and Peck, Robert F.: *Investigation of the Lateral Stability Characteristics of the Douglas X−3 Configuration at Mach Numbers From 0.6 to 1.1 by Means of a Rocket-Propelled Model.* NACA RM L54L20.
33. Day, Richard E.; and Fischel, Jack: *Stability and Control Characteristics Obtained During Demonstration of the Douglas X−3 Research Airplane.* NACA RM H55E16.
34. Schult, Eugene D.: *Large-Scale Flight Measurements of Zero-Lift Drag at Mach Numbers From 0.8 to 1.6 of a Wing-Body Combination Having an Unswept 4.5-Percent-Thick Wing With Modified Hexagonal Sections.* NACA RM L51A15.
35. Sandahl, Carl A.; and Strass, H. Kurt: *Rolling Effectiveness of a Thin Tapered Wing Having Partial-Span Ailerons as Determined by Rocket-Powered Test Vehicles.* NACA RM L50D17.
36. Mitcham, Grady L.; Crabill, Norman L.; and Stevens, Joseph E.: *Flight Determination of the Drag and Longitudinal Stability and Control Characteristics of a Rocket-Powered Model of a 60° Delta-Wing Airplane From Mach Numbers of 0.75 to 1.70.* NACA RM L51I04.
37. Mitcham, Grady L.; Stevens, Joseph E.; Crabill, Norman L.; and Hinners, Arthur H., Jr.: *Low-Lift Drag and Duct Pressure Recovery of a 1/8.25-Scale Model of the Consolidated Vultee XF−92 Airplane at Mach Numbers From 0.7 to 1.4.* NACA RM SL51E23.
38. Welsh, Clement J.; and deMoraes, Carlos A.: *Results of Flight Tests to Determine Drag of Parabolic and Cone-Cylinder Bodies of Very Large Fineness Ratios at Supersonic Speeds.* NACA RM L51E18.
39. Nelson, Robert L.; and Stoney, William E., Jr.: *Pressure Drag of Bodies at Mach Numbers up to 2.0.* NACA RM L53I22c.
40. Stoney, William E., Jr.: *Transonic Drag Measurements of Eight Body-Nose Shapes.* NACA RM L53K17.
41. Stoney, William E., Jr.: *Some Experimental Effects of Afterbody Shape on the Zero-Lift Drag of Bodies for Mach Numbers Between 0.8 and 1.3.* NACA RM L53I01.
42. Katz, Ellis; and Stoney, William E., Jr.: *Base Pressures Measured on Several Parabolic-Arc Bodies of Revolution in Free Flight at Mach Numbers From 0.8 to 1.4 and at Large Reynolds Numbers.* NACA RM L51F29.
43. Stoney, William E., Jr.: *Pressure Distribution at Mach Numbers From 0.6 to 1.9 Measured in Free Flight on a Parabolic Body of Revolution With Sharply Convergent Afterbody.* NACA RM L51L03.
44. Stoney, William E., Jr.; and Katz, Ellis: *Pressure Measurements on a Sharply Converging Fuselage Afterbody With Jet On and Off at Mach Numbers From 0.8 to 1.6.* NACA RM L50F06.
45. Purser, Paul E.; Thibodaux, Joseph G.; and Jackson, H. Herbert: *Note on Some Observed Effects of Rocket-Motor Operation on the Base Pressure of Bodies in Flight.* NACA RM L50I18.
46. Gillespie, Warren, Jr.: *Jet Effects on Pressures and Drags of Bodies.* NACA RM L51J29.
47. Hart, Roger G.: *Effects of Stabilizing Fins and a Rear-Support Sting on the Base Pressures of a Body of Revolution in Free Flight at Mach Numbers From 0.7 to 1.3.* NACA RM L52E06.
48. Hart, Roger G.: *Flight Investigation of the Drag of Round-Nosed Bodies of Revolution at Mach Numbers From 0.6 to 1.5 Using Rocket-Propelled Test Vehicles.* NACA RM L51E25.
49. Welsh, Clement J: *The Drag of Finite-Length Cylinders Determined From Flight Tests at High Reynolds Numbers for a Mach Number Range From 0.5 to 1.3.* NACA TN 2941, June 1953.
50. Jackson, H. Herbert: *Flight Measurements of the Effects of Surface Condition on the Supersonic Drag of Fin-Stabilized Parabolic Bodies of Revolution.* NACA RM L52B26.
51. Hopko, Russell N.: *The Effect of Some Surface Roughness Elements on the Drag of a Body of Revolution at Supersonic Speeds.* NACA RM L54I21.
52. Welsh, Clement J.; and Morrow, John D.: *Flight Investigation at Mach Numbers From 0.8 to 1.5 of the Drag of a Canopy Located at Two Positions on a Parabolic Body of Revolution.* NACA RM L51A29.
53. Stoney, William E., Jr.; and Putland, Leonard W.: *Some Effects of Body Cross-Sectional Shape, Including a Sunken-Canopy Design, on Drag as Shown by Rocket-Powered-Model Tests at Mach Numbers From 0.8 to 1.5.* NACA RM L52D07.
54. Graham, Ernest W.: *The Pressure on a Slender Body of Non-Uniform Cross-Section Shape in Axial Supersonic Flow.* Douglas Aircraft Co., Inc., Rep. No. SM−13346, Aug. 19, 1948.
55. Hayes, W. D.: *Linearized Supersonic Flow.* North American Aviation, Inc., Report No. AL-222, June 1947, p. 94.
56. Welsh, Clement J.; and Morrow, John D.: *Effect of Wing-Tank Location on the Drag and Trim of a Swept-Wing Model as Measured in Flight at Transonic Speeds.* NACA RM L50A19.

57. Pepper, William B., Jr.; and Hoffman, Sherwood: *Transonic Flight Tests to Compare the Zero-Lift Drag of Underslung and Symmetrical Nacelles Varied Chordwise at 40 percent Semispan of a 45° Sweptback, Tapered Wing.* NACA RM L50G17a.
58. Hoffman, Sherwood: *Comparison of Zero-Lift Drag Determined by Flight Tests at Transonic Speeds of Pylon, Underslung, and Symmetrically Mounted Nacelles at 40 Percent Semispan of a 45° Sweptback Wing and Body Combination.* NACA RM L51D26.
59. Pepper, William B., Jr.; and Hoffman, Sherwood: *Comparison of Zero-Lift Drags Determined by Flight Tests at Transonic Speeds of Symmetrically Mounted Nacelles in Various Spanwise Positions on a 45° Sweptback Wing and Body Combination.* NACA RM L51D06.
60. Hoffman, Sherwood: *Transonic Flight Tests to Compare the Zero-Lift Drag of Underslung Nacelles Varied Spanwise on a 45° Sweptback Wing and Body Combination.* NACA RM L52D04a.
61. Pepper, William B., Jr.; and Hoffman, Sherwood: *Comparison of Zero-Lift Drags Determined by Flight Tests at Transonic Speeds of Symmetrically Mounted Nacelles in Various Chordwise Positions at the Wing Tip of a 45° Sweptback Wing and Body Combination.* NACA RM L51F13.
62. Whitcomb, Richard T.: *A Study of the Zero-Lift Drag-Rise Characteristics of Wing-Body Combinations Near the Speed of Sound.* NACA RM L52H08. Reissued as NACA TR 1273, 1956.
63. Hoffman, Sherwood; and Wolff, Austin L.: *The Effect of Nacelle Location on the Zero-Lift Drags of 45° Sweptback Wing-Body Configuration Having Boattail and Cylindrical Afterbodies as Determined by Flight Tests at Transonic Speeds.* NACA RM L54B02.
64. Hoffman, Sherwood; and Pepper, William B., Jr.: *Transonic Flight Tests to Determine Zero-Lift Drag and Pressure Recovery of Nacelles Located at the Wing Tips on a 45° Sweptback Wing and Body Combination.* NACA RM L51K02.
65. Hoffman, Sherwood; and Wolff, Austin L.: *Transonic Flight Tests to Determine Zero-Lift Drag and Pressure Recovery of Nacelles Located at the Wing Root on a 45° Sweptback Wing and Body Combination.* NACA RM L53R20.
66. Hoffman, Sherwood; and Mapp, Richard C., Jr.: *Transonic Flight Tests to Compare the Zero-Lift Drags of 45° Sweptback Wings of Aspect Ratio 3.55 and 6.0 With and Without Nacelles at the Wing Tips.* NACA RM L51L27.
67. Hoffman, Sherwood; and Pepper, William B., Jr.: *The Effect of Nacelle Combinations and Size on the Zero-Lift Drag of a 45° Sweptback Wing and Body Configuration as Determined by Free-Flight Tests at Mach Numbers Between 0.8 and 1.3.* NACA RM L53E25.
68. Judd, Joseph H.: *Flight Investigation of Engine Nacelles and Wing Vertical Position on the Drag of a Delta-Wing Airplane Configuration From Mach Number 0.8 to 2.0.* NACA RM L53L21.
69. Jackson, H. Herbert; Rumsey, Charles B.; and Chauvin, Leo T.: *Flight Measurements of Drag and Base Pressure of a Fin-Stabilized Parabolic Body of Revolution (NACA RM–10) at Different Reynolds Numbers and at Mach Numbers From 0.9 to 3.3.* NACA RM L50G24. Reissued as NACA TN 3320, Nov. 1954.
70. Piland, Robert O.: *Drag Measurements on a 1/6-Scale, Finless, Sting-Mounted, NACA RM–10 Missile in Flight at Mach Numbers From 1.1 to 4.04 Showing Some Reynolds Number and Heating Effects.* NACA RM L54H09.
71. Hoffman, Sherwood: *Free-Flight Tests to Determine the Power-On and Power-Off Pressure Distribution and Drag of the NACA RM–10 Research Vehicle at Large Reynolds Numbers Between Mach Numbers 0.8 and 3.0.* NACA RM L55H02.
72. Rumsey, Charles B.; and Loposer, J. Dan: *Average Skin-Friction Coefficients From Boundary-Layer Measurements in Flight on a Parabolic Body of Revolution (NACA RM–10) at Supersonic Speeds and at Large Reynolds Numbers.* NACA RM L51B12.
73. Van Driest, E. R.: *The Turbulent Boundary Layer for Compressible Fluids With Heat Transfer.* North American Aviation, Inc., Rep. No. AL–997, Jan. 27, 1950.
74. Maloney, Joseph P.: *Drag and Heat Transfer on a Parabolic Body of Revolution (NACA RM–10) in Free Flight to Mach Number 2 With Both Constant and Varying Reynolds Number and Heating Effects on Turbulent Skin Friction.* NACA RM L54D06.
75. Loposer, J. Dan; and Rumsey, Charles B.: *Flight Measurements of Average Skin-Friction Coefficients on a Parabolic Body of Revolution (NACA RM–10) at Mach Numbers From 1.0 to 3.7.* NACA RM L54G14.
76. Mottard, Elmo J.; and Loposer, J. Dan: *Average Skin-Friction Drag Coefficients From Tank Tests of a Parabolic Body of Revolution (NACA RM–10).* NACA TN 2854, Jan. 1953. Reissued as NACA TR 1161, 1954.
77. Loposer, J. Dan: *Average Skin-Friction Coefficients From Boundary-Layer Measurements on an Ogive-Cylinder Body in Flight at Supersonic Speeds.* NACA RM L52K28a.
78. Fricke, Clifford L.; and Smith, Francis B.: *Skin-Temperature Telemeter for Determining Boundary-Layer Heat-Transfer Coefficients.* NACA RM L50J17.
79. Johnson, Caldwell C.: "Magnesium in NACA's Pilotless Aircraft." *Magnesium,* Nov. 1950.
80. Chauvin, Leo T.; and deMoraes, Carlos A.: *Correlation of Supersonic Convective Heat-Transfer Coefficients From Measurements of the Skin Temperature of a Parabolic Body of Revolution (NACA RM–10).* NACA RM L51A18. Reissued as NACA TN 3623, Mar. 1956.
81. Chauvin, Leo T.; and Maloney, Joseph P.: *Turbulent Convective Heat-Transfer Coefficients Measured From Flight Tests of Four Research Models (NACA RM–10) at Mach Numbers From 1.0 to 3.6.* NACA RM L54L15.
82. Colburn, Allan P.: "A Method of Correlating Forced Convection Heat Transfer Data and a Comparison With Fluid Friction." *Trans. Am. Inst. Chem. Eng.,* vol. XXIX, 1933, pp. 174–210.
83. Hoffman, Sherwood; and Chauvin, Leo T.: *Aerodynamic Heat Transfer and Zero-Lift Drag of a Flat Windshield Canopy on the RM–10 Research Vehicle at High Reynolds Numbers For a Flight Mach Number Range From 1.5 to 3.0.* NACA RM L56G05.
84. Crocco, Luigi: "Transmission of Heat From a Flat Plate to a Fluid Flowing at a High Velocity." *L'Aerotecnica,* vol. XII, no. 2, Feb. 1932, pp. 181–197. Translated and reissued as NACA TM 690, 1932.
85. Swanson, Andrew G.; Buglia, James J.; and Chauvin, Leo T.: *Flight Measurements of Boundary-Layer Temperature Profiles on a Body of Revolution (NACA RM–10) at Mach Numbers From 1.2 to 3.5.* NACA TN 4061, July 1957.
86. Morrow, John D.; and Nelson, Robert L.: *Large-Scale Flight Measurements of Zero-Lift Drag of 10 Wing-Body Configurations at Mach Numbers From 0.8 to 1.6.* NACA RM L52D18a.

87. Wallskog, Harvey A.; and Morrow, John D.: *Large-Scale Flight Measurements of Zero-Lift Drag and Low-Lift Longitudinal Characteristics of a Diamond-Wing-Body Combination at Mach Numbers From 0.725 to 1.54.* NACA RM L53C17.
88. Kurbjun, Max C.; and Faber, Stanley: *Transonic Drag Characteristics of a Wing-Body Combination Using a Thin Tapered Wing of 45° Sweepback.* NACA RM L50B22.
89. Kurbjun, Max C.; and Thompson, Jim Rogers: *Free Fall Measurements of the Effects of Wing-Body Interference on the Transonic Drag Characteristics of Swept-Wing-Slender-Body Configurations.* NACA RM L53C31.
90. Gillis, Clarence L.; and Vitale, A. James: *Wing-On and Wing-Off Longitudinal Characteristics of an Airplane Configuration Having a Thin Unswept Wing of Aspect Ratio 3, as Obtained From Rocket-Propelled Models at Mach Numbers From 0.8 to 1.4.* NACA RM L50K16. Reissued as NASA TN D–7, Mar. 1960.
91. McFall, John C., Jr.; and Hollinger, James A.: *Longitudinal Stability, Control Effectiveness, and Drag Characteristics at Transonic Speeds of a Rocket-Propelled Model of an Airplane Configuration Having an Unswept Tapered Wing of Aspect Ratio 3.0 and NACA 65A004.5 Airfoil Sections.* NACA RM L52L04.
92. Gillis, Clarence L.; and Mitchell, Jesse L.: *Determination of Longitudinal Stability and Control Characteristics From Free-Flight Model Tests With Results From Three Airplane Configurations.* NACA TR 1337, 1957.
93. Parks, James H.: *Longitudinal Aerodynamic Characteristics of a Model Airplane Configuration Equipped With a Scaled X–1 Airplane Wing.* NACA RM L51L10a.
94. Vitale, A. James; McFall, John C., Jr.; and Morrow, John D.: *Longitudinal Stability and Drag Characteristics at Mach Numbers From 0.75 to 1.5 of an Airplane Configuration Having a 60° Swept Wing of Aspect Ratio 2.24 as Obtained From Rocket-Propelled Models.* NACA RM L51K06.
95. Parks, James H.; and Kehlet, Alan B.: *Longitudinal Stability, Trim and Drag Characteristics of a Rocket-Propelled Model of an Airplane Configuration Having a 45° Sweptback Wing and an Unswept Horizontal Tail.* NACA RM L52F05.
96. Parks, James H.; and Kehlet, Alan B.: *Longitudinal Stability and Trim of Two Rocket-Propelled Airplane Models Having 45° Sweptback Wings and Tails Mounted in Two Positions.* NACA RM L53J12a.
97. Parks, James H.: *Transonic Longitudinal Aerodynamic Effects of Sweeping Up the Rear of the Fuselage of a Rocket-Propelled Airplane Model Having No Horizontal Tail.* NACA RM L54K12.
98. Faber, Stanley; and Eagleston, John M.: *A Transonic Investigation By the Free-Fall Method of an Airplane Configuration Having 45° Sweptback Wing and Tail Surfaces.* NACA RM L53D10.
99. Vitale, A. James: *Effects of Wing Aeroelasticity on the Aerodynamic Characteristics of an Airplane Configuration Having 45° Sweptback Wings as Obtained From Free-Flight Rocket-Model Tests at Transonic Speeds.* NACA RM L52L30.
100. Kraft, Christopher C., Jr.; and Mathews, Charles W.: *Determination By the Free-Fall Method of the Drag and Longitudinal Stability and Control Characteristics of a Canard Model at Transonic Speeds.* NACA RM L50D04.
101. Peck, Robert F.; and Mitchell, Jesse L.: *Rocket-Model Investigation of Longitudinal Stability and Drag Characteristics of an Airplane Configuration Having a 60° Delta Wing and a High Unswept Horizontal Tail.* NACA RM L52K04a.
102. Chapman, Rowe, Jr.; and Morrow, John D.: *Longitudinal Stability and Drag Characteristics at Mach Numbers From 0.70 to 1.37 of Rocket-Propelled Models Having a Modified Triangular Wing.* NACA RM L52A31.
103. Purser, Paul E.; and Mitchell, Jesse L.: *Miscellaneous Directional-Stability Data for Several Airplane-Like Configurations From Rocket-Model Tests at Transonic Speeds.* NACA RM L52E06b.
104. Purser, Paul E.: *An Approximation to the Effect of Geometric Dihedral on the Rolling Moment Due to Sideslip For Wings at Transonic and Supersonic Speeds.* NACA RM L52B01.
105. Dietz, Albert E.; and Edmondson, James L.: *The Damping in Roll of Rocket-Powered Test Vehicles Having Rectangular Wings With NACA 65–006 and Symmetrical Double-Wedge Airfoil Sections of Aspect Ratio 4.5.* NACA RM L50B10.
106. Edmondson, James L.: *Damping in Roll of Rectangular Wings of Several Aspect Ratios and NACA 65A–Series Airfoil Sections of Several Thickness Ratios at Transonic and Supersonic Speeds as Determined With Rocket-Powered Models.* NACA RM L50E26.
107. Sanders, E. Claude, Jr.: *Damping in Roll of Straight and 45° Swept Wings of Various Taper Ratios Determined at High Subsonic, Transonic, and Supersonic Speeds With Rocket-Powered Models.* NACA RM L51H14.
108. Sanders, E. Claude, Jr.: *Damping in Roll of Models With 45°, 60°, and 70° Delta Wings Determined at High Subsonic, Transonic, and Supersonic Speeds With Rocket-Powered Models.* NACA RM L52D22a.
109. Sanders, E. Claude, Jr.; and Edmondson, James L.: *Damping in Roll of Rocket-Powered Test Vehicles Having Swept, Tapered Wings of Low Aspect Ratio.* NACA RM L51G06.
110. Stone, David G.: *A Collection of Data For Zero-Lift Damping in Roll of Wing-Body Combinations as Determined With Rocket-Powered Models Equipped With Roll-Torque Nozzles.* NACA RM L53E26. Reissued as NACA TN 3955, Apr. 1957.
111. Stone, David G.; and Sandahl, Carl A.: *A Comparison of Two Techniques Utilizing Rocket-Propelled Vehicles for the Determination of the Damping-in-Roll Derivative.* NACA RM L51A16.
112. Bland, William M., Jr.; and Sandahl, Carl A.: *A Technique Utilizing Rocket-Propelled Test Vehicles For the Measurement of the Damping-in-Roll of Sting-Mounted Models and Some Initial Results For Delta and Unswept Wings.* NACA RM L50D24. Reissued as NACA TN3314, May 1955.
113. Bland, William M., Jr.; and Dietz, Albert E.: *Some Effects of Fuselage Interference, Wing Interference, and Sweepback on the Damping-in-Roll of Untapered Wings as Determined By Techniques Employing Rocket-Propelled Vehicles.* NACA RM L51D25.
114. Bland, William M., Jr.: *Effect of Fuselage Interference on the Damping-in-Roll of Delta Wings of Aspect Ratio 4 in the Mach Number Range Between 0.6 and 1.6 as Determined With Rocket-Propelled Vehicles.* NACA RM L52E13.
115. Bland, William M., Jr.: *Effect of Wing Flexibility on the Damping-in-Roll of a Notched Delta Wing-Body Combination Between Mach Numbers of 0.6 and Approximately 2.2 as Determined With Rocket-Propelled Models.* NACA RM L54E04.

CHAPTER 9

MANDATE FOR RESEARCH AT HIGHER SPEEDS AND ALTITUDES: 1952

HYPERSONIC RESEARCH PLANNING

The first suggestion that the NACA initiate research in the speed range of Mach 5 to 10 came from the NACA's subcommittee on Stability and Control at its meeting of June 14–15, 1951. A special group, representing manufacturers responsible for the development of 13 guided missiles,[1] had been invited to present their ideas on the direction in which NACA research should move for greatest benefit in missile development. In addition to numerous suggestions regarding missile aerodynamics and stabilization, the suggestion was made by Max Hunter, aerodynamicist of Douglas Aircraft Company, that exploratory investigations should be made of problems to be encountered by missiles at speeds between Mach numbers of 5 and 10. Douglas was involved in development of both the Sparrow and Nike missiles and anticipated that, with the contemplated increase in speeds of interceptor aircraft to Mach 3, the next step in interceptor-missile design would be in the Mach number range from 5 to 10 (ref. 1).

By this time, all of the manufacturers represented at the meeting had been involved in flight testing their products in much the same manner as that followed by PARD at Wallops. They had not been as successful at obtaining reliable data from their firings, however, and at the meeting asked for assistance in "reducing these data to transfer functions or stability derivative form." As reported by H. J. Goett, Ames Laboratory representative on the subcommittee,

> Most of the missile manufacturers are engaged in obtaining aerodynamic data from firings of their missiles. Almost without exception they would like to know the secret of PARD's success in getting reliable data from such firings.

The Atlas intercontinental ballistic missile, on which work had been resumed by Convair in January 1951, was not represented in this special group of manufacturers who presented their problems and suggestions; but at the NACA Conference on the Aerodynamic Design Problems of Supersonic Guided Missiles held at Ames on October 2–3, 1951, William H. Dorrance, Convair aerodynamicist on the Atlas study contract, made a strong plea for the NACA to expand its research on missile problems to speeds up to Mach 20. Without mentioning the secret Atlas project by name, he stated that data at such speeds were urgently needed.

1. The 13 missiles were the Sperry and Douglas Sparrow, Hughes Falcon, MIT Meteor, APL Terrier, APL Talos, Bell Telephone and Douglas Nike, Bell Rascal, Grumman Rigel, General Electric Hermes, Martin Matador, Northrop Snark and Boojum, and North American Navaho.

The Committee on Aerodynamics met on October 4, 1951, at Ames following the missile conference and acted on recommendations of its subcommittees. The Stability and Control subcommittee acknowledged the assistance of the special missile group but made no recommendation to its parent committee regarding the need for research at higher speeds. In addition, no recognition was given to Dorrance's request for extension of research to Mach 20. Robert J. Woods, Bell Aircraft representative on the Aerodynamics Committee, made his first recommendation that the NACA consider obtaining data at extreme altitudes and speeds. His action was reported as follows:

> Mr. Woods recommended that the NACA consider research required in the development of a V-2 research airplane, the objective of which would be to obtain data at extreme altitudes and speeds, and to explore the problems of re-entry into the atmosphere. He strongly recommended that a study of the feasibility of such a project be carried out at this time.

The recommendation was considered too long-range and was tabled (ref. 2).

No mention of satellites was made at this time although the Air Force, early in 1951, had sponsored studies by the RAND Corporation into the feasibility of reconnaissance by such vehicles (refs. 3 and 4).

The subcommittee on Stability and Control met again on November 1, 1951. There was general agreement at this time that aerodynamic research should be extended to at least Mach 5. It was resolved that "NACA should give special priority to research related to aerodynamic characteristics at Mach numbers up to 4 and above." Ralph H. Shick, long-time airplane aerodynamicist from Convair, and a new member of this subcommittee, "called attention to the lack of data at Mach Numbers above 5.0 and stated that it was not too soon for considerable effort to be expended on the development of experimental techniques for research in the hypersonic speed range (Mach numbers of 5 to 25)" (ref. 5). No doubt Shick was thinking of the needs of Atlas by this time. It was pointed out that Ames Laboratory had a 10-inch by 14-inch hypersonic tunnel and that Langley had a Mach 7 hypersonic tunnel. Shick insisted on the need for free-flight tests in the higher speed range. No further action was taken by the subcommittee in view of the earlier resolution calling for additional research at Mach 4 and above.

The subcommittee on High Speed Aerodynamics met on December 6, 1951, with both John Stack and Robert R. Gilruth as members from Langley. The lack of facilities for hypersonic research up to Mach numbers of 15 to 20 was discussed. Stack described the tunnel facilities under construction for testing to Mach 5 and the gas dynamics facility, nearing completion, in which research could be conducted well into the hypersonic range. Gilruth mentioned that PARD had obtained heat-transfer data in flight to Mach 3.8 in the RM-10 program, and that drag models would soon be flown to Mach 4, but stability and control models appeared to be limited to a Mach number of about 1.7. Shock tubes were discussed, and it was agreed that new ideas were needed (ref. 6).

Researchers at PARD were not unmindful of this need for data at higher speeds. At this point the Deacon was the largest motor on hand. Two had been used together as a booster behind a third Deacon in achieving the Mach 3.8 flight for heat-transfer measurements. Triple and quadruple Deacon boosters were over a year away and attempts were underway to obtain larger motors to perform the same function as the clustered Deacons. This was not to bear fruit, however, until late in 1953 when Wallops launched its first Nike booster. Paul R. Hill had tried earlier to interest the PARD rocket experts in the multiple staging of clustered rocket motors, but the structural complications seemed overwhelming, and progress in this direction was slow.

At the next meeting of the Aerodynamics committee on January 30, 1952, the resolution of the Stability and Control subcommittee regarding the high-priority need for aerodynamic research in the Mach number range from 1.5 to 4 was endorsed and extended further to include consideration of problems in the hypersonic range beyond Mach 5. A proposal of Robert J. Woods for a research study leading to space flight, which was presented at this meeting, was referred to NACA laboratories for evaluation and for recommendations to be presented at the next meeting (ref. 7). Woods' proposal was a followup to his previous suggestion at the October 1951 meeting, that the NACA should consider a V-2 research airplane. His formal proposal at the January 1952 meeting (ref. 8) was "to establish a small, specialized scientific study group within the NACA to analyze and evaluate possible approaches to a solution" of the problems associated with the operation of a manned aircraft which, like the V-2, would leave the earth's atmosphere and therefore would require special controls. Unlike the V-2, the aircraft would have wings and would be designed for reentry into the atmosphere and a glide landing.

A speed in excess of Mach 5 was envisioned. This proposal was considered to be the beginning of the X-15 research airplane.

Woods' proposal was accompanied by an even more ambitious suggestion by another employee of Bell Aircraft, Dr. Walter Dornberger of German V-2 fame (ref. 9). Dornberger reasoned that the effectiveness of defensive missiles would force manned aircraft to altitudes above 100,000 feet and to hypersonic speeds. He pointed out that if such aircraft were to be realized, "experimental ionosphere-planes monitored by human beings and capable of pushing forward into almost free space for research purposes have to be developed." He also pointed out that such an airplane was needed to realize "the more fancier technical goals of a piloted artificial satellite and of any space traveling." He calculated that such an airplane, weighing 57,700 pounds and being launched from the ground, could reach an altitude of 78.6 miles and still have a speed of 4,000 feet per second; or it could reach an altitude of 107 miles with a speed of 4,600 feet per second if launched from an airplane at an altitude of 30,000 feet.

At Langley, Woods' proposal was given to PARD branch head D. G. Stone for appraisal and comment. He recommended that a good first start would be to equip the Bell X-2 research airplane with reaction controls and add two droppable Sergeant solid-rocket motors as boosters. With such booster rockets, an air-launched X-2 airplane could be flown at altitudes above 100,000 feet and at speeds above Mach 3. Good control of reentry angles could limit temperature rise of the skin of the airplane to 300° F (ref. 10).

Following this preliminary study, F. L. Thompson prepared a letter to NACA Headquarters in which he recommended "that a group be formed to study these problems in some detail with a view towards formalizing the program that would be required to set up a space flight project and to look into the feasibility of using the X-2 as a test vehicle."[2]

Albert E. Lombard, Jr., Scientific Adviser of USAF Headquarters and member of the NACA Committee on Aerodynamics, studied Woods' proposal and sent a letter to the committee,[3] in which he heartily endorsed Woods' proposal and proposed a resolution for adoption by the committee. Lombard suggested that the higher altitudes be divided into two regions: one between 12 and 50 miles, and the other above 50 miles. He stated that guided missiles such as the Navaho II and Bomarc II, as well as glide rockets, would fly in the first region, and the critical reentry of satellites and ballistic rockets would occur in this region. He pointed out that the Air Force was interested in the second region (above 50 miles) for satellite vehicles and long-range ballistic vehicles for military operation in the reconnaissance and bombardment fields.

The Committee on Aerodynamics met at Wallops Island on June 24, 1952, after making a tour of the station and witnessing a rocket launching. (See figure 144.) The way had been well cleared for action on Woods' proposal by this time. With little discussion, the committee adopted a resolution that was essentially the one proposed by Lombard. It read as follows (ref. 11):

> Whereas, The upper stratosphere is the important new flight regime for military aircraft in the next decade and certain guided missiles are already under development to fly in the lower portions of this region, and
>
> Whereas, Flight in the ionosphere and in satellite orbits in outer space has long-term attractiveness to military operations, studies are already under contract, by at least one military service, to develop feasible and economic means of such flight, and
>
> Whereas, The NACA is in a position to make important contributions through research to provide the scientific information and tools for development of future aeronautical vehicles, it is
>
> Resolved, That the Main Committee on Aerodynamics recommends that (1) the NACA increase its program dealing with problems of unmanned and manned flight in the upper stratosphere at altitudes

2. Letter from Langley to NACA Headquarters, May 26, 1952, regarding meeting of Committee on Aerodynamics at Wallops Island on June 24, 1952.
3. Letter from Albert E. Lombard, Jr., to NACA Committee on Aerodynamics, June 23, 1952, regarding upper stratosphere, ionosphere, and space flight.

FIGURE 144. The NACA Committee on Aerodynamics stands behind RM–10 model at Assembly Shop at Wallops for official photograph prior to regular meeting on June 24, 1952. Left to right: R. L. Krieger, Engineer-in-Charge, Wallops; E. O. Pearson, Jr., NACA Hq.; M. B. Ames, Jr., NACA Hq., Committee Secretary; F. L. Thompson, Chief of Research, Langley; A. E. Lombard, Jr., USAF, Directorate of R and D; R. G. Robinson, Ames Aero. Lab.; A. H. Flax, Cornell Aero. Lab.; J. A. Shortal, Chief, PARD; J. W. Crowley, Associate Director for Research, NACA; R. H. Widmer, Convair; R. R. Gilruth, Asst. Chief of Research, Langley; H. L. Dryden, Director, NACA; C. B. Millikan, Ca. Tech.; H. J. E. Reid, Director, Langley; C. L. Johnson, Lockheed Aircraft Corp.; F. A. Louden, Navy BuAer; Col. J. A. Gibbs, USAF AMC; R. E. Littell, NACA Hq.; Capt. M. R. Kelley, USN (Ret.); H. D. Hoekstra, CAA; A. E. Puckett, Hughes Aircraft Co.; I. H. Abbott, NACA Hq.; Capt. W. S. Diehl, USN (Ret.), Vice Chairman; G. Loening; T. P. Wright, Cornell University, Chairman; G. S. Schairer, Boeing Airplane Co.; C. Wood, NACA Hq.; R. J. Woods, Bell Aircraft Corp.; and W. B. Oswald, Douglas Aircraft Co.

between 12 and 50 miles, and at Mach numbers between 4 and 10, and (2) the NACA devote a modest effort to problems associated with unmanned and manned flights at altitudes from 50 miles to infinity and at speeds from Mach number 10 to the velocity of escape from the earth's gravity.

Essentially the same resolution was adopted by the NACA Executive Committee at its meeting on July 14, 1952.

NACA Headquarters asked the laboratories for comments and recommendations. Langley replied with a proposal that a study group consisting of C. E. Brown, C. H. Zimmerman, and W. J. O'Sullivan, Jr., be assigned the task of preparing a report covering the various phases of a proposed program that would carry out the intent of the resolution. In order to effect coordination, Langley recommended that the work of the study group be reviewed by a board consisting of representatives from the three laboratories and the High-Speed Flight Research Station at Edwards.

This recommendation of Langley was approved by NACA Headquarters on August 14, 1952. On September 8, 1952, RA A73L95 was issued as authorization for the three-man study. Concurrently, PARD began studies of rocket systems capable of extending the Mach number of rocket models.

EXPANSION OF RESEARCH FACILITIES

During 1952, a major expansion of research facilities at Wallops was completed. The Independent Offices Appropriation Act, 1950, which was approved on August 24, 1949, provided $638,000 to start financing this expansion, and $373,000 in contract authority to complete it, for a total of $1,011,000. This was the largest C & E appropriation for Wallops since the initial funding in 1945. Funds in the amount of $93,239 (Project 917) for the purchase of the island in its entirety came from this appropriation, as discussed earlier in Chapter 6.

The total funds expended were divided as follows:

Project	Item	Contract	Cost
917	Purchase of Island		$ 93,239
927	Model Assembly Shop	NAw-5905	315,915(1)
	Control Center 2	NAw-6005	166,539
	Propellant Shop		48,672
	Station 1	NAw-5826	6,000
	Station 2		6,685
	Ramjet Fuel Storage		12,000
	Launch Area 2, Seawall, Roads, Utilities, and Grading		207,902
1038	Ferry		126,799(2)
	Ferry Slips	NAw-6090	128,600(3)
	Total		$1,112,351

Notes: (1) Includes architects' fees.
(2) Includes engine for ferry.
(3) Includes architects' fees.

The difference between the appropriated and expended totals was provided by a transfer of funds from other construction projects at Langley.

The three major contracts under Project 927 were with Doyle and Russell, and all of the buildings were in use by May 1952. The new construction on the island is shown in figures 145 and 146.

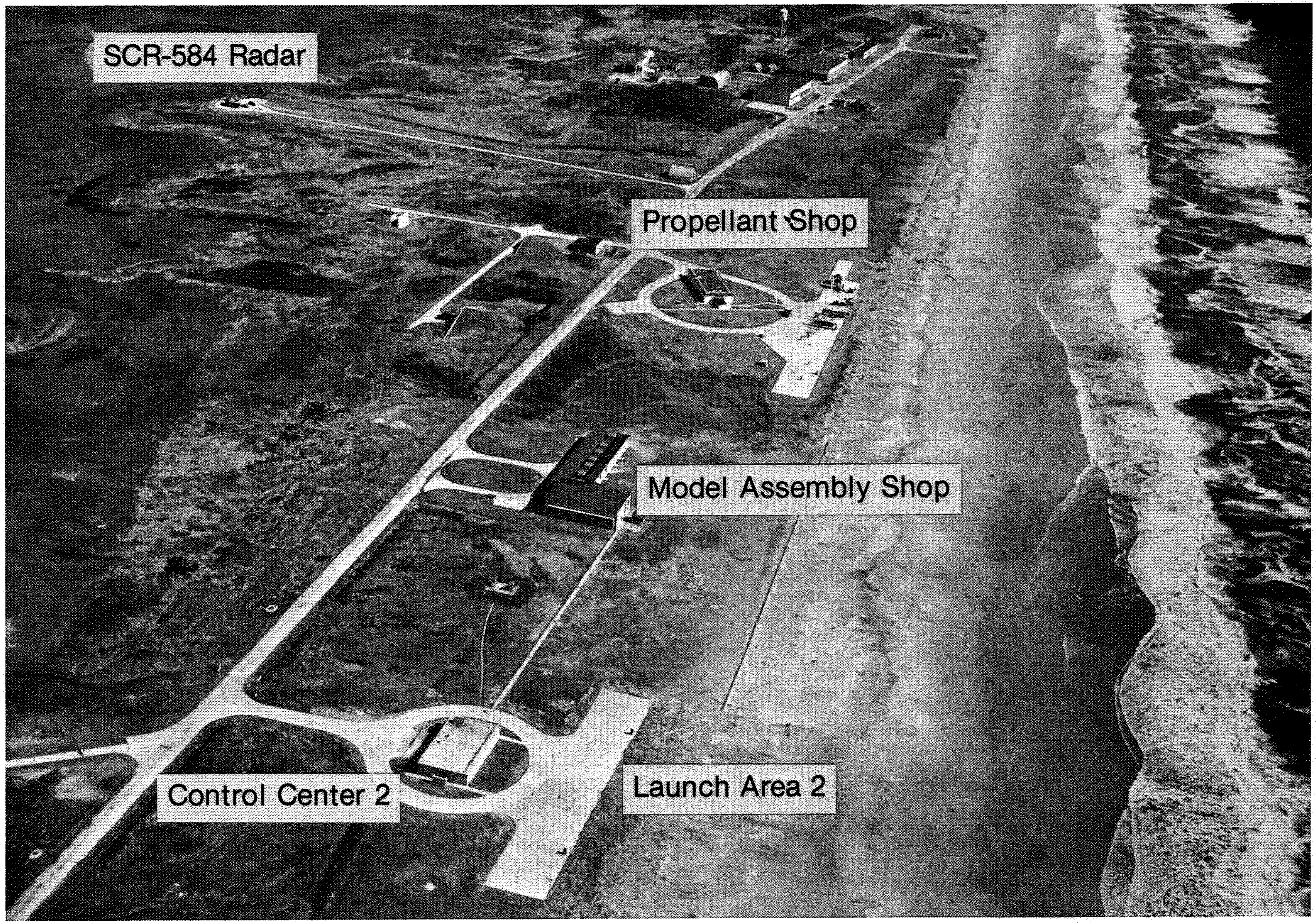


FIGURE 145. Aerial view of Wallops Island looking north, with new construction identified, March 20, 1952.

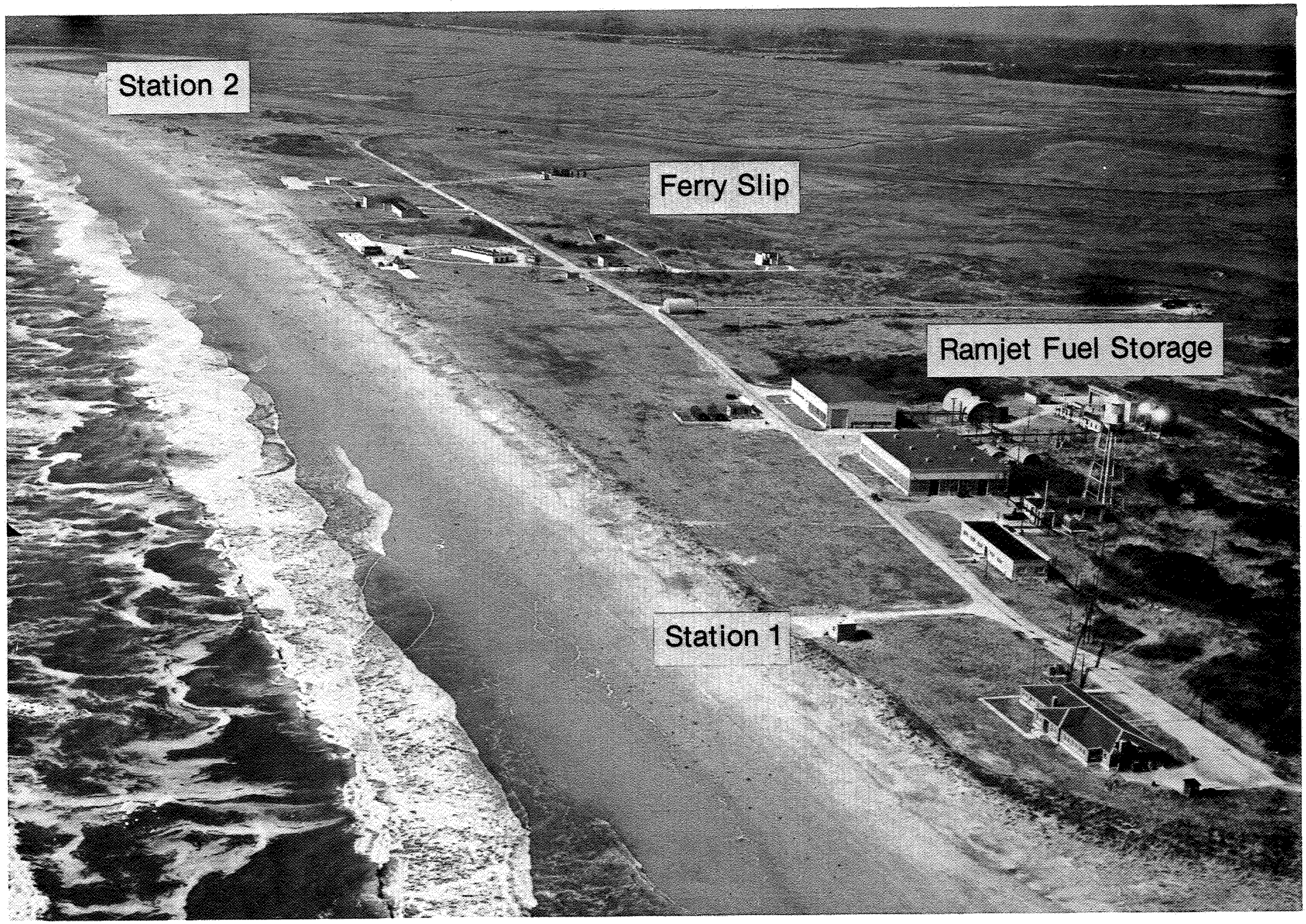


FIGURE 146. Aerial view of Wallops Island looking south, with new construction identified, March 20, 1952.

Launch Area 2 with its Control Center 2 was constructed in anticipation of a threefold increase in number of launchings, as recommended by a special Transonic Aircraft Subcommittee in 1948. Launch Area 2 and Control Center 2 were similar in construction to Launch Area 1 and Control Center 1. The new launching area consisted of a concrete slab 50 feet wide and 300 feet long, located along the ocean front. It was connected with the main road by a circular driveway, in the center of which was the Control Center. This building was 44 feet by 75 feet, and contained separate instrumentation rooms and a heating plant large enough to heat the new Model Assembly Shop as well as the Control Center. The seawall was extended along the beach to a point just beyond the new launching area. This new launching area was not used regularly for rocket launchings until later (under NASA) because the threefold increase in launchings did not materialize. In the meantime the building was used as a photographic laboratory.

The Model Assembly Shop was the fulfillment of a longtime need at Wallops and, for the years ahead, was to be the center for all rocket-model preparation, loading and storage. It was easily the most valuable building on the island. Originally planned in 1948 to have a central shop with a row of special rooms on either side, it was redesigned in 1949 at the suggestion of J. A. Shortal and R. L. Krieger to have a large shop area with seven rooms in a row on the north side only. All of these rooms were separated by heavy concrete walls and were provided with blowout walls on the ocean side for safety in case of an explosion. A 12-foot overhanging canopy along the entire length of the building allowed protected access to the different rooms.

The rooms were arranged in production-line fashion. Models and boosters were mounted on special model-handling dollies or Air Force bomb dollies, and were rolled from one room to another. Models were received in the main shop area, where necessary modifications were made. The first adjoining room contained equipment for weighing, and for the determination of center of gravity and moments of inertia. In the next room, rocket motors were loaded and booster fins and adapters were added. Completed models and boosters were stored in the following two rooms, pending launch. On the day of a launch, a model would be moved to one of the next two rooms, which were equipped for telemeter checkout and repair. These telemeter rooms were shielded to minimize radio interference. The final room was arranged for photography, but it was also used for storage. The main shop was 52 feet by 83 feet, the balance room was 20 feet by 47 feet, the next five rooms were each 20 feet by 32 feet, and the photoroom was 40 feet by 32 feet. The building had a total length of 212 feet.

The seven preparation rooms adjoining the main shop may be seen in figure 147, which shows a model of the Douglas X-3 research airplane in the truck and its double Deacon booster already assembled on the mobile launcher ready for transport to the launch area. The mating of the model to its booster was done on the launch pad by available manpower, as shown in figure 148. These were typical scenes on the day of a launching.

The Propellant Shop consisted of a room 26 feet by 36 feet for work on rocket motors, a room 13 feet by 16 feet for work on squibs and igniters, and a boiler room 13 feet square. The rooms were separated by concrete walls and had blowout walls in one end. This building was located within the fenced-in restricted propellant area, as shown in figure 145.

Two camera stations were constructed as a part of this expansion. Station 1 was located just south of the Service Building or hotel, while Station 2 was located 1,400 feet south of Launch Area 2 and 500 feet east of the main road. Both stations are identified in figure 146. Both were 15 feet square and 15 feet high and had outside stairs for access to the flat roof on which the cameras were to be located. The raised deck was desired to get the cameras above the ground haze for better tracking pictures and to provide better visibility of the launch area. Concrete roads were constructed to each station.

A circular concrete pad 85 feet in diameter was poured at the SCR-584 radar site, and a concrete road was run from there to the main road, as a part of this expansion. The radar site is identified in figure 145, but it can also be seen in figure 146. The main road leading to the island dock was widened to 20 feet all the way, as a part of the paving program. In addition, parking strips were poured in front of the Administration and Service Buildings. The road leading to the Preflight Jet was widened, and additional outside work areas were constructed of concrete in the vicinity of the Jet.

The last building under Project 927 was the Ramjet Fuel Storage Building, identified in figure 146. This building was 20 feet by 30 feet and was located near the Preflight Jet. It was used for the storage of cylinders of ethylene and other ramjet fuels.

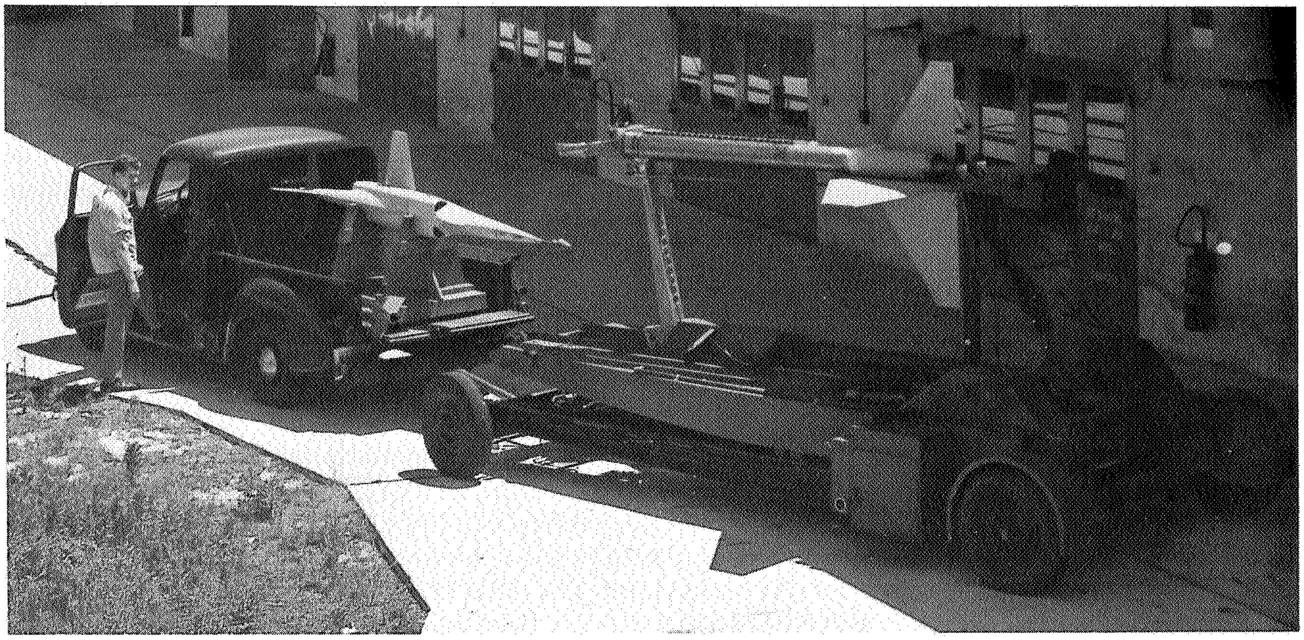


FIGURE 147. View of Model Assembly Shop area, June 13, 1952. Engineer J. A. Hollinger prepares to drive away truck carrying model of Douglas X−3 research airplane and towing mobile launcher with a double Deacon booster.

FIGURE 148. From left, technician D. A. Dereng and engineer R. F. Peck are assisted by H. Bloxom, R. Hindle, and J. A. Hollinger in mating a model of the Douglas X−3 research airplane with its double Deacon booster in the launch area, June 13, 1952.

Project 1038 covered the procurement of a ferry and the construction of ferry slips on the island and the mainland. Procurement of a ferry to replace the two wartime LCM boats and two 35-foot personnel boats had been recommended by the Langley Executive Safety Committee at its meeting at Wallops on June 24, 1948. Two smaller boats were to be retained for emergency use. After the appropriation was received in August 1949, a request for approval was sent to NACA Headquarters by Langley on September 26, 1950. Approval was granted and Project 1038 was assigned for identification.

In requesting approval, Langley pointed out that a large ferry would provide more efficient transportation because it could carry several trucks and a number of people, thus reducing the number of trips. Less maintenance would be required, and a diesel-powered ferry would be safer than the existing gasoline-powered boats. In addition, a ferry could be made available to future contractors, thereby reducing construction costs on the island.

Procurement of a suitable ferry was the next step. A survey of boats available failed to locate one suitable for operation in the dredged channel between Wallops and the mainland, and it was concluded that a special ferry would have to be designed and constructed (ref. 12). A survey of available naval architects with experience in the design of ferryboats revealed that Eads Johnson of New York had the best reputation. Accordingly, the Langley Architect-Engineer Advisory Board recommended that a contract be negotiated with him for the design (ref. 13). This recommendation was endorsed by H. J. E. Reid, Langley Director, and passed on to NACA Headquarters for approval. Approval was given on January 5, 1951. Negotiations were held with Eads Johnson on January 15, 1951, and the general design, including the use of a slow-speed heavy-duty diesel engine, was agreed upon (ref. 14). A speed of 10 knots in the channel was estimated by Johnson. Four lift points were to be provided for removing the boat from the water for overhaul.

The ferry was constructed by the Chesapeake Marine Railway Company, Baltimore, Maryland, and was named "*Langley*." It was completed on June 13, 1952. The engine was provided by Langley under contract NA1-1417 with Fairbanks-Morse Company, at a cost of $34,134. The U. S. Coast Guard provided inspectors during the construction. Thomas M. McComb, Jr., of Wallops participated in the official trials on June 10, 1952.

The ferry *Langley*, shown in figure 149, was of steel, double-end construction with passenger cabins on both sides of the central vehicle area. It had a length of 76 feet and a beam of 32 feet, and displaced 109 tons with a draft of 5 feet. The wheelhouse atop one of the passenger cabins was designed for one-man operation through direct engine and rudder controls.

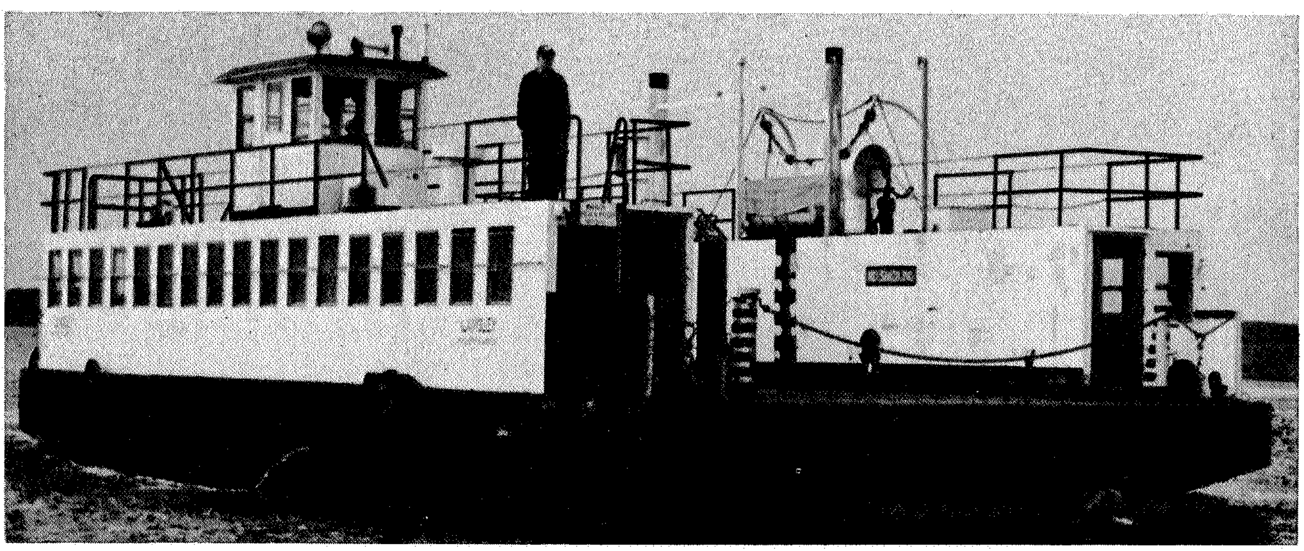


FIGURE 149. **Ferry boat *Langley* used for transportation between Island Dock at Wallops and Mainland Dock.**

On August 5, 1952, the ferry was brought down Chesapeake Bay from Baltimore, through the Virginia Capes and up to Wallops Island along the Atlantic coast. In open water, the vessel handled well and appeared to be the answer to the needs. Once in the Wallops channel, however, extreme difficulty developed in steering. The speed had to be reduced and even then it took the combined efforts of two men to keep the ferry under control. The difficulty was attributed to the shallow channel, and a permit was requested to dredge it to a depth of 12 feet below mean low water.[4] A permit was granted on August 28, 1952, but no action was taken at that time because of lack of funds.

While the ferry was being constructed, ferry slips at the mainland and at Wallops were likewise being constructed. Earlier, the channel between the mainland and the island had been straightened except for a turn at each end. The turn at the island end was now eliminated by dredging a new channel (as an extension of the main channel) right across Cat Creek and through the marsh approximately 700 feet to solid ground, terminating near Launch Area 2. This channel can be seen in figure 146.

At the mainland end of the channel in Assawaman Creek, the turn to reach the NACA dock was only 45 degrees, and it was felt that the ferry could make this turn without difficulty. Consequently, the location of the mainland end of the ferry route was not changed, despite a suggestion by H. J. E. Reid that this turn be eliminated also.

Although the location of the dock on the mainland was not changed, additional land was required for the new slip and the access road to it. The sketch in figure 150 shows the general layout of the Mainland Dock after the ferry slip and roads had been completed. The different parcels of land acquired at different times are shown in the figure. As discussed in Chapter 3, and shown in figure 150, parcel A-A, consisting of 0.8 acre, was purchased from Mrs. J. T. Lewis in 1945. Purchase of the 0.7-acre parcel B-B from P. B. Taylor followed in 1946, to provide land for the original dock facilities. The parcel C-C, 0.96 acre, also owned by P. B. Taylor, was acquired by condemnation on June 9, 1947, to provide space for employee parking.[5] As shown in figure 150, this area later provided space for the access road to the ferry slip. The condemnation suit was settled on January 17, 1950, and Taylor was paid $250 for the land.

The final parcel of land, D-D, as shown in figure 150, was acquired for the ferry slip and access road. This parcel of 1.0 acre was purchased from P. B. Taylor for $300, and the deed was signed by Taylor on June 30, 1950.[6]

The first three parcels of land were acquired by the authority granted in the 1945 appropriation to acquire 100 acres of land. The fourth parcel was acquired by authority granted in the 1950 appropriation to acquire Wallops Island.

A contract was negotiated with the Tidewater Construction Corporation, Norfolk, Virginia, for design of the ferry slips and transfer bridges. A fee of $5,300 was agreed upon, on the basis of an estimated cost of $90,000. A permit was obtained from the U. S. Engineer's Office on April 19, 1951, to construct ferry slips and to redredge part of the channel. Dredging was required at the mainland as well as at the island site.

Tidewater Construction Corporation also received a contract for construction of the ferry slips. The final cost of the contract, NAw-6090, was $123,300, considerably above the earlier estimate of $90,000. For this reason, the planned lifting rig for raising the ferry out of the water for bottom overhaul was eliminated from the contract. The slips, transfer bridges, access channels, and roads were completed by February 1952. In June 1952, an electric hoist, costing $1,500 was added to the transfer bridge at the mainland. The work was performed under Project 1318, with the use of GOE funds.

As was noted earlier, the main channel was too shallow for efficient operation of the ferry. The first solution proposed was to dredge the channel to a depth of 12 feet, and plans were made to do this, but funds were unavailable. The only recourse was to request funds in the budget being prepared in 1952.

4. Letter from W. Kemble Johnson, Administrative Management Officer, Langley, to Corps of Engineers, August 21, 1952, regarding channel dredging at Wallops Island.
5. Letter from A. Devitt Vanech, Assistant Attorney General, to NACA, June 13, 1947, regarding condemnation proceedings U.S. vs. 0.96 acre of land, P. B. Taylor et al, Misc. No. 7150.
6. Letter from U.S. Attorney General to Chairman, NACA, July 26, 1950, regarding deed for one acre of land in Accomack County, Virginia.

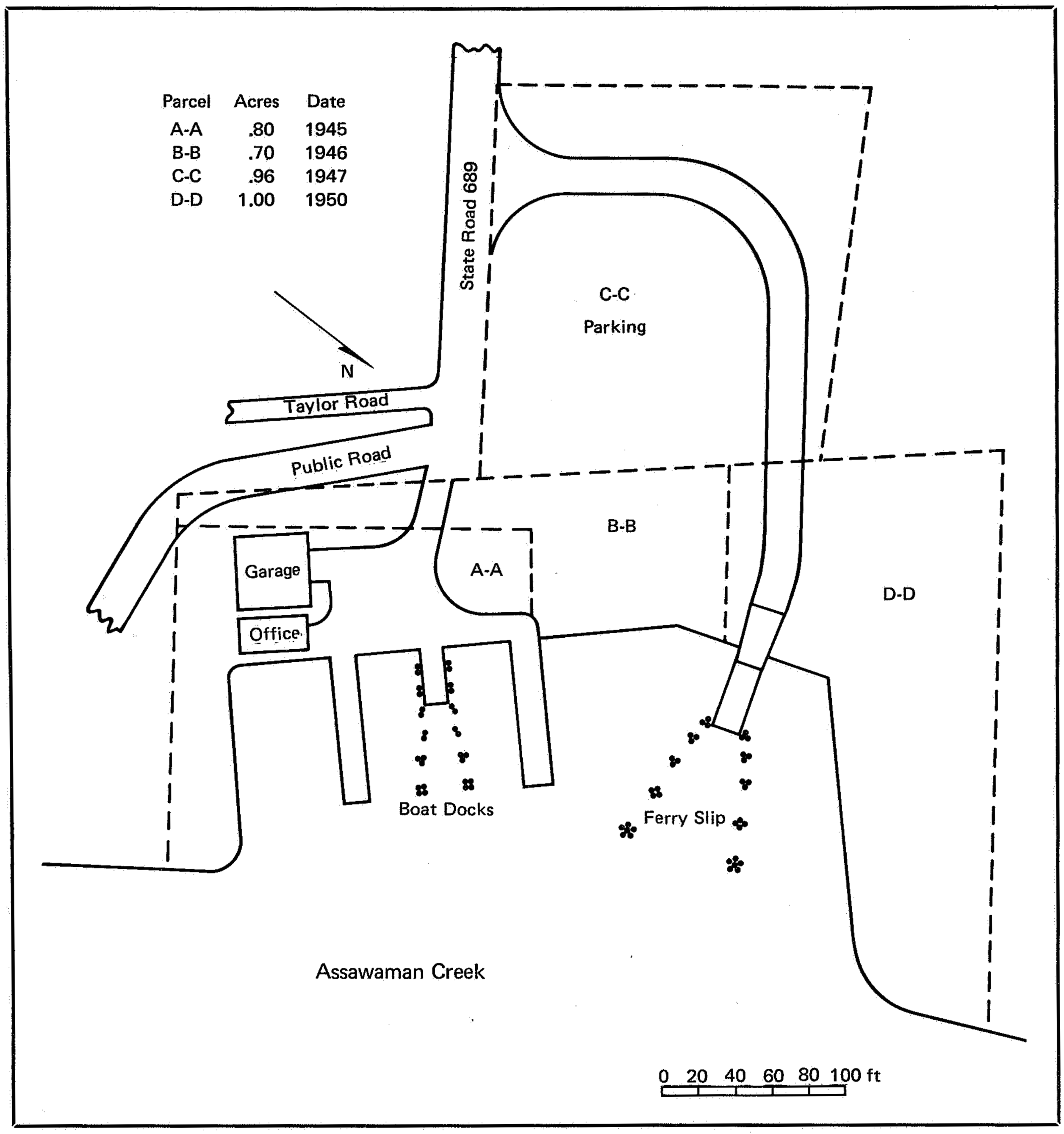


FIGURE 150. Sketch of Mainland Dock area, showing land parcels purchased, buildings, boat docks, ferry slip, and road.

This was the budget for fiscal year 1954, beginning July 1, 1953. Funds were requested by Langley for redredging the entire channel and for constructing the lifting rig that had been removed from the ferry slip contract.

Between August 1952 and September 1953, the ferry could be used only at high tide and was used mainly for transporting trucks and supplies for contractors. The personnel boats were kept in service for regular passenger travel. The disastrous fire in one of these boats on July 1, 1953, discussed in Chapter 8, emphasized the urgency of the situation and expedited approval of the request for redredging the channel. Funds became available from the GOE section of the 1954 budget, and Langley made its official request for approval to NACA Headquarters on September 8, 1953.[7]

7. Letter from Langley to NACA Headquarters, September 8, 1953, with request for approval of redredging ferryboat channel and building new ferryboat lift at Wallops Island.

Approval was given on September 29, 1953, under Project 1458, for an estimated cost of $96,600. The plan now was to widen the channel to 80 feet at the bottom, and to dredge to a depth of 10 feet.

The redredging of the channel was performed by Steen Contracting Company for a cost of $76,740, and was completed on March 12, 1954. The ferry was placed in regular operation at that time. As was the case in earlier dredging operations, damages were paid to owners of oyster beds after completion of the work. This time T. F. Mears received $50 and Elihu Matthews $300.

The lifting rig consisted of two large beams located 22 feet above mean high water atop piling on each side of the ferry slip at the mainland. Four 40-ton hoists on the beams provided the lift. Figure 151 shows this rig in use, with the ferry out of the water. The lift was constructed by Smith Brothers under contract NAw-6353, for a cost of $21,820, and was completed in June 1954. Later, the four-point lift was found to cause some racking of the ferry if it was not lifted evenly. A new lift point was constructed at one end of the ferry between the two lift points at that end, and the suspension was changed to a three-point system. Two of the 40-ton hoists were moved to the center of the beam and attached to the new single lift point by means of a yoke.

During this period, some alterations were made to the Preflight Jet with GOE funds. The largest was the addition of a third test section, especially designed for testing of ramjet engines under simulated high-altitude conditions. Figure 152 shows the interior of the Preflight Jet test area after the altitude simulator, shown along the left wall, had been completed. Ramjet engines may be seen in test position in the 12-inch main jet and the 8-inch side jet. The shadowgraph equipment may also be seen at the side of the engine in the main jet.

The test section of the altitude simulator was a closed one and may be seen in the center of the lower or primary piping system in figure 152. The low-density test condition was provided by a secondary piping system that was above the primary piping, but that joined it downstream of the test section. The storage spheres provided the air for the evacuation system as well as that for the engine under test.

A request for approval for the installation of the altitude simulator had been made on June 14, 1950, and had been approved by NACA Headquarters as Project 1027 on July 14, 1950, for a total cost of $10,425. The goal was to provide test conditions of Mach 3 at an 80,000-foot altitude. Auxiliary piping was to be run from both the upstream and downstream ends of the heat exchanger to allow direct control of air temperature by appropriate mixing. By April 1951, bids had been received for

FIGURE 151. The Ferry *Langley* shown in raised position as it undergoes bottom maintenance in ferry slip at Mainland Dock, July 13, 1954.

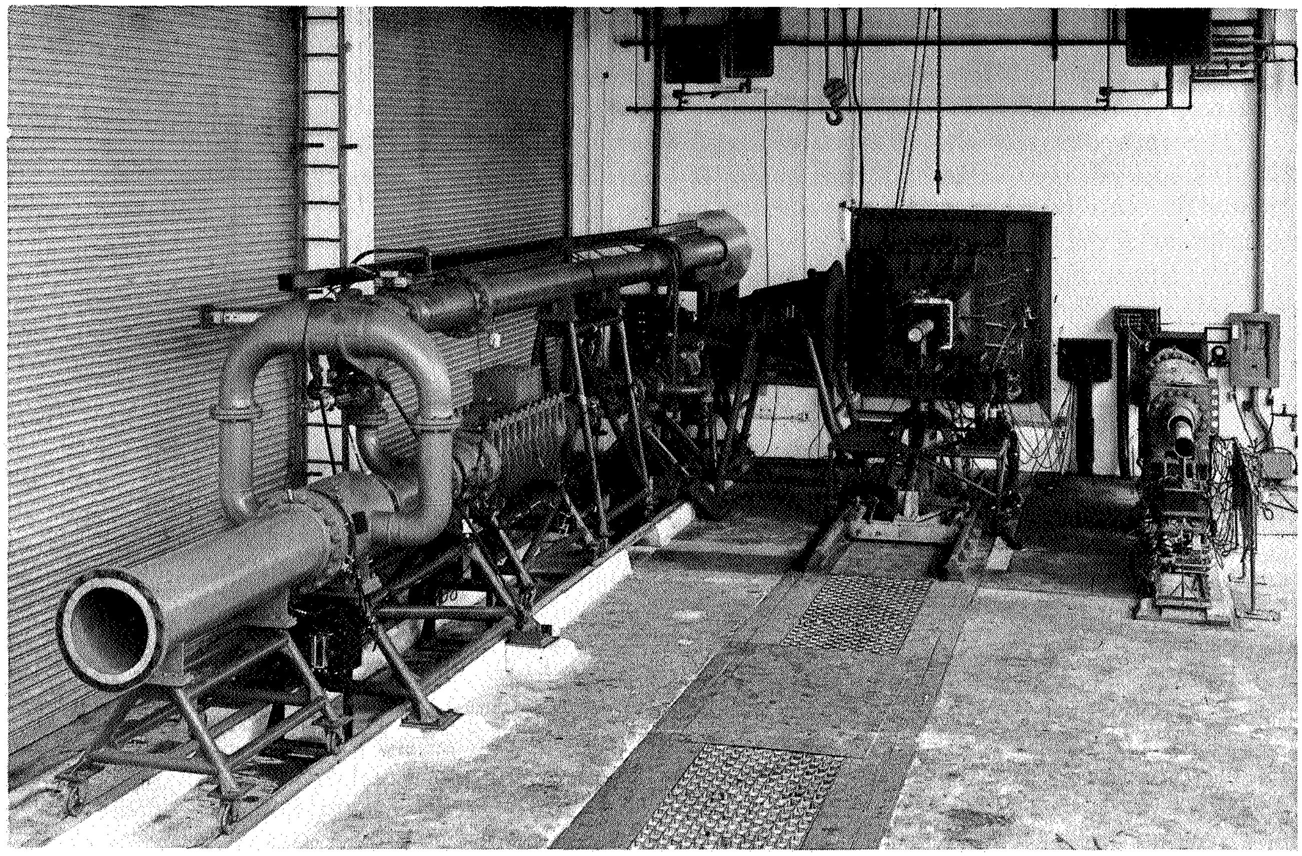


FIGURE 152. Interior of test house of Wallops Preflight Jet with altitude simulator, main A jet. and B side jet ready for operation, November 18, 1953.

doing the work and the estimated cost had risen to $16,425. In January 1952, the estimate was raised to $17,895. The piping and valves were installed by contract, with Wallops personnel constructing the foundations, supports, and instrumentation.

The first test of the ejector system was made satisfactorily on April 22, 1953, and the first run with primary airflow in addition was made on June 1, 1953. The mechanical valves were changed to hydraulically operated valves to make remote operation possible. On August 10, 1953, the first remote run was made at a Mach number of 2.5 at a simulated altitude of 55,000 feet.

The system was so arranged that the altitude simulator could be rolled out of the way and the primary air supply used to feed an 8-inch jet similar to the "B" jet already in operation. In the time to come, the system was to be used more as a third open jet than as an altitude simulator. It became known as "C" jet.

The early operations with ramjet engines in the Preflight Jet were conducted with a temporary fuel system. The ethylene fuel was received, stored, and used directly from manifolded pressure bottles. When plans were made for the use of liquid fuels, a permanent fuel system was installed, which was capable of handling either liquids or gasses, and the temporary ethylene system was incorporated into the new system.

This installation was approved by NACA Headquarters as Project 1027 on July 14, 1950, for a cost not to exceed $11,175. Work was to be done by NACA labor. The system consisted of storage tanks for vapor and liquid fuels, pumps, remotely controlled valves, meters, pressure regulators, piping, and controls. The system was located on an existing concrete pad extending from the west side of the rotovalve housing. It was placed in operation in September 1951.

Another addition to the Preflight Jet, to increase its operational efficiency, was initiated in 1952. The factor that governed the frequency of blowdown operations was the air compressor capacity. As was pointed out earlier in Chapter 6, up to 7 hours were required to recharge the spheres after a run, while only 4 hours were required to restore heat in the tubular heat exchanger. On November 4, 1952, Langley requested approval for the addition of a second 125-hp air compressor and associated drying and cooling equipment. NACA Headquarters gave approval on November 28, 1952, as Project 1365. The new equipment was installed by NACA labor in the compressor house beside the original equipment, and operation began in March 1954. The final cost was $29,000.

With air more readily available from the second air compressor, another modification was made to improve operations. An air gate was added upstream of the main jet nozzle, a project authorized by NACA Headquarters on June 24, 1954, as Project 1542. The gate was hydraulically operated and designed to withstand the pressure of 200 pounds per square inch in the system when closed. With this gate, the auxiliary jets could be operated alternately with the main jet. Before this, it had been necessary to remove the test model and seal the main jet by bolting a plate over the exit, a time-consuming task. The air gate also made it possible to keep the heat exchanger pressurized with dry air at all times, thus minimizing corrosion of the steel tubing. The air-gate system was constructed at Langley and installed at Wallops March 7, 1955, for a cost of $7,379.

ASSISTANCE IN UPPER ATMOSPHERE RESEARCH

Wallops was to become NASA's major range for the launching of sounding rockets and unmanned satellites for upper atmosphere and space science exploration. PARD activity in these areas began in June 1947, when W. J. O'Sullivan, Jr., Assistant to Chief, PARD, was appointed to represent the NACA on the Upper Atmosphere Rocket Research Panel (UARRP), replacing Dr. Calvin N. Warfield, who had resigned. The UARRP was a semiofficial group of scientists that had assumed cognizance over upper atmosphere research in the United States. It had been formed in January 1946 as a V-2 panel interested in the high-altitude research conducted with captured German V-2 missiles fired at White Sands Proving Ground.

When the supply of V-2 missiles was exhausted, Johns Hopkins University's Applied Physics Laboratory (APL), with James A. Van Allen as technical director, sponsored the development of a medium-altitude sounding rocket, the Aerojet Aerobee, while the Naval Research Laboratory (NRL) sponsored the development of the high-altitude Martin Viking sounding rocket, under the leadership of Homer E. Newell, Jr., and Milton W. Rosen. The first Aerobee was flown on November 24, 1947, and the first Viking, on May 3, 1949 (ref. 15). Both of these vehicles were to be used extensively in upper atmosphere and space research. In fact, modified forms of these rockets were to be used in the first U. S. satellite launch vehicle, the Martin Vanguard.

Early in 1946, the NACA Committee on Aerodynamics appointed a Panel on the Upper Atmosphere. The NACA had been the source of the nation's definition of a standard atmosphere since the beginning of the NACA in 1915. This panel recommended tentative standards for the atmosphere to an altitude of 100,000 feet, extending the tables from the limit of 65,000 feet as prepared by Walter S. Diehl in 1925 (ref. 16). These new tables were prepared by Langley member, C. N. Warfield (ref. 17).

In April 1946, the panel was superseded by the Special Subcommittee on the Upper Atmosphere of the NACA Committee on Aerodynamics, whose chief concern, according to the annual report of the NACA for 1947, was "the continued evaluation of upper atmosphere data until such time as it may be able to recommend with certainty final extensions of the tables of the NACA standard atmosphere. The subcommittee is continuing to serve as a medium for the interchange of information on research in progress or proposed and also as an advisory body for the formulation and coordination of programs of research on problems of physics of the upper atmosphere" (ref. 18). W. J. O'Sullivan, Jr., was to be the editor of such a document on standard atmosphere when it was finally published by the NASA in 1962 (ref. 19).

On December 30, 1947, W. J. O'Sullivan, Jr., was appointed as the NACA representative on the Special Subcommittee on the Upper Atmosphere, replacing C. N. Warfield. Through membership on this subcommittee, as well as on UARRP, O'Sullivan kept abreast of upper atmosphere research in the United States, and also kept the other members abreast of the rocket activity at PARD and Wallops. Contacts made with other members were to continue for many years to come. Some of these members were: Harry Wexler, U. S. Weather Bureau, Chairman; Marcus D. O'Day, Air Force Cambridge Research Laboratory; Homer E. Newell, Jr., Naval Research Laboratory; W. G. Brombacher, National Bureau of Standards; Joseph Kaplan, University of California; J. A. Van Allen, Applied Physics Laboratory; and Fred L. Whipple, Harvard University. There was overlapping membership in the NACA subcommittee and the UARRP. In fact, many meetings were held consecutively with practically the only changes in the group being the presiding officer and the secretary.[8]

In October 1951, a decision was made which was to have a lasting effect on the course of upper atmosphere research. The International Council of Scientific Unions decided to hold the Third International Polar Year, renamed in October 1952, the International Geophysical Year (IGY), from July 1, 1957, to December 31, 1958. This decision encouraged researchers to develop new rocket techniques for the extensive uses planned during the IGY. One of these was the Rockoon—a Deacon rocket launched from a high-altitude Skyhook balloon, developed by James A. Van Allen and his associates, following a suggestion made to Van Allen by Lee Lewis (ref. 20).

O'Sullivan was interested in the use of the Deacon rocket in the Rockoon system and provided Van Allen with methods for calculating the dynamic stability of the rocket. PARD assisted in the procurement of the Deacon motors although the Rockoon was never used at Wallops. Inability to predict the flight path of Rockoon because of its vulnerability to high winds aloft practically restricted its use to ships at sea. A more practical scheme to obtain a low-cost sounding rocket, as proposed later by O'Sullivan, involved the substitution of a Nike rocket for the balloon and resulted in a system, the Nike-Deacon, which could be launched from any test range as well as from ships at sea. As discussed in a later chapter, this sounding rocket was of great benefit in the IGY upper atmosphere program.

GRUMMAN XF10F–1 AIRPLANE

The Grumman XF10F-1 airplane was designed for the Navy as a transonic fighter with variable-sweep wings and manually operated longitudinal controls. This design represented an attempt to avoid the necessity for all power-operated control surfaces. The need for all-moving horizontal tails for longitudinal control at transonic speeds had already been demonstrated. For the XF10F-1, Grumman proposed a unique horizontal tail arrangement in which the horizontal tail was not only all-movable but also free-floating, with the floating angle being governed by a small canard surface attached ahead of the tail surface and operated directly by the pilot as an aerodynamic servo. Such a tail arrangement would provide control but would not contribute to the stability. To increase the stability, Grumman added another feature to the tail system—a linked, unbalancing, trailing-edge flap. Thus there were three moving parts to the control: the small canard surfaces movable by the pilot; the complete all-movable tail; and the interconnected trailing-edge flap.

BuAer, on March 29, 1950, requested the NACA to test the effectiveness of this tail arrangement with rocket-propelled models at transonic speeds. The NACA approved BuAer's request on April 25, 1950, and issued RA 1565 to cover the program. Four 1/7-scale models were flown, two with the unique tail arrangement mounted on a simplified body, and two using models of the complete airplane. The first test was made on December 19, 1950, and the last, November 19, 1952.

The first complete model is shown in figure 153. The all-movable horizontal tail and its servo had 63-degree delta planforms and were mounted atop the vertical tail. The variable-sweep wing was located in a high-wing position on the fuselage. The wing on the rocket model was sweptback 42.5 degrees, the maximum possible on the airplane, and it was 8-percent thick. The jet engine exhausted from the rear of the fuselage beneath the vertical tail. The side inlets of the airplane were faired over on the models. Both of the complete models were launched from the mobile launcher with Deacon boosters and with reduced-length Deacon motors mounted internally. The two simplified models were launched from a crutch-type launcher with Deacon boosters and Cordite motors mounted internally.

In the tests, the small canard servoplane was pulsed in a square wave at a frequency of one cycle per second, and the transient response of the model was measured and transmitted by telemetry. The first

8. Author's interview with W. J. O'Sullivan, Jr., NASA Langley Research Center, January 8, 1968.

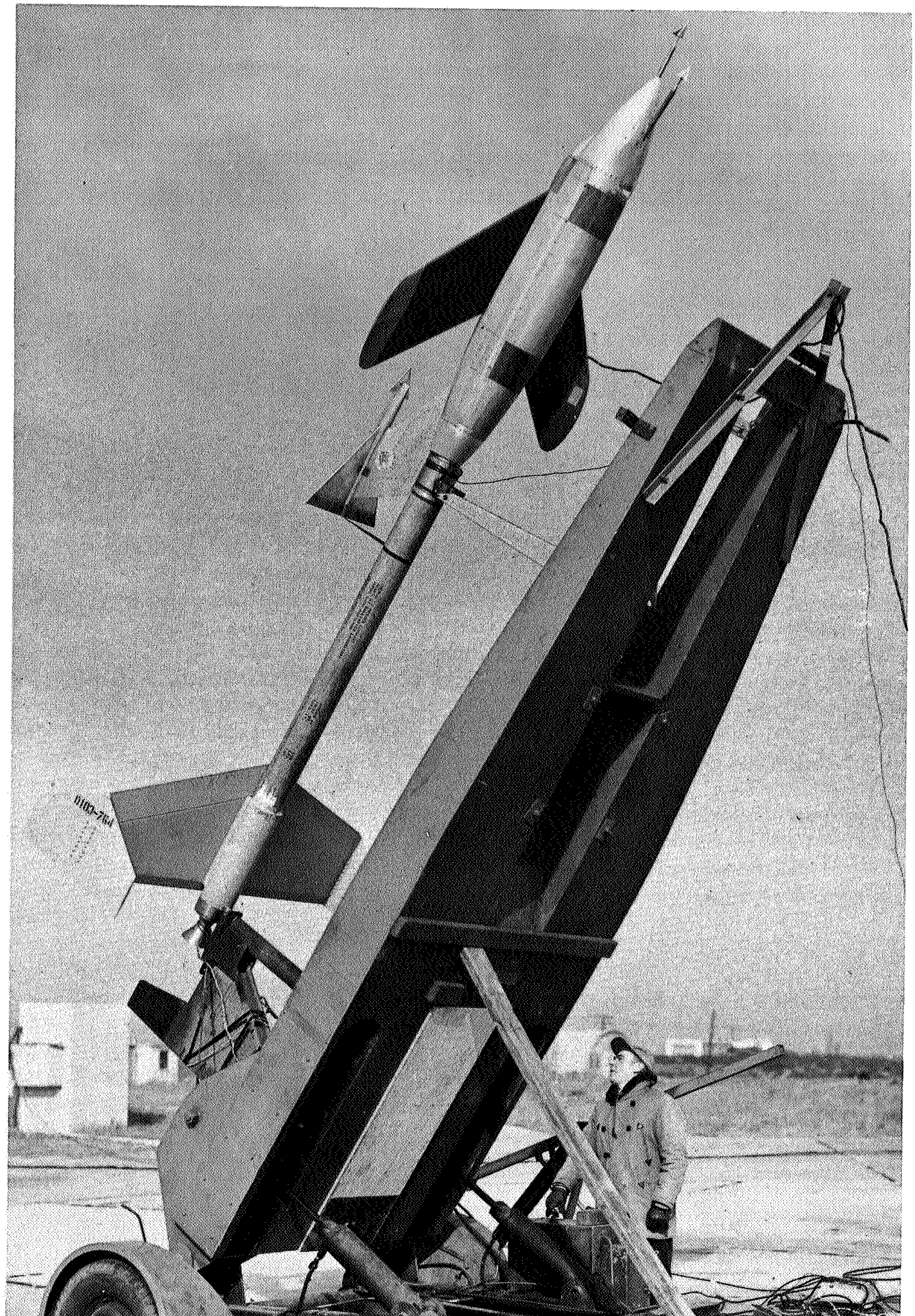


FIGURE 153. Technician Harry Bloxom makes final launcher adjustment for flight test of Grumman XF10F–1 airplane model with Deacon booster at Wallops, December 19, 1951.

simplified model demonstrated that the system would work, although near Mach 1 some buzz of the whole unit was observed, and a gradual trim change was noted above Mach 1 (ref. 21).

Before the flight tests, the isolated tail unit was tested in the Langley Stability Tunnel to obtain data on low-speed tail effectiveness. The internal rocket motor in the first flight model had an excessive delay in ignition, which reduced the maximum Mach number to 1.2. A second model was flown, which performed properly and provided data to a Mach number of 1.46. Again, dynamic instability of the tail surface was observed at Mach 1 (ref. 22).

Additional tests were conducted in the Langley 8-Foot Transonic Tunnel with one of the remaining complete tail assemblies, to study in more detail its characteristics at transonic speeds. The tests were in agreement with the rocket-model tests and showed that the loss of damping of the free-floating tail near Mach 1, as well as a trim change, was caused by interference effects of the vertical tail on the horizontal tail (ref. 23).

When the first complete model was tested, a most unexpected result was obtained. Immediately after the Deacon booster burned out at Mach 0.9 and the model separated from it, the model diverged in yaw and then in pitch and executed an erratic spiral motion throughout the remainder of the flight. Analysis of the records indicated that a severe lack of directional stability started the trouble (ref. 24). Before tests proceeded further, a wind-tunnel investigation was conducted in the Langley High-Speed 7-Foot by 10-Foot Tunnel with a 1/14-scale model of the complete airplane, to determine corrective measures. The tests confirmed the lack of directional stability and indicated that small triangular horizontal tail fins with negative dihedral, located on the fuselage near the base of the vertical tail, would provide stability. Such fins also improved the longitudinal stability at high angles of attack (ref. 25).

For the last flight test, the small triangular fins developed in the tunnel tests were added to the model, and as an extra precaution a second vertical tail was added to the bottom of the fuselage. This tail was added to ensure that the purpose of the test—determination of longitudinal stability and control—would not be defeated by unwanted motions in any other plane. The test was quite successful and indicated that this type of longitudinal control should be very effective, with high maneuvering capabilities. Low damping of the free-floating tail, however, persisted near Mach 1 (ref. 26).

The full-scale airplane was modified by the addition of the small ventral fins and was flown successfully. The low damping of the horizontal tail was overcome by the addition of artificial damping. The airplane, however, turned out to be heavier than expected and never achieved its designed maximum speed. It was not put into production, but the experience gained by Grumman with this variable-sweep design was to be a factor later in the selection of contractors for the controversial TFX supersonic fighter in the 60's. Grumman obtained the contract for the Navy version of the airplane, the F-111B.

DOUGLAS XF4D–1 SKYRAY AIRPLANE

The Douglas XF4D-1 Skyray was one of the Navy's low-drag supersonic fighter airplanes. It was aptly named Skyray from its general appearance, that of a stingray. It was a tailless airplane of 33.5-foot span, weighing about 21,000 pounds, and being designed for shipboard operation. It had a modified 52-degree delta wing and a sweptback vertical tail. The wing thickness ratio varied from 4.5 percent at the tip to 8 percent at the root. Twin wing-root inlets supplied air for the single turbojet engine in the fuselage. It was to be quite a successful, low-supersonic fighter airplane for the Navy. In fact, one of the prototypes established a world speed record of 753.4 miles per hour on October 3, 1953, at the Salton Sea in California (ref. 27). In the production version of the airplane, the J40 engine in the prototype was replaced by the higher thrust J57 engine. Between 1954 and 1958, 419 such airplanes were to be delivered to the Navy.

On December 12, 1949, Navy BuAer requested the NACA to determine the drag characteristics of the design by using rocket models. The NACA approved the request on December 22, 1949, and issued RA 1557 to cover the tests. Five 1/10-scale models were supplied by the Navy and were flown successfully at Wallops with Deacon boosters. A maximum Mach number of 1.4 was obtained with the models, each of which weighed approximately 110 pounds. The first model was launched on March 23, 1951, and the last, March 13, 1952. One of the models on its booster is shown in figure 154. The inlets and

FIGURE 154. Technician Durwood Dereng makes final adjustment of booster adapter on model of Douglas XF4D–1 Skyray airplane on mobile launcher at Wallops, June 27, 1951.

duct system were simulated on the models, and proper mass flow was obtained through the use of a "choking-cup" at the exit. The use of such a cup minimized the problem of measuring internal drag in flight. The models contained an eight-channel telemeter and were instrumented to measure inlet and exit pressures as well as the usual accelerations.

The first test was made with a model of the airplane in the "clean" condition, without external stores. The drag coefficient was 0.012 at subsonic speeds and 0.038 at a Mach number of 1.25, with a drag-rise Mach number of 0.95. There was no evidence of buffeting, and the trim change was small (ref. 28). The test indicated that with a J40 engine, the airplane would not reach Mach 1 at an altitude of 35,000 feet. It is of interest that even with the higher thrust J57 engine used in the production airplane, the maximum speed at 36,000 feet was only Mach 1.05.

Two models were flown with external stores. The addition of four small rocket packets on short pylons beneath the wing had only a small effect on the drag, but the addition of two large Douglas Aircraft Company stores increased the drag coefficient to 0.049 at supersonic speeds. This increase in drag was twice that obtained when the stores were tested by themselves in the Helium Gun (ref. 29).

In one test of a model without external stores, pulse rockets were used to disturb the model in pitch. The disturbances from these rockets, plus the accidental disturbances encountered at booster separation and near Mach 1, allowed evaluation of damping-in-pitch as well as static stability of the speed range of the test. The longitudinal and directional stability was quite satisfactory, but the damping was found to be low, as was expected from such a design, i.e., one having no horizontal tail (ref. 30).

All of the data were collected in a final report, prepared for general distribution (ref. 31). An analysis was made of the supersonic drag of the model, and it was concluded that a considerable reduction in drag would be obtained if the large boattail angle of the fuselage and the adjoining wing-root fillet were reduced, principally by thinning the fillet behind the air duct. Tests of several bodies of revolution representing the original XF4D-1 airplane and various modifications to reduce the drag were made in the Wallops Helium Gun. As predicted, thinning the wing-root fillet was very effective. The XF4D-2 version of the airplane was designed to incorporate this change plus a reduction of the thickness of both the wing and the vertical tail, and a lengthening of the forebody. Tests of a body of revolution representing this design indicated a reduction in the pressure drag of 28 percent below that for the original airplane, at Mach 1.1 (ref. 32).

COUPLING OF LATERAL AND LONGITUDINAL OSCILLATIONS OF AIRPLANES

The E7 airplane stability and drag program began with models generally similar to the Douglas D-558-I and D-558-II research airplanes, as being representative of straight and swept wing transonic configurations. (See Chapter 6.) The program did not contribute directly to the development of these airplanes but was rather a study of general phenomena by the rocket-model technique. In fact, several models of the D-558-II were flown long after the airplane had been flown successfully to new world records. The last model in the series, flown on August 6, 1952, experienced an unusual phenomenon involving coupling between longitudinal and lateral motions.

This model, shown in figure 155, was flown with primary disturbances applied to it in the yaw direction by pulse rockets located in the nose section. In addition to the usual accelerations, angle of attack and of sideslip were measured with a free-floating vane indicator mounted on a boom extending ahead of the nose.

In flight, as the model decelerated from Mach 0.96 to 0.80, a pulse rocket induced a yawing oscillation, with its associated rolling and sideslip motions. Large motions in angle of attack of twice the frequency of the yawing motions were unexpectedly induced. The coupled oscillations were sustained

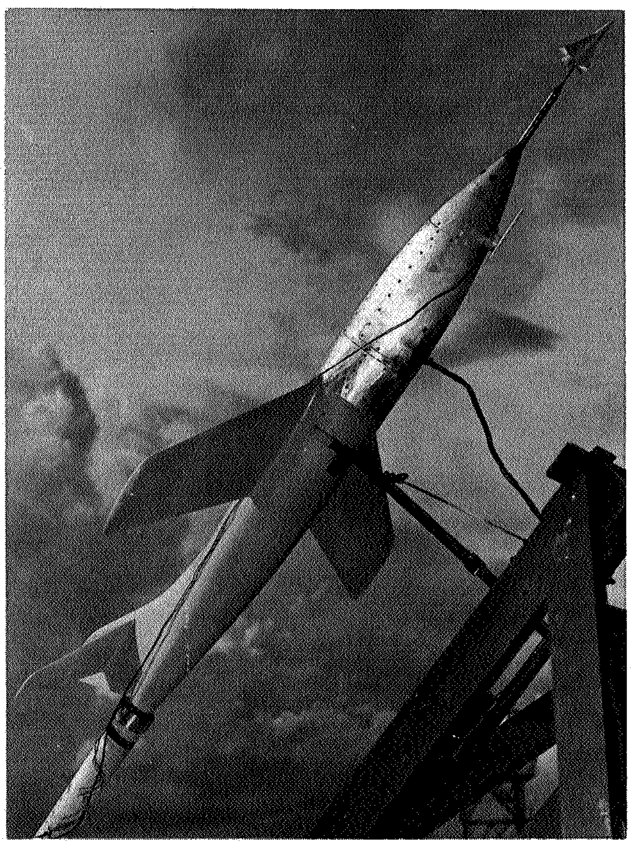


FIGURE 155. Model of Douglas D–558–II research airplane flown on August 6, 1952, to investigate coupled pitch and yaw motions. View shows vane mounted on nose boom to measure angle of attack and angle of sideslip.

long after the pulse rocket was fired and lift loads of appreciable magnitude rapidly developed. Analysis of the motion indicated that the pitching moments were primarily the result of the coupling of inertia with rolling velocity. Such coupling was found to be appreciable for airplanes having long fuselages and relatively small wings, characteristic of jet airplanes (ref. 33).

A similar coupling of pitching and rolling motions caused great concern in flight tests of the Douglas X-3 research airplane and the North American F-100 airplane at the NACA High-Speed Flight Station. The classical assumption of independence of longitudinal and lateral motions could no longer be assumed in calculating airplane stability. In fact, inertia effects, including the inclination of the principal axis of inertia, were to become of primary importance in dynamic stability analyses.

JET BOARD AND THE WHIRLIGIG

On February 2, 1951, it was demonstrated for the first time that a man could fly while standing on a simple platform supported only by a jet of air. This successful test of a "Jet Board" at Wallops showed that the natural reactions of a man standing on such a platform were sufficient for proper control. The device was a laboratory experiment designed to test this balancing principle, first proposed in a device patented by Charles A. Zimmerman.

Zimmerman had worked at Langley from 1929 to 1937, when he left to direct the development of the XF5U-1 circular-wing vertical takeoff airplane and its V-173 prototype at Chance Vought Aircraft Company, Bridgeport, Connecticut. For some time, he had been interested in finding minimum means for providing air mobility for a man. The device he patented while at Vought to accomplish this purpose was a stand-on affair with two counter-rotating propellers beneath a small platform. Control was achieved by natural reactions of the pilot in shifting his body in the direction of desired motion. In 1946, he had constructed such a device, and some flights had been attempted on it. He abandoned the project when he failed to enlist much interest or support. After the XF5U-1 project was canceled in 1948, he returned to Langley as Assistant Chief of the Stability Research Division.

After returning to Langley, Zimmerman remained convinced that his device had considerable merit for providing a man with air mobility, but he was reluctant to push for research on it at Langley because of his patent interest. On many occasions at lunch when he joined members from PARD in the West Cafeteria, he discussed his balancing principle and its possibilities with Gilruth, Shortal, Hill, Hulcher, and O'Sullivan. Hill was enthusiastic about making a simple test of the principle, and many methods of doing this were discussed. A simpler system than Zimmerman's earlier propeller-driven device was desired. Hulcher and Zimmerman looked into the possibility of using a high-pressure water jet to provide the thrust.[9] Hulcher had worked earlier with Zimmerman in the Langley Spin Tunnel and had learned firsthand of Zimmerman's interest in unconventional flying devices. In fact, in 1937 (in his spare time) he had constructed for Zimmerman a twin-engine flying model of the circular wing design which led to the XF5U-1.

Hulcher and Hill discussed the use of a rocket motor to provide the thrust, but this idea was abandoned as too risky. Hill proposed that the high-pressure air available in the storage spheres of the Preflight Jet at Wallops be used to provide the required jet. Rough calculations indicated that this would be feasible. Zimmerman could not resist joining with Hill in a second attempt to prove his idea a practical one, and a joint project was agreed upon between the Stability Research Division and PARD. Hill took the initiative in getting the required hardware designed and constructed with the assistance of PARD engineer Thomas L. Kennedy.

Approval of Langley management was obtained after Zimmerman prepared a memorandum describing the proposal with its many safety features (ref. 34). Approval of NACA Headquarters was bypassed by charging the project to an existing RA, number 1508, issued in 1948 to cover the investigation of propeller-driven vertically rising aircraft. This RA was used because the description of the RA stated in part, "Preliminary investigations will be made of simplified models not corresponding to any particular configuration." Such use of a general research authorization was common at Langley in those days.

9. Author's interview with Charles A. Hulcher, Hampton, Virginia, August 19, 1968.

The Jet Board consisted of a platform or board 19 inches by 29 inches, with straps for the flyer's feet and a nozzle on the bottom. Two flexible opposing fire hoses fed the nozzle with high-pressure air under the control of a second operator on the ground. The flyer wore a parachute harness which was attached to an overhead suspension for safety. In addition, in the early flights, guy ropes were attached to the flyer to restrict excessive lateral motions. The first flight was made by Zimmerman on February 2, 1951. He found, as predicted, that natural instincts were sufficient to maintain good control. In fact, in the first test, Zimmerman was unaware when he first became airborne and continued to call for more air, thus showing that the device was inherently flyable by subconscious actions.[10]

Following the first flight, Hill took over as chief pilot in the remaining tests, although Kennedy and two Wallops employees, J. C. Palmer and T. N. McComb, also flew on the Jet Board to demonstrate that no training was required to achieve successful control. The guy ropes were removed after the first few flights, and lateral mobility was demonstrated by Hill. Some modifications to the system were tried, but none were as good as the original idea of simply standing on the platform. Contrary to expectations, neither gusty winds, the addition of gyroscopic moments, nor increases in inertia of the platform had any objectionable effect (ref. 35).

When Jet Board was moved outdoors for greater exposure to wind effects, the safety harness was attached to an overhead wire, strung between two poles. Hill continued his experiments with this arrangement as shown in figure 156, in a test made in January 1954. The Jet Board was demonstrated to many visitors, and a number of them were allowed to fly the device. Among these were H. J. E. Reid, Langley Director; John P. Reeder, Langley Test Pilot; and several U. S. and Canadian Air Force pilots.

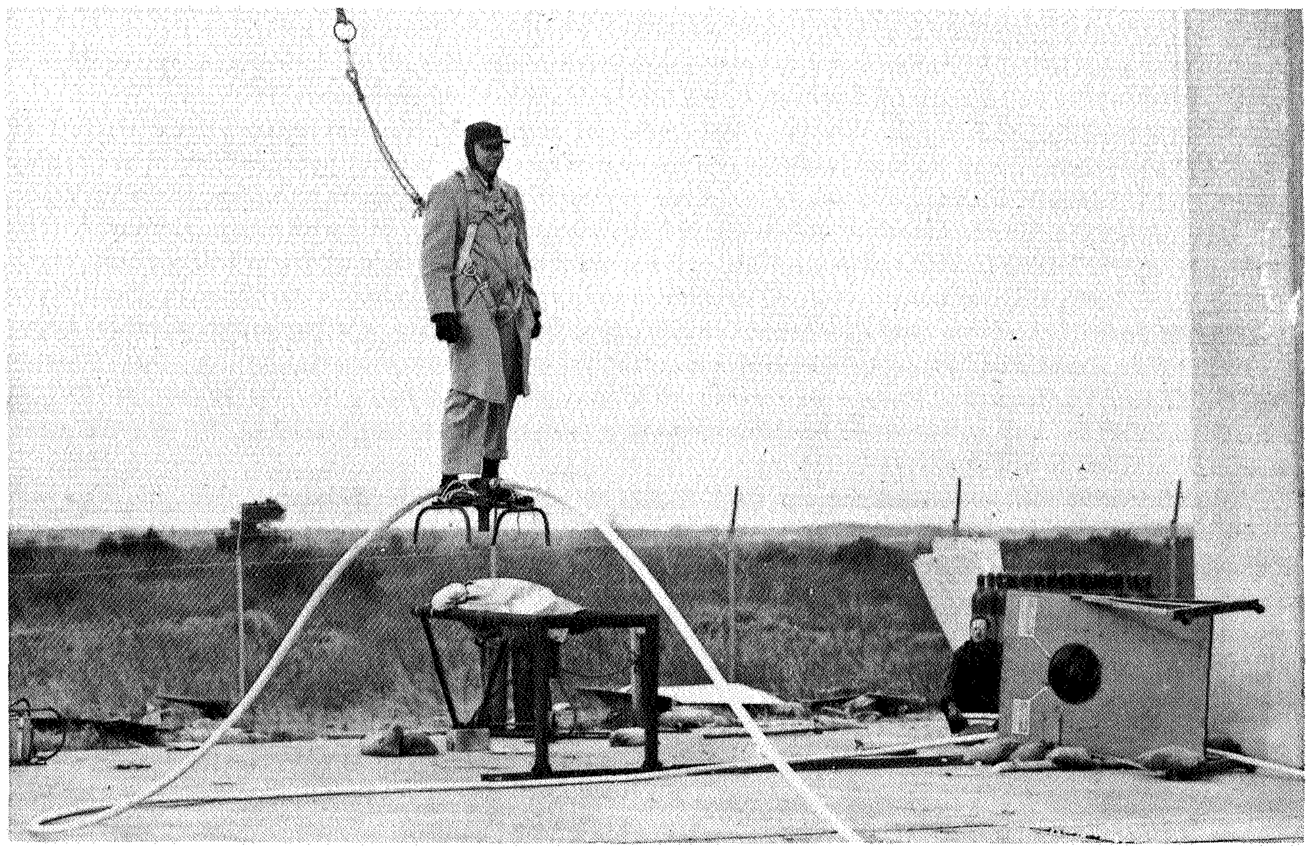


FIGURE 156. Paul R. Hill demonstrates ease of standing on Jet Board, and A. Spinak handles air-supply controls. Demonstration was given during visit of Air Force pilots, January 14, 1954.

10. Author's interview with Charles H. Zimmerman, Hampton, Virginia, August 1968.

As the next step in the program, Hill and Kennedy set about to devise a simple rotor system of greater efficiency than the jet. Hill made a proposal in January 1952 to replace the direct air jet with a 7-foot two-blade teetering rotor driven by small air jets at each blade tip (ref. 36). Hill calculated that such a system would have ten times the flight endurance of a direct jet. A rigid, teetering rotor was proposed to eliminate undesirable gyroscopic moments. Later, springs were added between the rotor and the frame to provide damping.

The rotor-supported platform, locally called the "Whirligig," was flown successfully at Wallops on October 21, 1953. In figure 157, Kennedy is shown on this device inside the shop area of the Instrumentation Laboratory. Air was led to the rotor from overhead, and a safety ring and screen were installed around the flyer and the rotor. A simple landing gear was also added. Later, the device was flown from the concrete ramp in front of the building for greater exposure to winds. It was found that the rotor-supported platform was smoother in a no-wind condition than the Jet Board, but there was a greater tendency toward oscillations in gusty air (ref. 37).

The Whirligig was described to the helicopter community by Hill at the NACA Conference on Helicopters held at Langley, May 1954 (ref. 38).

Two manufacturers, Hiller, under a contract with the Navy, and De Lachner, under a contract with the Army, attempted to develop practical, self-contained machines patterned after the Whirligig, for military use. Representatives of both companies visited Wallops and flew both the Jet Board and the

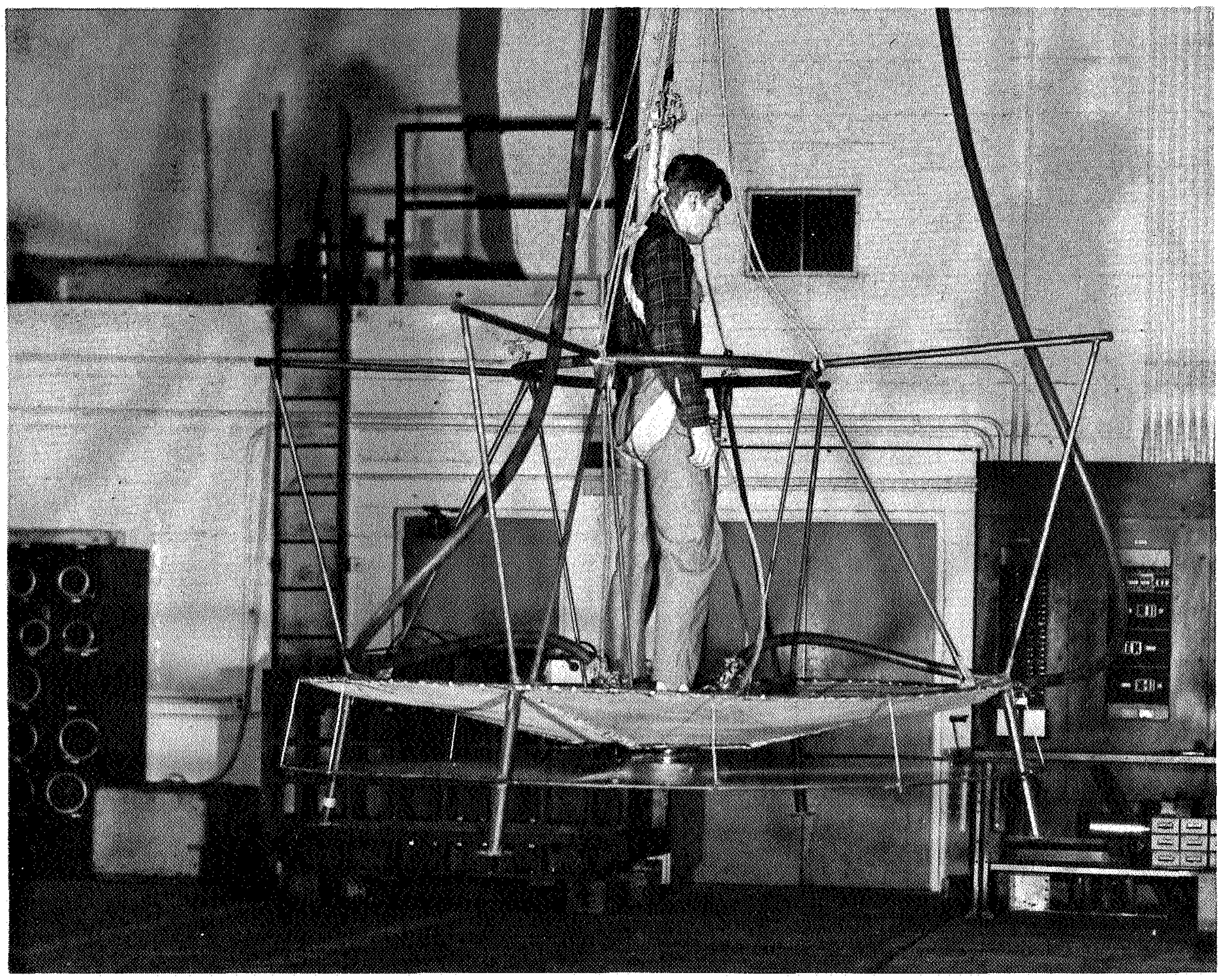


FIGURE 157. Engineer Thomas L. Kennedy in flight on "Whirligig," rotor-supported platform, in Instrumentation Laboratory shop at Wallops, December 8, 1953.

Whirligig. They also consulted with Hill and Zimmerman in connection with their designs. The project manager on the De Lachner machine was Louis McCarty, who spent many hours at Langley and Wallops. Although both machines were constructed and flown extensively with self-contained propulsion systems, they were never accepted for production. They were two of the many devices under study to provide one-man mobility for a military force.

Although interest in the Jet Board and the Whirligig died out after these efforts, it was to be revived again in 1967 when Hill resumed investigation of the use of a rocket-powered jet board for possible use by the Apollo astronauts as a transportation device on the lunar surface.

TAILPIPES FOR SOLID-FUEL ROCKET MOTORS

In some rocket models having internal rocket motors, the addition of a tailpipe between the motor proper and the exit nozzle was necessary to avoid undesirable changes in center of gravity as the propellant was burned. In fact, the first missile flown at Wallops, the Tiamat, had such a tailpipe. To provide design data and to evaluate losses in such systems, two programs were conducted at the rocket test area at Langley. Both low-pressure and high-pressure tailpipes were considered.

A low-pressure tailpipe is a duct attached to the nozzle exit to convey gases that have been expanded to near-atmospheric pressure. A high-pressure tailpipe is constructed by inserting a tube between the converging and the diverging sections of the nozzle, and is, in effect, an extension of the nozzle throat. The high-pressure tailpipe is smaller in diameter but may be heavier because of the higher pressures and temperatures.

Several low-pressure tailpipes of different lengths were tested on a standard 3.25-inch rocket motor. Losses in total impulse varied from 2.9 to 5.8 percent for tailpipe length-diameter ratios varying from 2.5 to 7.5 (ref. 39).

High-Pressure tailpipes were tested on a 5-inch Navy HVAR rocket motor. The losses in total impulse were lower than those found with the low-pressure tailpipes, varying from 3 percent to 4.4 percent for tailpipe length-diameter ratios varying from 5 to 15. In the high-pressure tailpipe tests, the inside diameter was kept constant, which resulted in an increase in pressure as the length was increased. The increase in pressure was due to the buildup of a boundary layer along the wall, which reduced the effective size (ref. 40). In a practical case it would be expected that a tapered duct would be used to compensate for the boundary layer.

PREFLIGHT JET AND FLIGHT TESTS OF SOLID-FUEL RAMJETS: F29

As part of a continuing search for propulsion means for obtaining higher test velocities in the rocket-model program at Wallops, M. A. Faget and J. G. Thibodaux visited the Bureau of Mines (BuMines) and the NACA Lewis Laboratory in May 1950 to explore the possibilities of adapting solid-fuel ramjets (ref. 41). Thibodaux felt that PARD had practically reached its limit in speed with the existing solid-rocket motors, and ramjets seemed to be the answer to the need for both higher speeds and higher altitudes. A successful flight of the F23 ramjet with ethylene fuel had been demonstrated, but a solid-fuel ramjet was more attractive because it approached the solid rocket in its simplicity. The idea was to use a solid-rocket booster as the first stage and a cluster of solid-fuel ramjets for the second stage.

In the visit to BuMines, Pittsburgh, Pennsylvania, Faget and Thibodaux, accompanied by H. E. Alquist of NACA Headquarters, met Dr. G. H. Damon, who took them to his Explosives Research Laboratory at Bruceton, Pennsylvania. BuMines had been conducting research on solid fuels for several years under a contract with the Navy's BuAer. Their work started with compressed powdered coal but had been expanded to include metallic fuels, such as aluminum, magnesium, and boron powders. The method of BuMines was to compress the fuel into a magnesium tube and use end-burning. The magnesium tube would burn along with the basic charge.

Dr. Damon was interested in having his fuel charges tried under flight conditions, and plans were made during the visit to make tests at Wallops with 4.5-inch charges in a 6.5-inch engine. At the Lewis Laboratory, the visitors learned that Lewis was working with metallic fuels mixed with a small amount of hydrocarbon fuel to form a slurry, which could be handled as a liquid. Plans were discussed to investigate these slurry fuels at Wallops, but their testing was to come later.

An informal agreement was reached whereby BuMines would furnish solid-fuel charges in magnesium tubing formed at Langley, for the initial tests. In view of the basic research value of the tests, an existing general RA was used.

A ramjet engine was designed and constructed at Langley for the solid-fuel tests. Generally similar to the engine used in the F23 program, this ramjet engine had a diameter of 6.5 inches and a length of approximately 6 feet. It consisted of three sections: inlet and diffuser section; fuel charge; and combustion chamber. Two types of inlets were investigated in the tests in the Preflight Jet: a simple normal-shock inlet, and a Ferri-type conical-shock inlet. The combustor shell was constructed of inconel. The plan was to test the engine in the Preflight Jet under supersonic flight conditions and, if the tests were successful, to continue with actual flight tests. The program was given the designation F29.

Figure 158 shows the first engine mounted on the thrust stand in the B jet of the Preflight Jet at Wallops, for tests which began on December 19, 1950. The end-burning charges were ignited by electric squibs buried within a black-powder igniter ring cemented to the downstream end of the charge. Approximately 25 percent of the charge consisted of oxidizer. In the first test, rapid charge ignition was obtained, but a serious problem of fuel-charge breakup developed. The pressure and air mass flow in the Wallops jet were much greater than those used by BuMines. Large pieces of fuel could be seen being expelled from the nozzle, with most of the burning taking place downstream of the exit. Testing was suspended, pending improvement of the bonding technique.

By August 1951, BuMines had modified its fabrication process, with changes including use of a different binder and different fuels. Additional tests of such charges were made in the Preflight Jet during October and December, 1951, without success. At this time, BuAer took an active interest in the program and enlisted the aid of the Naval Air Development Center (NADC), Johnsville, Pennsylvania. Following further revision to the molding technique, vibration and acceleration tests were conducted by NADC. By April 1952, BuMines was ready for additional tests at Wallops,[11] and on April 5, 1952, BuAer made an official request for the assistance of the NACA in these tests. Despite this official action, the research was still considered of a general nature and was continued under the general RA.

The breakup problem appeared to have been solved with the new charges, but tests at Wallops showed poor mixing in the combustion chamber, as evidenced by external burning and low combustion efficiency. NACA personnel then proposed a flame holder consisting of an annular ring located 2 inches downstream of the charge. Addition of the flame holder increased combustion efficiency from 33 percent to 60 percent at a fuel-air ratio of 0.08. The only problem remaining was overheating and burnout of the combustor shell. The 0.093-inch inconel was not sufficient to withstand the highest impulse conditions.

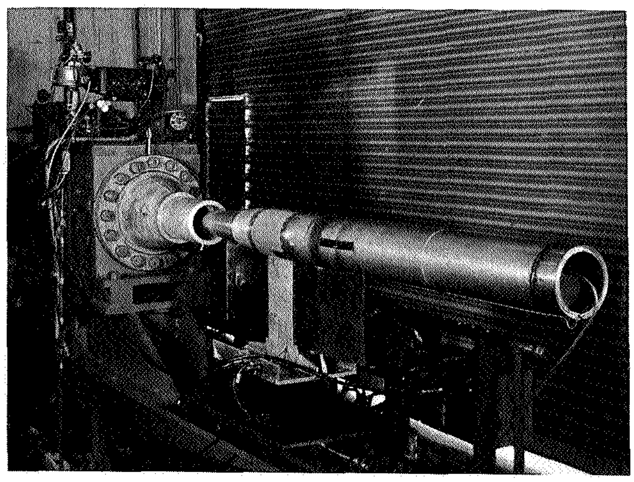


FIGURE 158. Solid-fuel ramjet engine with Bureau of Mines end-burning charge shown in B jet of Preflight Jet at Wallops, January 2, 1951.

11. Letter from Glenn H. Damon, BuMines, to Chief, BuAer, April 14, 1952, regarding development of fuel charges meeting NACA requirements.

During the period of development of the end-burning charges by BuMines, PARD personnel learned of a hollow, radial-burning, solid-fuel charge under development by Continental Aviation and Engineering Company under an Air Force contract. Several of these charges were procured from Continental to broaden the F29 research program. The charges were prepared to fit the engines designed for the BuMines charges and were also tested in the Preflight Jet, beginning in December 1951.

The radial-burning charges prepared by Continental consisted of atomized magnesium, sodium nitrate oxidizer, and a linseed oil binder, formed under pressure and baked in an oven. The charges filled the ramjet chamber and had an internal opening approximately 4 inches in diameter. Ignition took place at the upstream end of the charge, and burning was radial all along the length. No flameholders were required. These charges broke up in the first tests, but changing the binder to rubber cement solved the problem. As with the end-burning charges, however, under high impulse conditions the combustor shell burned through. The combustion efficiency and impulse measured for both types of charges were, surprisingly, almost identical (ref. 42).

A flight evaluation of one of the Continental radial-burning charges was made on March 18, 1952. The test engine was identical to the Preflight Jet engine with a conical-shock inlet, except that four 45-degree delta stabilizing fins, made of stainless steel, were welded to the rear of the body. A Deacon booster was used to bring the engine to Mach 2 prior to ignition, as illustrated by the second flight model shown in figure 159. No telemeter was used in the test model, and all flight data were obtained from ground-based radars. After ignition of the ramjet, the Mach number increased from 1.95 to 2.73, at which time the combustor shell burned through as in the ground tests. Some breakup of the fuel charge was evident prior to the burn-through. An overall specific impulse of 412 was obtained from this test, compared with 1,059 obtained in the flight test of the F23 engine burning ethylene, and a value of 200 for a typical solid-fuel rocket motor. This specific impulse looked attractive for the solid-fuel ramjet until the mass ratio was examined. The fully loaded test vehicle weighed 82.5 pounds, of which only 16.3 pounds was fuel, for a propellant mass fraction of only 0.20 (ref. 43).

The first successful flight test of an end-burning solid-fuel ramjet was made on June 18, 1953. The flight vehicle was similar to the one used in the test of the radial-burning charge. A Deacon booster carried the model to Mach 1.9, and then the ramjet accelerated to Mach 2.52 at an altitude of 25,000 feet. Prior to the flight test, additional tests were made in the Preflight Jet to solve the combustor burnout problem. It was found that the use of a cloverleaf flame holder in combination with a concentric fuel charge solved the problem. The concentric charge was actually two concentric charges; the outer charge next the wall consisted of aluminum and magnesium fuels, while the inner charge contained less aluminum but had boron added. Thus, the hotter fire was confined to the center of the chamber. Some trouble was experienced with separation of the model from the booster in flight, but thereafter good performance was obtained (ref. 44).

The burnout of the combustor shell with radial-burning charges was solved by use of an air-cooled shell. Part of the air entering the engine was bypassed around the fuel charge through a 3/8-inch annular gap. A special flight test of this bypass engine was made on March 23, 1955, with excellent results. This model is shown in figure 160. No combustor shell burnout was encountered, and a maximum Mach number of 2.94 was reached at an altitude of 19,700 feet. Fuel specific impulse was 410 seconds (ref. 45).

The overall result of the solid-fuel ramjet investigation was that effective burning of such an engine had been demonstrated, but its empty weight was too great to permit competition with solid-fuel rocket motors.

ASSISTANCE ON NAVY ACOUSTIC SEEKER PROJECT

During this period, the military services were exploring different devices to be used as a target seeker for guided missiles. One of these was an acoustic homing device under development at NADC, Johnsville, Pennsylvania, under the direction of Dr. Max O. Kramer, who had worked on a similar device in Germany during World War II. In August 1951, Kramer visited Langley to enlist the support

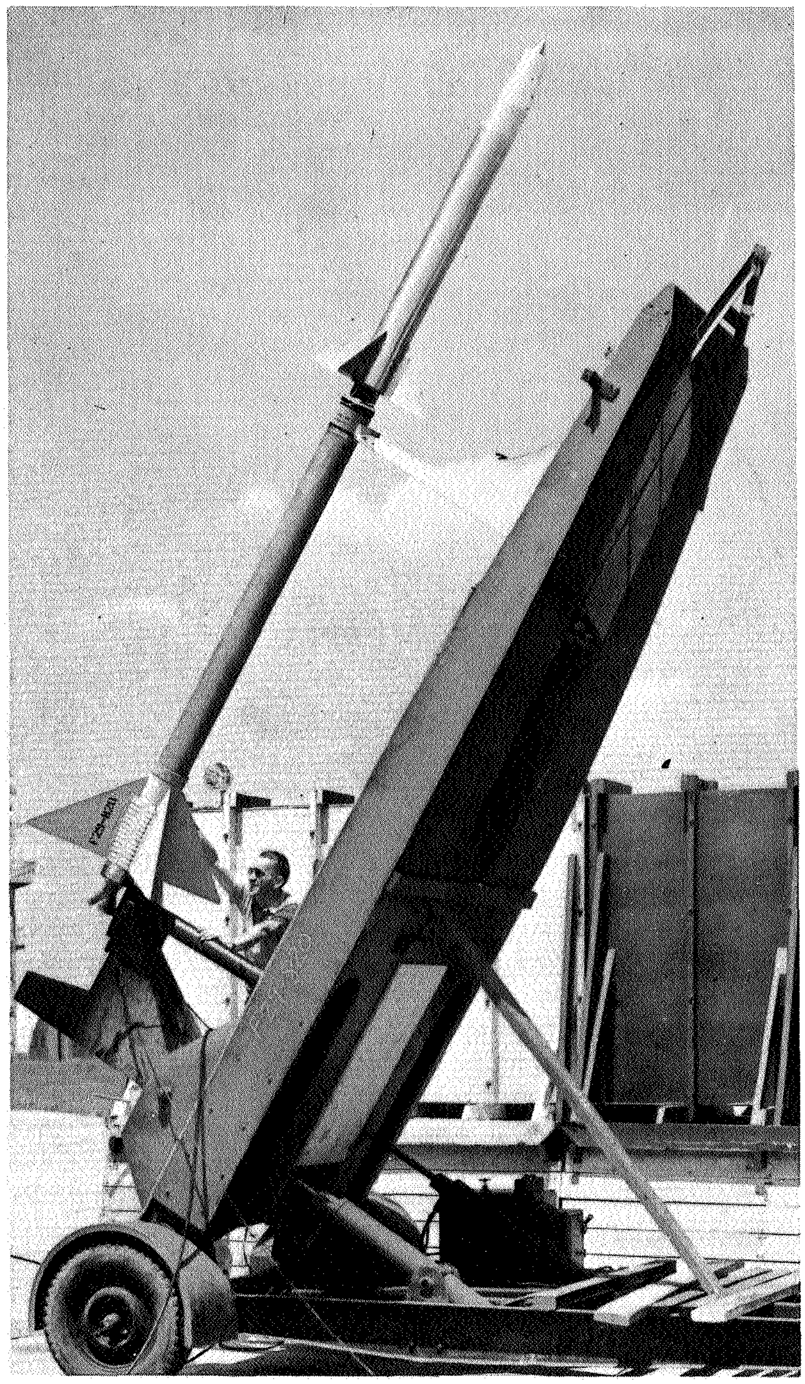


FIGURE 159. Langley propulsion technician Carl G. Baab makes final check of Deacon booster prior to launch of solid-fuel ramjet engine with Continental radial-burning charge, May 22, 1952.

of Langley and assistance in a flight test of the device at Wallops. The plan was to fly a subsonic Grumman F6F drone airplane by remote control from NAOTS, Chincoteague, over the Wallops range on a prescribed course and to fly a supersonic, rocket-propelled vehicle from the Wallops launch area close to the drone and measure the output of the acoustic pickups in the nose of the rocket vehicle. The request seemed to fit in with NACA fields of interest, and local agreement to participate was reached, pending official approval. On September 25, 1951, BuAer made an official request to the NACA for assistance, and the NACA gave approval on November 9, 1951, issuing RA A74L80 to cover the

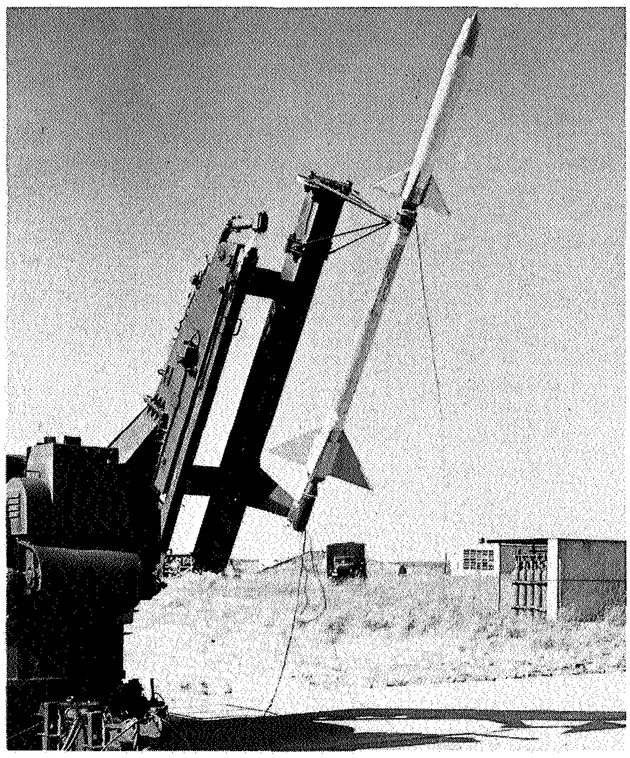


FIGURE 160. Solid-fuel ramjet engine with air-cooled combustor shell, shown with its Deacon booster on Terrier launcher at Wallops, March 23, 1955.

assistance. PARD assigned the designation D109 to the project. On February 14, 1952, BuAer requested the Chief of Naval Operations to supply the necessary F6F drone target airplanes.[12]

Ernest C. Seaberg of PARD was assigned the project for Langley. He selected a Deacon rocket motor as the first stage of the test vehicle and strapped two 3.25-inch rocket motors on the sides of the Deacon, to be fired at the apogee to maintain supersonic speed at a fairly constant altitude, consistent with the flight path of the F6F drone. The strap-on motors remained attached to the Deacon during the flight, and the acoustic head was located in the nose of the Deacon vehicle.

For each flight test, a special control truck was brought to Wallops from Chincoteague for directing the drone along the prescribed flight path at constant altitude. Control was transferred from Chincoteague after the drone had taken off and had arrived over Wallops. The drone was tracked by Wallops SCR-584 radar, and its flight path was followed on the plot board. The flight path of the rocket vehicle was superimposed on the same plot.

The first job was to assure that the rocket vehicle selected would achieve the desired flight path. In the first trial of the rocket on April 23, 1952, the nozzle of the Deacon failed and ended the test. This nozzle was a new, less expensive casting being tried on the Deacon. A second flight on June 3, 1952, was successful, but the 3.25-inch motors were not powerful enough to provide the desired performance (ref. 46). The motors were then changed to two high-performance, air-to-ground (HPAG) rockets strapped to the Deacon, as shown in figure 161, and on September 19, 1952, the required performance was achieved.

The next test was to be one with the acoustic seeker installed in the rocket vehicle, and with the F6F drone as a target. This test was made on December 12, 1952, but unfortunately the two sustainer rockets failed to ignite. Enough was learned from the flight test, however, to show that the seeker was not suitable in its existing form because, at supersonic speeds, the local flow over the seeker nose was turbulent and aerodynamic noise masked any target noise. Finally, in December 1953, the project was canceled.[13]

12. Letter from Chief, BuAer, to CNO, February 14, 1952, regarding assistance in conducting flight test of supersonic sound pickup.
13. Letter from BuAer to the NACA, December 10, 1953, regarding cancellation of acoustic seeker rocket-model tests.

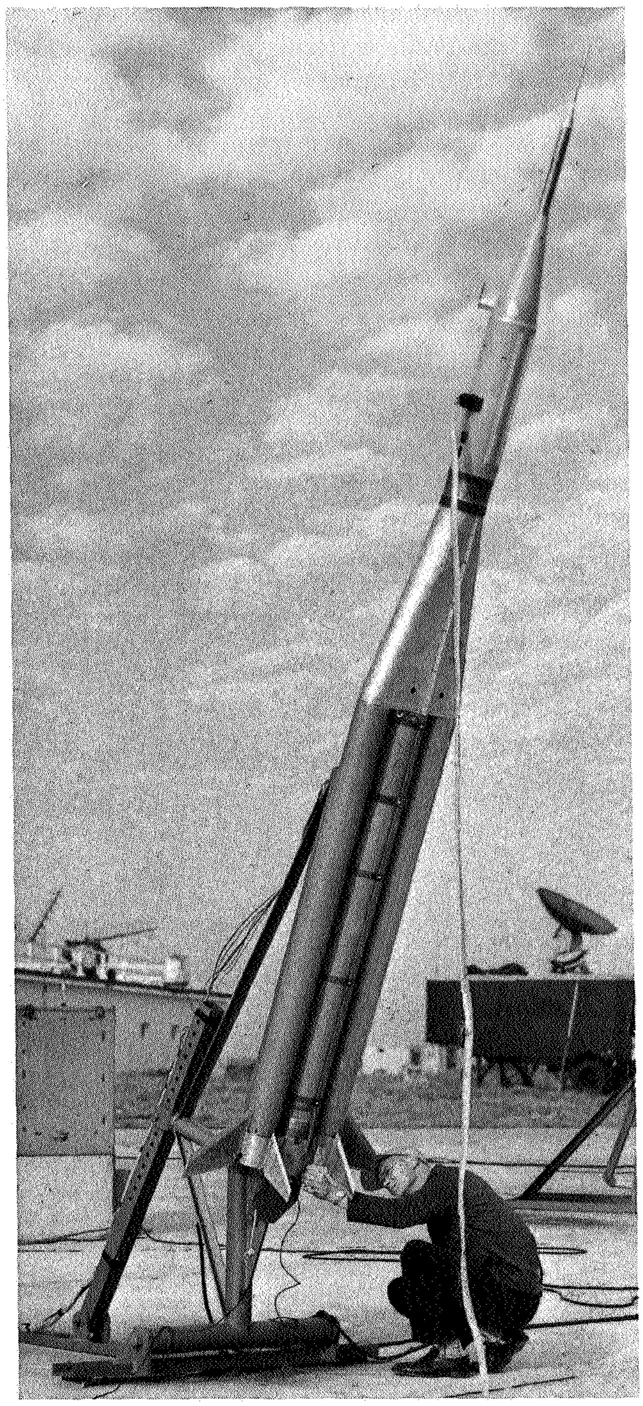


FIGURE 161. Technician Durwood Dereng checks wiring on final D109 acoustic seeker test vehicle at Wallops, December 12, 1952.

DRAG OF NOSE SHAPES SUITABLE FOR TARGET SEEKERS

During this period, the shaping of missile noses to accommodate target seekers was given considerable attention. The Automatic Control Dynamics section at PARD, under the leadership of Robert A. Gardiner, not only devoted more effort to the automatic control of missiles but also began to consider the overall problem, including various target seekers and their installation. In August 1950, Gardiner, with C. A. Taylor of IRD, visited the Eastman Kodak Company Optical Laboratory, Rochester, New York, to discuss the Eastman Kodak heat seeker and its requirements as far as nose shape and transparency were concerned.[14] The Eastman Kodak seeker had been developed for use in the Dove guided bomb. One of these seekers was obtained and some tests were made of it in the Wallops Preflight Jet, beginning in 1951. In December 1950, Gardiner took steps to obtain a DAN-3 infrared seeker for similar tests behind different nose shapes (ref. 47).

One nose shape acceptable for target-seeker application was hemispherical. The drag penalties of such a shape, however, had been shown to be very high. The problem of developing an acceptable shape with less penalty was investigated by Robert O. Piland, from the General Aerodynamics branch of PARD. He made flight tests of a series of E2-type bodies with different compromise nose shapes. The models were propelled to a Mach number of 1.8 by the standard two-stage system shown in figure 162. The models were 5 inches in diameter and were cylindrical except for a converging afterbody and an approximately conical nose. All bodies were made of wood and were given a smooth finish with red Phenoplast, a phenolic-resin lacquer found to be able to withstand the aerodynamic heating at least to Mach 1.8. The seeker was assumed to be at the 3-inch diameter station, 7.65 inches aft of the nose, and all modifications were made ahead of this station.

Eight different shapes were tested, including parabolic, conical, and spherical designs, cones with longitudinal slots, and other "bird-cage" designs, as well as small conical windshields for drag reduction (ref. 48). Piland gave Robert T. Jones credit for pointing out the drag-reducing possibilities of such a conical windshield. Before flight testing, all of the noses were placed in the Mach 1.8 A jet at Wallops. In May 1951, flow patterns around the various shapes were determined by shadowgraph equipment. Two examples are shown in figures 163 and 164.

All of the shapes tested affected the drag far less than the spherical shape. For example, at a Mach number of 1.6, the drag coefficient with the spherical shape was 0.53, compared with 0.31 for the basic parabolic design, whereas with a 30-degree cone, the drag was only 0.35. In addition, the drag

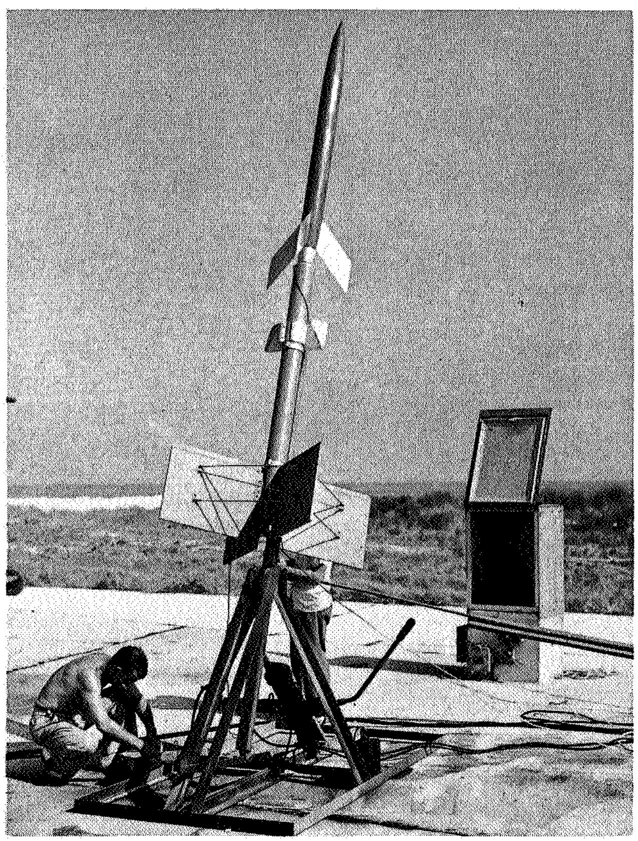


FIGURE 162. Technician Nat Johnson connects firing leads on booster for E2 model in investigation of nose shape for guided missile, September 12, 1951.

14. Letter from Langley to the NACA, August 22, 1950, regarding problems of aerodynamic nose shapes for supersonic target-seeking missiles.

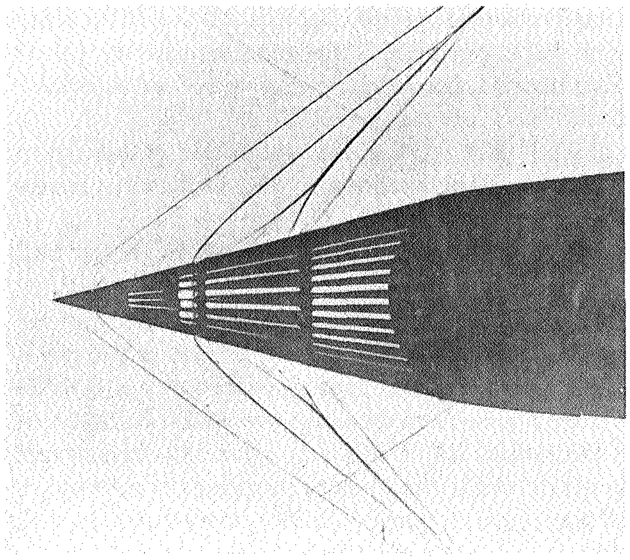


FIGURE 163. Shadowgraph of supersonic flow around hemispherical nose with conical windshield to reduce drag. Shadowgraph was obtained in test in Wallops Preflight Jet.

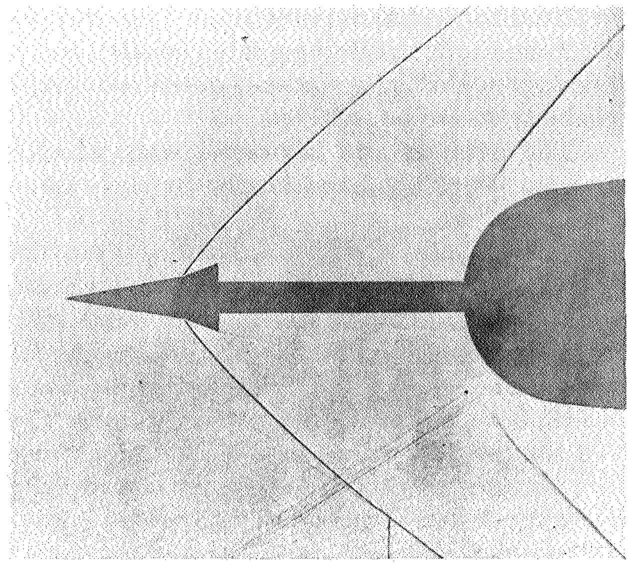


FIGURE 164. Shadowgraph of supersonic flow around "birdcage" nose design for guided missile with target seeker. Shadowgraph was obtained in Wallops Preflight Jet.

increased rapidly with Mach number for the spherical shape but decreased with all the others. All of the other modifications, including the "bird cages," were about as good as the conical shape. An evaluation of the relative effectiveness of the noses with a seeker behind them was required before a choice could be made.

Another series of tests, this time with E2 parabolic bodies, investigated the effect of flattening the nose of a spherical shape to form a flat window. The body was a parabolic body of revolution with a fineness ratio of 8.91 and had the same shape as the one used by Roger G. Hart earlier in an investigation of spherical noses. (See ref. 48, Chapter 8.) All models had 3.25-inch internal rockets and either HVAR or Deacon boosters, for maximum Mach numbers of 1.5 and 2.3. With a Deacon booster used with E2 models, higher altitudes and more nearly horizontal flight paths were reached by the time the models had slowed to subsonic speeds. Harvey A. Wallskog questioned the normal assumption that winds aloft could be ignored in analyzing flight data under such conditions. Although models were not launched unless the ground winds were low, the models could encounter very high winds aloft, particularly in the jet stream. Corrections to the Mach number were found to be appreciable. In fact, for a proper comparison, the data presented earlier by Hart on spherical noses were reevaluated by this method, and the new results were published to supersede the earlier report (ref. 49). The principal finding of the tests was that a spherical nose could be cut off to form a flat window without increasing the drag, provided some of the spherical shape was left at the corners.

Some tests were made of additional nose shapes applicable for target seeker installation. In these tests, models were launched from the Helium Gun at Wallops. Bodies with 30-degree or 40-degree conical noses had only slightly less drag than spherical shapes. It was also found that spikes in front of spherical noses did not reduce the drag to the same degree that the conical windshield had (ref. 50).

CONTINUATION OF GUIDED MISSILE AUTOMATIC CONTROL PROGRAM: D4

The beginning of the D4 automatic control and stabilization program at PARD in 1948 has been discussed in Chapter 6. As noted, successful roll stabilization in flight was achieved for a model at supersonic speeds. This was the first of a series of nine flights of D4 models in the period from May 1949 to October 1955. Of these nine flights, five were failures. Two involved the control system; one, the telemeter; and two, the structure. Of the four successful flights, only three were analyzed and had data prepared for technical publication. This unimpressive experimental record emphasized the difficulties of automatically stabilizing guided missiles, and paralleled the experience of the missile industry. Many "breakthroughs" in gyroscope construction and handling procedures were necessary before adequate reliability was to be achieved.

The analyses and laboratory tests, which were a vital part of the D4 automatic stabilization program, were not handicapped by such failures, and many contributions to the field were made (refs. 51-56).

The second D4 rocket model flown was similar to the one discussed in Chapter 6 in that it had automatic roll stabilization, but this time the pitch control surfaces were pulsed in a square wave to allow an evaluation of the roll system under varying lift conditions. The ailerons were pulsed also to provide disturbances for the autopilot to correct. The aileron pulsing rate was about twice as fast as the pitch control rate. The roll autopilot was of the direct-coupled, gyro-actuated type used before. A double Deacon booster like the one shown in figure 75 of Chapter 6 provided a maximum Mach number of 1.79 for the 162-pound model. The flight, made on December 23, 1949, was quite successful and demonstrated that the gyro-actuated control system was effective for this type of missile over a range of lifting conditions. The flight data enabled evaluation of some aerodynamic stability derivatives, as well as frequency response in the longitudinal plane (ref. 57).

The overall plan of the D4 program was to follow the roll stabilization investigation with investigations of systems for pitch and yaw.[15] Since the D4 was a cruciform configuration, identical systems could be used in the pitch and yaw planes. A cruciform arrangement was favored for small interceptor missiles because they could maneuver in any direction without rolling. Practically all interceptor missiles were cruciform except the Boeing Bomarc monowing missile. Simultaneous operation in the pitch and yaw planes with cruciform wings was found to produce large rolling moments that complicated the roll stabilization problem even more. Considerable wind-tunnel and analytical research was conducted on the problem of induced rolling moments, but they were not eliminated except by changes in configuration. The D4 program in roll stabilization was extended to include the condition of simultaneous pitch and yaw motions.

The performance of a rate-gyro system in adding damping-in-pitch to a D4-type model was determined in the flight test of a D3 model. It is discussed here because of its direct connection with the D4 program. The D3 was a 7/8-scale model of the D4. The rate gyro provided signals to a pneumatic servomotor that activated wing-tip controls on the wings. The results were very encouraging and showed that the theoretical method provided an accurate means of predicting missile response when experimental aerodynamic and rate-system characteristics were known (ref. 58).

Up to this point, the analyses and tests of D4 automatic stabilization systems in pitch and yaw had been responsive to gyro measurements of airframe attitude and angular velocity or rate. The next system considered was one that was responsive to accelerations. Such a system, basically simpler than an attitude system, was not new but was being used by such military missiles as the Nike ground-to-air interceptor. Damping was obtained through use of a rate gyro. Theoretical studies were made of such a system for the D4, and good response over a wide range of conditions was indicated (refs. 59 and 60).

A flight test was made of the system in a D4 model but with one major change, which added to the simplification. The rate gyro was replaced by a second accelerometer displaced from the center of gravity to provide indications of angular motion. The canard control surfaces were operated by a pneumatic servomotor. This model was flown successfully on September 2, 1954. A double Deacon booster was used to accelerate the model to a Mach number of 1.72. A 10-channel telemeter transmitted the data to ground stations. A gyro-actuated roll stabilization system was used. Following separation from the booster, the model flew with less than 2-degree deviation in bank angle from the 0-degree angle desired. The acceleration-control system was installed in only one plane, and its effectiveness in flight was evaluated by programming a series of accelerations in a square-wave pattern. The accelerometer system had very high natural frequency compared with a gyro system. Excellent

15. Letter from Langley to the NACA, December 16, 1949, regarding PARD automatic control research program. Letter prepared by R. A. Gardiner.

performance was obtained, and use of the system in existing military interceptor missiles was recommended (ref. 61). This was, undoubtedly, a major achievement of the D4 program.

It was pointed out at the beginning of this chapter that, when the NACA Subcommittee on Stability and Control held its meeting of June 14–15, 1951, a group representing manufacturers of 13 guided missiles presented their views on the direction NACA research should take in the field of guided missiles. The representatives were nearly unanimous in their feeling that two important aerodynamic problems were (1) nonlinear variation of pitching moments with angle of attack, and (2) induced rolling moments in combined angles of attack and sideslip. These were to be major problems for researchers for some years to come. In the field of automatic control systems relating to the D4 program, the manufacturers recommended that the NACA concern itself with the complete system, including the guidance loop.

Another approach to meeting the needs of the guided missile manufacturers was suggested at the regular meeting of the High-Speed Aerodynamics Subcommittee on June 25–26, 1951. Some members suggested that a missile subcommittee be established. Apparently they had forgotten that such a committee had been established in 1945 but was disbanded in 1947 because of overlapping responsibilities with other committees. The High-Speed Aerodynamics Subcommittee recommended against establishing a new missile committee, on the basis that airplane and missile problems were overlapping and, therefore, could be handled jointly by the existing committee structure. The Aerodynamics Committee concurred at its meeting on October 4, 1951.

The Aerodynamics Committee and its High-Speed Aerodynamics and Stability and Control subcommittees were heavily loaded with airplane men, despite some attempt to add missile people. Of the 58 representatives on the above three committees, only three devoted full time to missile development: Herbert Harris of Sperry (Sparrow); Prof. R. C. Seamans, Jr., MIT (Meteor); and Dale D. Myers, North American (Navaho). In addition, as would be expected from the name of the committee, practically all of the members were aerodynamicists. It is not surprising that overall interest in automatic control and guidance systems was low. The committee members, of course, did not perform any of the NACA research, but their recommendations to NACA management were instrumental in assisting the research laboratories in obtaining personnel and facilities required for particular research areas of interest.

The automatic control people eventually won out, for on January 1, 1956, a new Subcommittee on Automatic Stabilization and Control was created under the Aerodynamics Committee, and the old Stability and Control Subcommittee was renamed the Subcommittee on Aerodynamic Stability and Control. This change, however, was too late and had little effect on the direction of the research at Wallops.

RESEARCH MISSILE AERODYNAMIC STABILITY AND CONTROL PROGRAM: D3

The aerodynamic characteristics of the D4 cruciform, canard guided missile were determined in a concurrent flight program designated D3. The D3 was a 7/8-scale model of the D4, with a 7-inch, rather than 8-inch, fuselage. Figure 165 shows one of the early models at Wallops with a single Deacon booster. The basic model had a cylindrical body with ogival nose and tail sections and four 60-degree delta wings and canard control surfaces. The control surfaces in one plane were pulsed in flight to allow determination of dynamic aerodynamic characteristics. Initially, a standard 6-channel telemeter was used, but this was later changed to an 8-channel, and then to a 10-channel, system. The 115-pound models were propelled to a Mach number of 1.45 by the Deacon booster. The initial tests were made with the identical configuration of the D4 missile, but, later, modified versions were flown. Thirteen D3 models were flown in the 1948–1951 period, with three structural failures and two partial failures of the telemeter.

The first flight was attempted on December 23, 1948, without success. It appeared that the A-frame of the crutch launcher hung on the model and flew with it for, according to the daily log, "Immediate search of the beach area after firing failed to disclose the 'A' frame and observers reported some such object flying with the model and booster." The second test on March 29, 1949, also was a

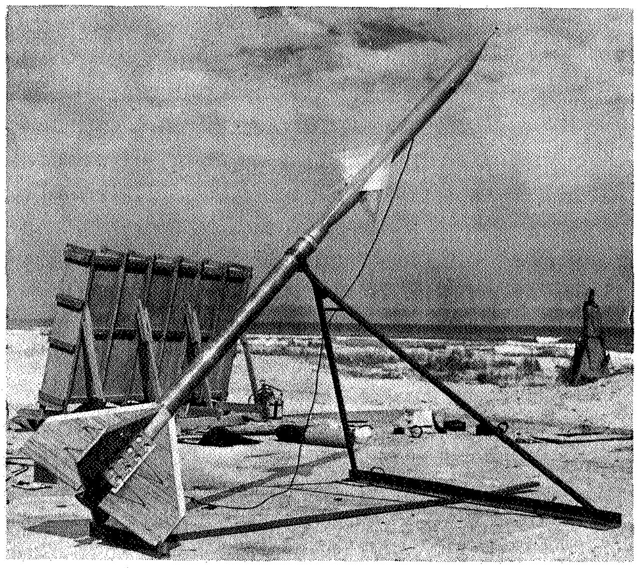


FIGURE 165. View of D3 missile stability research model on crutch launcher with Deacon booster, August 23, 1949.

failure—this time, a structural disintegration. The third trial, on August 23, was successful. The test showed that the basic D3 configuration had excellent stability and control characteristics over the Mach number range from 0.7 to 1.45 (ref. 62).

A 1/10-scale model of this D3 configuration was tested in the Langley 9-inch supersonic tunnel for comparison of flight and wind-tunnel methods. A good correlation was obtained, despite the large difference in Reynolds numbers (ref. 63). This was significant because the 9-inch tunnel was being used extensively for developmental testing of models of military missiles such as the Hughes Falcon.

The next flight series of D3 models was to evaluate control-surface effects. Tests were made with the canard surfaces reduced in size from 1/9 to 1/16 the wing area and located at different points: first, in line with the wings; then, interdigitated with respect to the wings. Finally, a test was made with the canard surfaces removed. In the latter test, stability was evaluated from disturbances caused by firing small pulse rockets (ref. 64). The first two models were propelled to approximately Mach 2 with double Deacon boosters, while the tailless model was boosted with a single Deacon system. The tests indicated that the control-surface of reduced size was still large enough to provide the needed control over the speed range and could function with about half the hinge moment. No differences were noted between the in-line and the interdigitated configurations. Apparently the small size of the canard surfaces minimized or eliminated nonlinearities in either case. The effect of interdigitation of large canard surfaces was usually the shifting of pitching-moment nonlinearities from low to high angles of attack. The aerodynamic damping-in-pitch of the tailless model was considerably lower than that of the models with tails, but the total damping of the pitching motion was still high because of the powerful effect of lift-curve slope, which was unaffected by absence of the tail.

Another tailless version of the D3 model was tested with wingtip controls providing longitudinal as well as lateral control. For this test, the fuselage section containing the canard surface was removed, which reduced the overall length from 114.2 inches to 91.8 inches, and reduced the weight to 87 pounds. With this reduced weight, the single Deacon booster was able to provide a Mach number of 1.65. The area of the wing-tip controls was the same as that of the basic canard surfaces. This test indicated that such a tailless missile arrangement would be feasible, in that good stability and control were maintained throughout the test range, although the wing-tip control produced only about one-third as much change in trim lift as that obtained with the canard control (ref. 65).

One flight was made with the control surfaces moved to the conventional aft location behind the wings. A double Deacon booster was used in this test, as shown in figure 166, and a Mach number of 1.81 was achieved. A 10-channel telemeter was used. It was found that, although the aft-tail provided about the same change in trim lift as the canard tail, it contributed little to the static stability or damping-in-pitch because of the large downwash field created by the delta wing (ref. 66).

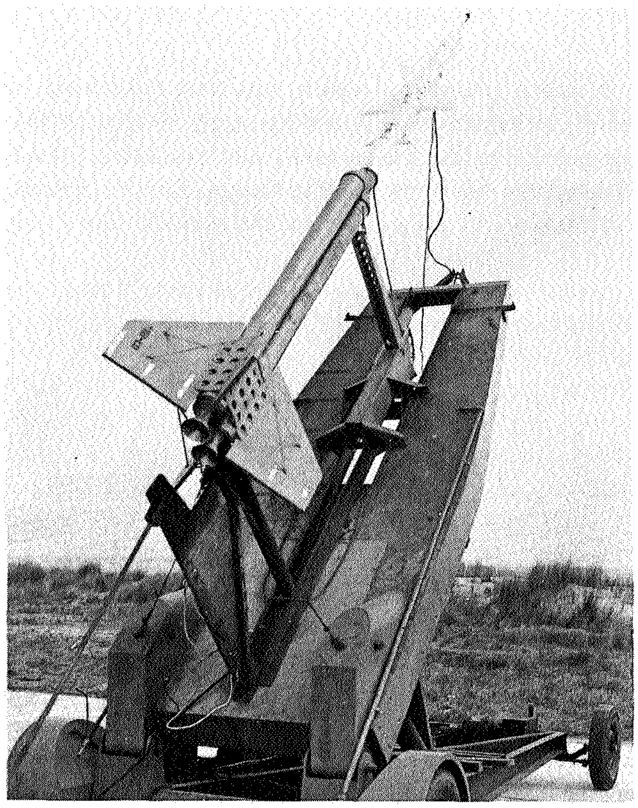


FIGURE 166. View of D3 research missile with aft tail surfaces. Model is shown with double Deacon booster on mobile launcher at Wallops, November 27, 1951.

Two flights of modified D3 models were made to provide data for use in the design of the PARD D22 interceptor missile described in Chapter 8. Pending construction of the D22 models, some of the characteristics of the D22 were simulated with existing D3 models. The first modification consisted of adding 40 inches to the fuselage between the canard surfaces and the wing, and reducing the area of the canard surfaces to one-sixteenth the wing area. In addition to these changes, the second modified model had the ogival nose changed to a 10-degree cone. The model weighed 124 pounds and was propelled to a Mach number of 2 with a double Deacon booster. Dynamic stability and control characteristics were determined from analyses of response to square-wave pulses of the canard surfaces. The measured effects of the increased tail length were about as expected, and the change to a conical nose had little effect (ref. 67).

A preliminary investigation was made of a unique method for stabilizing a missile. Although these tests were not made with D3 models, they are discussed here because of their application to missile stability. One of the problems in the installation of missiles, rockets, or bombs on aircraft was that of providing adequate clearance for the stabilizing fins. A possible solution to this problem was to eliminate the fins in the vertical plane and obtain stability by rotating the horizontal-tail assembly or the entire missile by building twist into the fins. These tests were proposed by Paul E. Purser and were of the "quick-and dirty" type he enjoyed making in preliminary studies of problems. The tests showed that stability of the total motion could be obtained by such a scheme, provided the basic rules developed by W. H. Phillips in NACA TN 1627 were followed (ref. 68).

Another evaluation of this method of stabilizing a missile was made by Purser with the aid of a large number of 2.25-inch aircraft rockets. About 150 rounds were fired, equipped either with the four standard cruciform fins or with only two monoplane fins, twisted to induce roll. A 70-mm rapid-sequence Hulcher camera mounted beneath the launching rail, as shown in figure 167, provided dispersion data. No appreciable difference in dispersion was noted between the cruciform and the rolling monoplane fins, which again verified the effectiveness of this method of stabilizing a body (ref. 69).

GUIDED MISSILE CONTROL HINGE MOMENT PROGRAM: D8 AND E16

The D8 guided missile aerodynamic-control hinge-moment program, which was first discussed in Chapter 6, and which had its first launching on March 3, 1949, was continued through 1952 with five more successful flights. The D8 models were generally similar to the D3 models, with the same 7-inch cylindrical body, ogival nose and tail sections, and cruciform 60-degree delta wings. Single Deacon boosters were used with either a crutch launcher, as shown in figure 168, or the mobile launcher. Maximum Mach number was about 1.45.

Additional data on tip ailerons on a 60-degree delta wing were obtained for several hinge-line locations, with the wings mounted on the standard 112-inch-long fuselage, with canard tail surfaces; or

FIGURE 167. Photographer W. Carr connects firing leads on a 2.25-inch rocket with twisted monoplane fins. Hulcher camera is shown in position to record dispersion of rocket in flight, December 22, 1952.

FIGURE 168. Technicians Nat Johnson and Durwood Dereng make final check of D8 aerodynamic control hinge-moment model on crutch launcher at Wallops, October 2, 1950.

on a shortened fuselage, 88 inches long and with no tail surfaces (ref. 70). The tests confirmed earlier findings that this type of control could be so hinged as to require very small hinge moments. In the next test, the identical wings and tip controls were used, but this time the controls were pulsed together as elevators, in order to allow evaluation of angle-of-attack effects on the hinge moment as well as on the forces (ref. 71). Hinge moments on a trailing-edge flap control hinged at 40 percent of the control chord were determined in a similar test, for comparison. The test showed that a control balance was effective throughout the speed range of the tests (ref. 72).

The next test in this series was of tip ailerons on a 60-degree diamond planform wing—the trailing edge was sweptforward 30 degrees. The results were generally similar to those for the tip aileron on the 60-degree delta wings (ref. 73).

The final test in the D8 series was with a tapered wing having 52.5-degree sweepback. The hinge moments of a trailing-edge control having its hinge at 40 percent of the chord (67-percent overhang balance) were determined for Mach numbers between 0.7 and 1.80 by using a double Deacon booster. The hinge moments were quite small (ref. 74).

To study the control balance problem, some preliminary tests were made with a much less expensive model. The program was derived from the E5 lateral control program, and was given the designation E16, although only a few models were flown. Ailerons were mounted on bearings and allowed to float free under the influence of inset tabs set at a fixed deflection. A one-channel telemeter transmitted measurements of the aileron floating angle from which tab-balancing effectiveness was derived. The normal two-stage E5 propulsion system was used. This test demonstrated that a balancing tab retained its effectiveness through the speed range tested, Mach numbers 0.7 to 1.4 (ref. 75).

CONTINUATION OF E5 LATERAL-CONTROL PROGRAM

The E5 lateral-control program continued to provide much-needed data for airplane and missile design. A wing with 63-degree sweepback and an aspect ratio of 3.5 had received considerable attention from researchers at the NACA Ames Laboratory, and had been recommended for airplane use. Consequently, this wing was added to the PARD E5 program, and a series of tests was made at Wallops with full-span, outboard and inboard ailerons on wings of a range of stiffnesses.

This wing was designated the "Jones wing" after its designer, Robert T. Jones, who had transferred from Langley to Ames in July 1946. The wing had a taper ratio of 0.25 and a NACA 64A005 airfoil section. Although the wing was found to have quite low drag characteristics, it was never to be put to practical use because of its severe pitch-up characteristics. In the E5 program, this highly swept and tapered wing was found to have high aeroelastic losses, even with a solid aluminum structure. The most effective spanwise location for the aileron was midspan (ref. 76).

The detrimental effect of a large trailing-edge angle on ailerons at transonic speeds has been discussed earlier in Chapter 5. Following these early tests, an additional program was undertaken to determine the effect of trailing-edge angles from 0 degree to 30 degrees, obtained by varying the thickness distribution over the rearward part of an airfoil. The basic airfoil section was a 6-percent circular arc. Full-span ailerons were tested on wings having 0-degree and 45-degree sweepback and aspect ratio 3.71. The results of this new program were correlated with the earlier data, and charts were prepared from which the effects of trailing-edge angle could be estimated for wings having thickness ratios of 3, 6, and 9 percent. The earlier conclusion that trailing-edge angles of greater than 7 degrees should be avoided was substantiated by this new correlation (ref. 77).

Some preliminary tests of spoilers for lateral control have been discussed in Chapter 5. The lower twisting moments of these controls prompted additional research on their effectiveness on thin swept-back wings. One such program was conducted with wing C (45-degree sweepback, taper ratio 0.4, aspect ratio 4.0, and NACA 65A006 airfoil section). The spoilers were all located along the 70-percent chord line and were varied in height and spanwise length and location. Wing stiffness was also varied. For this sweptback wing, the inboard spoilers were found to be almost twice as effective as outboard spoilers. As predicted, the spoilers had less twisting moment than ailerons of the same rolling effectiveness (ref. 78).

Spoilers located near the trailing edge for this wing planform were found to be somewhat less effective than those located at the 70-percent chord station (ref. 79).

The effects of flexibility on spoiler effectiveness on an unswept wing of aspect ratio 3.7 were determined in a separate program. Again, aeroelastic losses were found to be less for the spoilers than for ailerons (ref. 80).

A comparison of the relative effectiveness of an aileron and a spoiler was made on a wing of the same planform as that of the Douglas X-3 research airplane. In both cases, the controls extended only over the outer third of the span. The aileron, deflected 5 degrees, was found to have about the same effectiveness as a spoiler projected 2 percent of the wing chord (ref. 81).

DEVELOPMENT OF "AEROPULSE" TECHNIQUE: D35

Up to this time, two types of pulsing methods had been used to obtain longitudinal aerodynamic characteristics from pitching oscillations of free-flight models. One of these, used in the E15 and D3 programs, employed power-driven mechanisms to pulse the control surface. The other method used small pulse rockets to disturb the model from trim. The first method used space in the fuselage which otherwise could be used for an internal rocket for additional propulsion and, in addition, the pulsing mechanism was heavy. The second method could provide only a limited number of pulses.

A third system, proposed by PARD researcher Warren Gillespie, Jr., overcame some of these disadvantages and was simpler in operation. This system was termed the "aeropulse" technique and was given the designation of D35.

In this system, an all-movable, mass-balanced tail surface was hinged behind its aerodynamic center (overbalanced aerodynamically) and was provided with stops in each direction, with allowance for a few degrees' travel of the surface between the stops. In operation, the control would remain against one stop until pitching motion of the model reversed the lift on the tail. At that time, the tail would flip to the other stop and reverse the pitching motion. The action continued automatically throughout the flight. From such a test, an evaluation of lift and drag, lift-curve slope, and drag due to lift could be made, as well as evaluations of tail-lift effectiveness and effective downwash at the tail location.

Following an unsuccessful preliminary trial of the system on October 2, 1950, a successful flight was made on December 19, 1950. The model is shown in figure 169. A 65-inch HVAR booster was used in the test. The wing was a 67.5-degree modified delta wing with a modified double-wedge section. The test demonstrated the effectiveness of this new technique (ref. 82).

Following this preliminary flight, a new basic fuselage and tail were designed for use in a general program to evaluate drag due to lift, for various wing designs. For the purpose of comparison, the first flight of the new series was made without a wing. The new fuselage was designed to contain a 65-inch HVAR internal rocket motor or an HPAG motor. A Deacon booster was used, in addition, to provide a maximum Mach number of 2.3. The model was launched successfully on September 24, 1952. An improvement in the technique was made to allow determination of pitching moments by the addition of a second accelerometer in the nose section. Aerodynamic center locations so determined agreed well with theory. (ref. 83).

ROCKET-MODEL RESEARCH PROGRAM ON BUFFETING: D28

The phenomenon of low-lift buffeting in the transonic range has been discussed in Chapter 7. Data available at that time came from tests made primarily for other purposes. In 1950, a general research program was initiated with rocket models to explore the phenomenon further and to define the contributing factors. Such a program was designated D28 and was carried out in the Stability and Control branch of PARD, with Homer P. Mason as project engineer. In the period 1950-1956, 26 flights were made with only two failures, and these occurred near the end of the program.

Low-lift buffeting was known to be associated with shock-induced separation. To allow a study of this phenomenon on wings, tails, and external stores, a basic body was selected for minimum flow separation. It was a parabolic body of revolution of fineness ratio 10, with maximum diameter at the 50-percent station, and with a base diameter 0.384 maximum diameter. This body was chosen for its near-optimum drag characteristics and aerodynamic cleanliness, indicated by the earlier E2 body research by Roger Hart and Ellis Katz, as presented in RM L9I30. Different wing, tail, or external store configurations were mounted on the basic body.

Different propulsion systems were used in the D28 program, depending upon the weight and drag of the configuration under test. Initially, an HVAR booster was used with a Cordite sustainer. Later, the

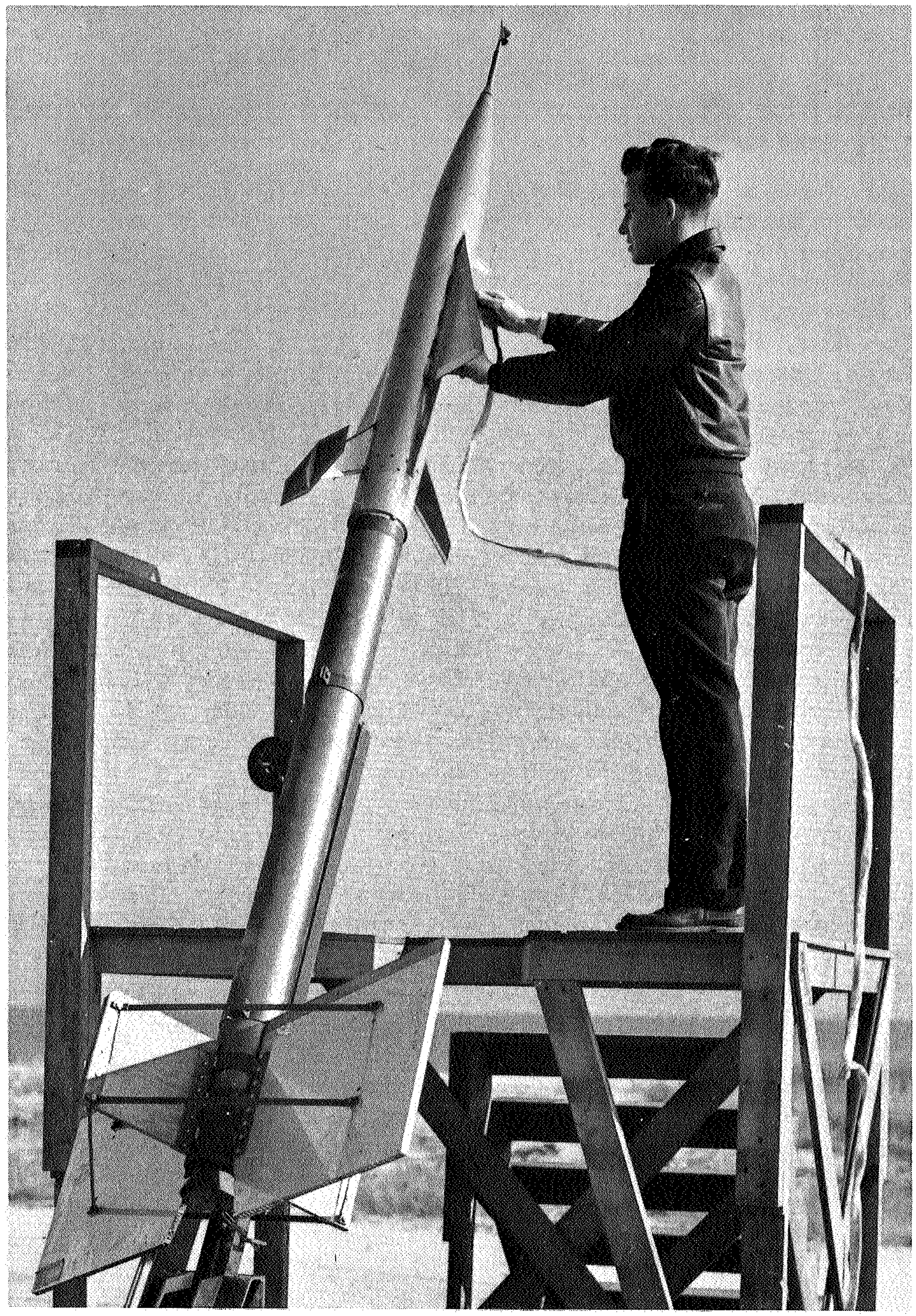


FIGURE 169. Engineer Albert E. Dietz prepares to pull external-power plug from D35 aeropulse model, shown with 65-inch HVAR booster, December 19, 1950.

booster was changed to a 65-inch HVAR, and then to a Deacon. In some tests, no sustainer was used, and in others the Cordite was replaced by an HVAR motor. The Mach number range was between 0.7 and 1.6.

Figure 170 shows the initial model on the rail launcher at Wallops, being readied for the flight on August 24, 1950. A six-channel telemeter was used to transmit measurements of accelerations and surface pressures on the body near the test wings. Rolling velocity was obtained from a spinsonde in the nose.

FIGURE 170. Technician William Ferguson prepares to pull the external-power plug on basic D28 buffeting-research body and tail configuration, August 24, 1950.

The initial tests with unswept wings of 6-, 7-, and 12-percent thickness, located rearward on the body, demonstrated the effectiveness of the technique and verified the earlier conclusion of Stone and Purser that severe low-lift buffeting, wing dropping, and normal-force changes occur almost simultaneously near Mach 0.9 on unswept wings of 12-percent thickness. With the 7-percent wings, buffeting was not encountered, but some wing dropping and normal-force changes were experienced (ref. 84).

The next phase of the program was to study the characteristics of thin, intersecting surfaces and of thick surfaces with a small amount of sweepback. The tests showed that a 6-percent-thick tail mounted on the vertical tail just above the fuselage surface encountered buffeting and a trim change, and that a sweepback of 35 degrees was not sufficient to eliminate buffeting of 12-percent-thick surfaces (ref. 85).

The next phase of the program involved addition of a typical fighter-type sweptback wing to the body. Figure 171 shows one of these models with a Deacon booster. Three tests were made: two with sweptback horizontal and vertical tails, and one with only the vertical tails. The wing was a close replica of the North American F-100 airplane wing and had 45-degree sweepback, an aspect ratio of 3.56, a taper ratio of 0.3, and an NACA 64A007 wing section. The tail surfaces were scaled copies of the wing. The horizontal tail was mounted at the center of the fuselage and, therefore, was directly in the wake of the wing. The slight buffeting encountered over a wide range of Mach numbers was believed to be the result of wing-body interference associated with the wing's being located near the maximum diameter of the body. No wing dropping was noted, although a longitudinal trim change at transonic speeds was experienced by the tail-on models (ref. 86). A second test of the tail-off model was then made with four external stores mounted under the wing. The isolated drag of the particular store design was determined by separate tests with larger scale models in the Helium Gun. Surprisingly, the addition of the stores reduced the buffeting intensity somewhat, although the total drag was increased by an amount equal to from 4 to 6 times the isolated drag values for the stores (ref. 87). Somewhat similar results were obtained when two larger external stores were placed on the wing (ref. 88).

The remaining models in the D28 program were designed to study the effects of adding various stores to the basic body and tail configuration without a wing. The first series of such tests employed a model of 10,000-pound store without fins, of fineness ratio 5, mounted successively (1) half-submerged within the fuselage, (2) tangentially to the surface, and (3) externally on pylons of 4-percent and 10-percent thickness. One of the pylon-mounted models is shown in figure 172. Very severe buffeting was encountered for all models except the one with the half-submerged store. The most severe case was the store mounted tangentially to the fuselage (ref. 89). One test was then made with the cavity that would be left after the half-submerged bomb had been dropped, and another, with the half-submerged bomb located farther aft on the fuselage. In addition, two external stores having smaller diameters and higher fineness ratios were tested as pylon-mounted stores. These additional tests showed that the cavity left by the half-submerged store caused some buffeting, but the stores of higher fineness ratio caused only mild buffeting (ref. 90).

The effects of carrying air-to-air guided missiles externally were determined in one flight test by mounting four small models of Sidewinder missiles on short struts out from the fuselage near the maximum diameter. Very little buffeting was noted. The incremental drag added by the four missiles was about equal to the sum of their isolated drag values at subsonic and supersonic speeds, while in the transonic range the added drag was about 40 percent greater than that of the missiles alone (ref. 91).

AERODYNAMIC DAMPING-IN-PITCH OF WINGS: D32

In the flight research conducted by the NACA with research airplanes and rocket models, some evidence of a loss of damping-in-pitch of wings in the transonic region had been noted. For aircraft with tails, the aerodynamic damping-in-pitch factor is principally a function of tail size and distance from the center of gravity. For tailless airplanes, however, this factor is considerably reduced and is a function of wing shape.

The aerodynamic damping-in-pitch factor in all the complete airplane and missile models tested was determined experimentally by either the pulsed-tail or pulse-rocket technique. The factor was also determined in flight for the research airplanes at the NACA High-Speed Flight Station. A comprehensive summary of such data for 22 rocket models and 4 research airplanes was made by C. L. Gillis and Rowe Chapman of PARD (ref. 92).

Airplanes and missiles with tails were shown to have values of the damping-in-pitch factor or derivative that varied typically from 10 for the North American F-86 airplane to 40 for the Sperry Sparrow missile. Tailless aircraft, on the other hand, had values varying from less than 1 for the Northrop X-4 research airplane to 3 for a 60-degree delta-wing model. In addition, the summary showed that the damping factor for the Northrop Snark missile and for the X-4 airplane dropped to almost zero at Mach numbers slightly below 1.0. The effect was not disastrous for these aircraft, however, because of the large stabilizing effect of lift-curve slope in providing damping of the total

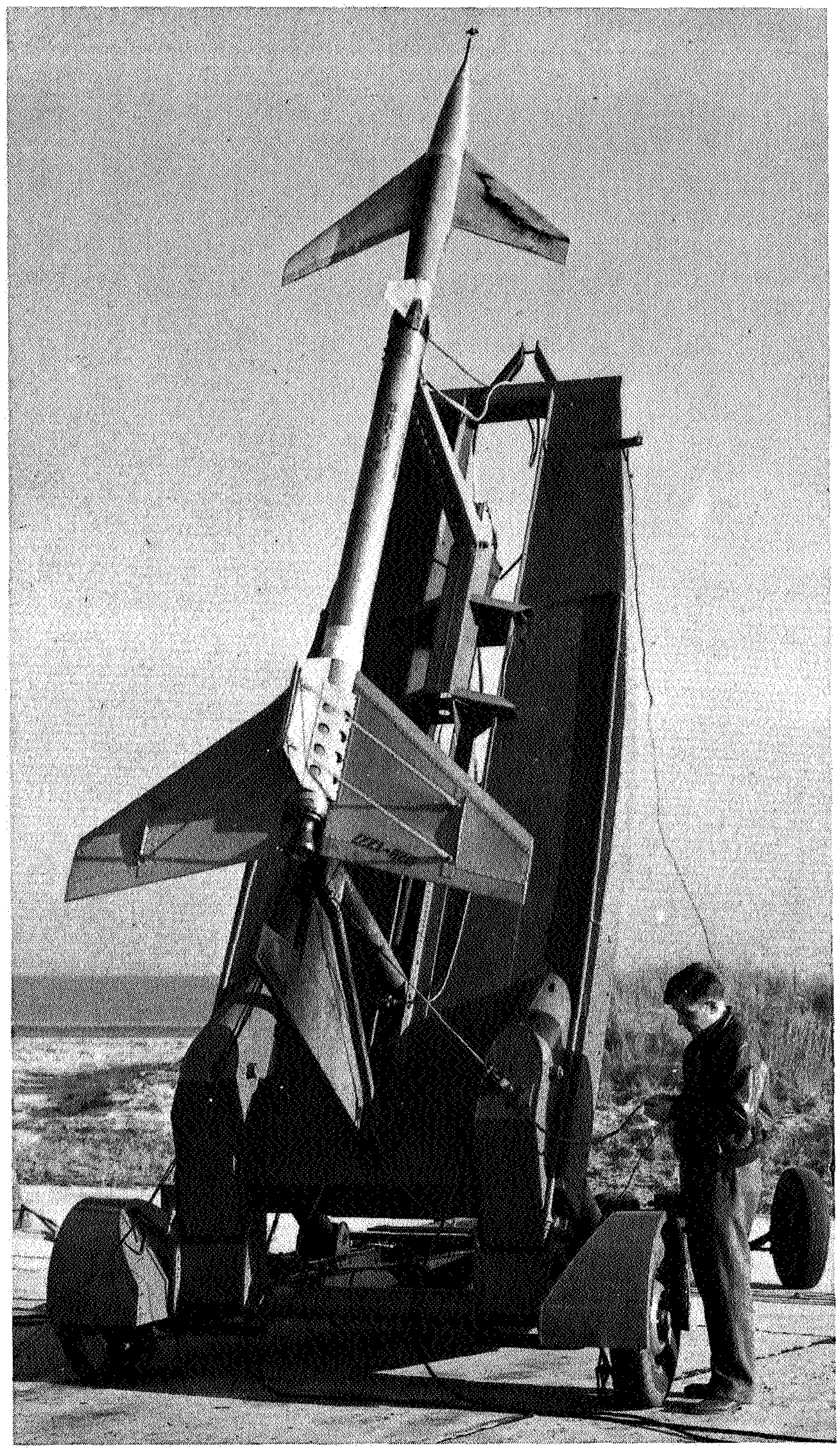


FIGURE 171. Engineer Homer P. Mason checks the firing cable leading to Deacon booster for D28 buffeting-research model, December 18, 1952.

pitching motion. In some cases, it did reduce the total damping below the recommended value and there was some concern about the possibility that other wing shapes might have even lower damping values.

In order to obtain more information about the loss of damping of wings in the transonic region, a special research program, designated D32, was initiated at PARD under the direction of Charles T. D'Aiutolo. Figure 173 shows one of these models on its rail launcher. The basic model had an ogival nose section containing the telemeter, a cylindrical fuselage containing a Cordite rocket motor, and

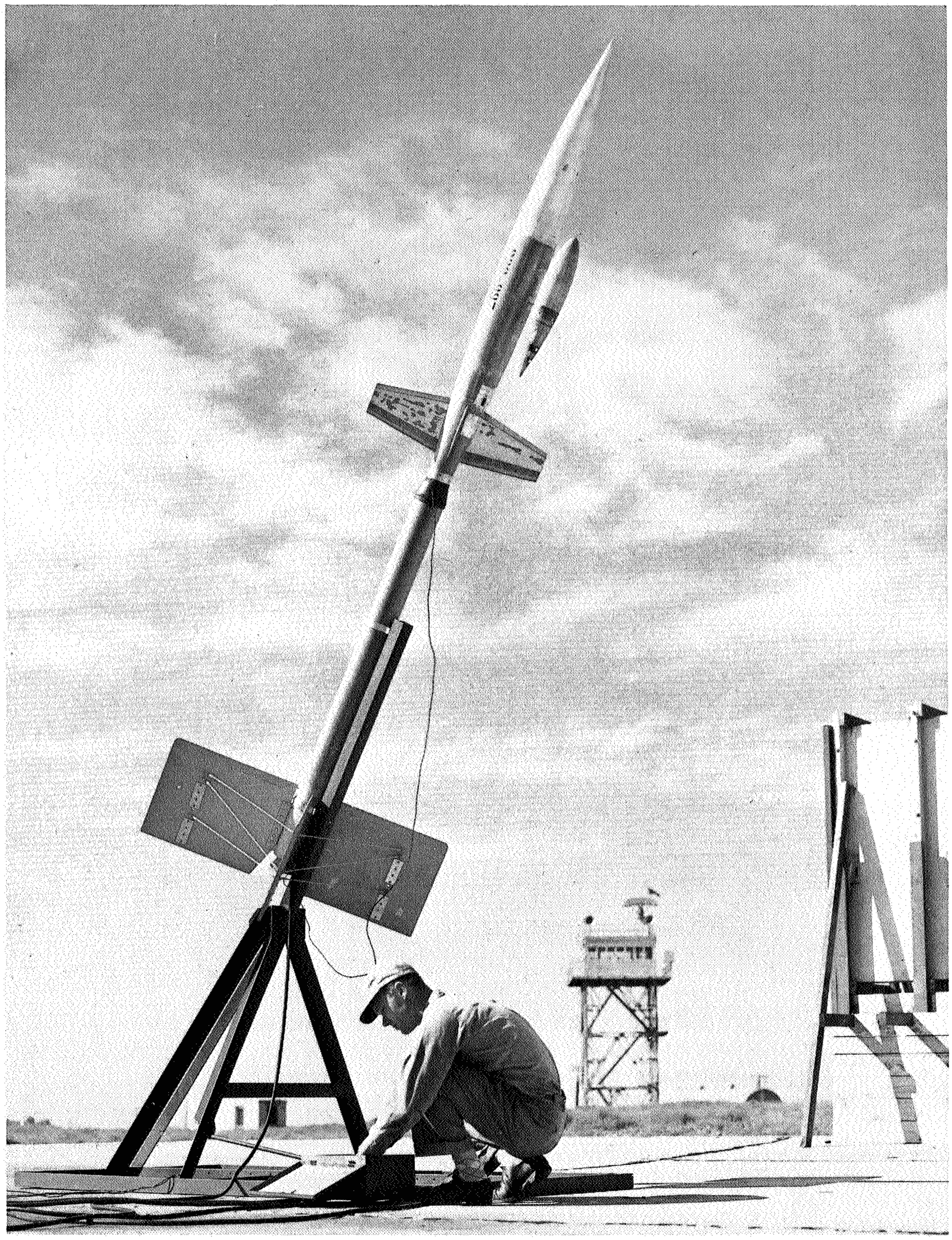


FIGURE 172. Technician Durwood Dereng checks the firing leads of HPAG booster for D28 buffeting-research model with a large external store, May 6, 1952.

rather large fairings on each side of the fuselage, which contained attachments for the wings. Vertical tails were attached above and below the fuselage at the rear. A lightweight HVAR booster rocket was used. The two-stage propulsion system provided a maximum Mach number of 1.33 for the 106-pound models. A four-channel telemeter transmitted measurements of normal and longitudinal accelerations, angle of attack, and total pressure. In the first series of tests, natural disturbances of the models were analyzed, but, later, small pulse rockets were used to provide somewhat larger disturbances. Between 1951 and 1953, 13 models were flown, with two failures. The first launching was made on August 22, 1951.

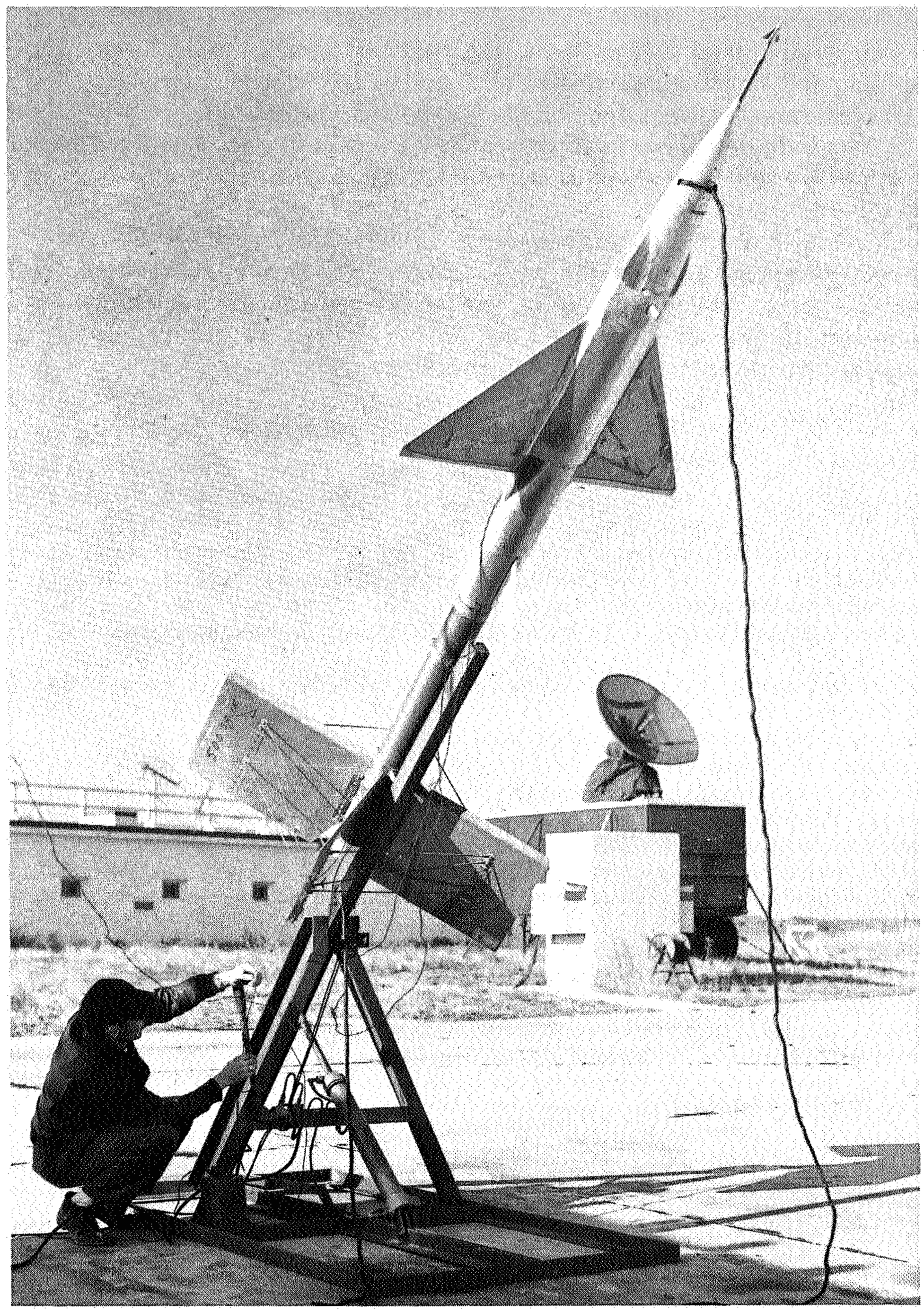


FIGURE 173. Technician connects firing leads to HVAR booster for D32 damping-in-pitch model, November 24, 1952.

The first series of tests was made with 45-degree delta wings having thickness ratios of 10 and 6 percent, and with 38-degree sweptback wings having thickness ratios of 12 and 6 percent. The thinner swept wing was similar to that of the X-4 research airplane. All four models exhibited negative damping near Mach 1.0, but the oscillations were so small that the results were questionable (ref. 93).

The second series of tests was made with 53-degree and 63-degree delta wings having thickness ratios of 6 percent. Two 63-degree delta-wing models were flown, one with the standard afterbody and one with the fuselage cut off just behind the wing. Pulse rockets provided disturbances in pitch. For the model without an afterbody, the two-stage propulsion system was replaced by a single Deacon booster, and the mobile launcher was used. All of these models exhibited unstable damping near Mach 1.0, for low-amplitude oscillations (ref. 94).

The last four models in the D32 program had sweptback wings. Two had aspect ratios of 4 with 45-degree sweepback, and two had aspect ratios of 3, one with 52-degree sweepback, and the other with 60-degree. All of the models were dynamically stable when disturbed beyond 0.5 degree. Below this amplitude, the data indicated either instability in the transonic range or very low damping. The contribution of the lift-curve slope to total damping was sufficient to provide positive overall damping even under this condition (ref. 95).

The main finding of the D32 program was that, although the earlier indications of loss of damping-in-pitch of certain sweptback wings in the transonic range was verified, it was found to be confined to low-amplitude conditions. In any event, most supersonic airplanes and guided missiles were equipped with automatic control systems that added artificial damping several times greater than the aerodynamic damping provided by conventional tail surfaces.

References

1. Goett, Harry J., Ames Laboratory, Memorandum to Director, June 22, 1951, regarding research suggestions submitted by missile manufacturers at the June 14–15 meeting of the Subcommittee on Stability and Control.
2. Minutes, meeting of the Committee on Aerodynamics, NACA, Oct. 4, 1951.
3. Lipp, J. E.; Salter, R. M.; and Wehner, R. S.: *Utility of a Satellite Vehicle for Reconnaissance,* Project Rand Report R–217, Apr. 1951.
4. Greenfield, S. M.; and Kellogg, W. L.: *Inquiry Into the Feasibility of Weather Reconnaissance From a Satellite Vehicle.* Project Rand Report R–218, Apr. 1951.
5. Minutes, meeting of the Subcommittee on Stability and Control, NACA, Nov. 1, 1951.
6. Minutes, Subcommittee on High-Speed Aerodynamics, NACA, Dec. 6, 1951.
7. Minutes, meeting of the Committee on Aerodynamics, NACA, Jan. 30, 1952.
8. Woods, Robert J.: "Establishment of a Study Group on Space Flight and Associated Problems." Research proposal for NACA Committee on Aerodynamics, Jan. 8, 1952.
9. Dornberger, W., Missile Specialist, Bell Aircraft Corp., Memorandum to R. J. Woods, Jan. 18, 1952.
10. Stone, D. G., Memorandum to Chief of Research, May 21, 1952, regarding preliminary study of the proposal for the flight of manned vehicles into space.
11. Minutes, Meeting of the Committee on Aerodynamics, NACA, June 24, 1952.
12. Hooker, Ray W., Memorandum for Engineering Service Division Files, Dec. 4, 1950, regarding design and procurement of a ferry for Wallops Island.
13. Messick, John C., chairman, Langley Architect–Engineer Advisory Board, Memorandum for Director, Dec. 5, 1950, regarding selection of naval architect for design of Wallops Island ferry.
14. Messick, John C., Memorandum for Engineering Service Division Files, Jan. 17, 1951, regarding negotiation with Eads Johnson for design of ferry for Wallops Island.
15. Newell, Homer E., Jr.: *Sounding Rockets,* McGraw-Hill, 1959. Chapter 4, Van Allen, J. A.; Townsend, J. W., Jr.; and Pressly, E. C.: "The Aerobee Rocket"; Chapter 13, Newell, Homer E., Jr.: "Viking."
16. Diehl, Walter S.: *Standard Atmosphere—Tables and Data,* NACA TR 218, 1925.
17. Warfield, Calvin N.: *Tentative Tables For the Properties of the Upper Atmosphere.* NACA TN 1200, Jan. 1947.
18. *Thirty-Third Annual Report,* National Advisory Committee for Aeronautics, 1947, p. 24.
19. *U.S. Standard Atmosphere, 1962,* Washington, D.C., GPO, Dec. 1962. Joint publication of NASA, USAF, and U.S. Weather Bureau.
20. Newell, Homer E., Jr.: *Sounding Rockets,* McGraw-Hill, 1959. Chapter 9, Van Allen, J. A.: "Balloon-Launched Rockets For High-Altitude Research."
21. Gardner, William N.; and Edmondson, James L.: *Preliminary Results Obtained From Flight Tests of a Rocket Model Having the Tail Only of the Grumman XF10F Airplane Configuration.* NACA RM SL51E04.

22. Gardner, William N.: *Aerodynamic Characteristics of a Canard-Balanced, Free-Floating, All-Movable Stabilizer as Obtained From Rocket-Powered-Model Flight Tests and Low-Speed Wind-Tunnel Tests.* NACA RM L53I28a.
23. Luoma, Arvo A.: *A Transonic Wind-Tunnel Investigation of the Trim and Dynamic Response Characteristics of the Horizontal Tail of a 1/7-Scale Model of the Complete Tail of the Grumman XF10F–1 Airplane.* NACA RM SL53D28.
24. Gardner, William N.: *Preliminary Results Obtained From Flight Test of a 1/7-Scale Rocket-Powered Model of the Grumman XF10F Airplane Configuration in the Swept-Wing Condition.* NACA RM SL52I25.
25. Kuhn, Richard E.; and Draper, John W.: *Aerodynamic Characteristics in Pitch and Sideslip at High Subsonic Speeds of a 1/14-Scale Model of the Grumman XF10F Airplane With Wing Sweepback of 42.5°.* NACA SL53G20.
26. Gardner, William N.: *Aerodynamic Characteristics at Transonic Speeds of a 1/7-Scale Rocket-Powered Model of the Grumman XF10F Airplane With Wing Sweepback of 42.5°.* NACA RM SL54D16.
27. *Jane's All the World's Aircraft 1954–1955*, p. 237.
28. Mitcham, Grady L.; Blanchard, Willard S., Jr.; and Hastings, Earl C., Jr.: *Flight Determination of the Low-Lift Drag and Longitudinal Stability of a 1/10-Scale Rocket-Powered Model of the Douglas XF4D–1 Airplane at Mach Numbers From 0.7 to 1.4.* NACA RM SL51L07.
29. Mitcham, Grady L.; Blanchard, Willard S., Jr.; and Hastings, Earl C., Jr.: *Summary of Low-Lift Drag and Directional Stability Data From Rocket Models of the Douglas XF4D–1 Airplane With and Without External Stores and Rocket Packets at Mach Numbers From 0.8 to 1.38.* NACA RM L52G11.
30. Blanchard, Willard S., Jr.; and Mitcham, Grady L.: *Longitudinal Stability and Estimated Flying Qualities of the Douglas XF4D–1 Airplane With and Without External Stores and Rocket Packets at Mach Numbers From 0.8 to 1.36 as Determined From Flight Tests of 0.10-Scale Rocket Models.* NACA RM L52K19a.
31. Mitcham, Grady L.; and Blanchard, Willard S., Jr.: *Low-Lift Drag and Stability Data From Rocket Models of a Modified-Delta-Wing Airplane With and Without External Stores at Mach Numbers From 0.8 to 1.36.* NACA RM L53A27.
32. Mitcham, Grady L.: *Free-Flight Zero-Lift Drag-Rise Measurements of Equivalent Bodies of Revolution of Several Versions of the Douglas XF4D–1 Airplane at Transonic Speeds.* NACA RM SL54K09.
33. Parks, James H.: *Experimental Evidence of Sustained Coupled Longitudinal and Lateral Oscillations From Rocket-Propelled Model of a 35° Swept-Wing Airplane Configuration.* NACA RM L54D15.
34. Zimmerman, Charles H., Memorandum for Chief of Research, Dec. 27, 1950, regarding request for a job order entitled "Preliminary Study of Jet-Propelled Vertically-Rising Aircraft."
35. Zimmerman, C. H.; Hill, Paul R.; and Kennedy, T. L.: *Preliminary Experimental Investigation of the Flight of a Person Supported by a Jet Thrust Device Attached to His Feet.* NACA RM L52D10.
36. Hill, P. R., Memorandum for Chief of Research, Jan. 18, 1952, regarding proposed tests of an inverted helicopter.
37. Hill, Paul R.; and Kennedy, T. L.: *Flight Tests of a Man Supported by a Teetering Rotor.* NACA RM L54B12a.
38. Hill, P. R.: "Flight Tests of a Man Standing on a Rotor-Supported Platform." Paper presented at NACA Conference on Helicopters, Langley Field, May 12–13, 1954.
39. Hagginbothom, W. K.; and Thibodaux, J. G.: *Aerodynamic Losses in Low-Pressure Exhaust Ducts For Rocket-Propelled Aircraft.* NACA RM L8C25.
40. Rodriguez, Charles J.: *An Experimental Investigation of the Effect of High-Pressure Tailpipe Length on the Performance of Solid-Propellant Motors For Rocket-Powered Aircraft.* NACA RM L52E12a.
41. Thibodaux, Joseph G.; and Faget, Maxime A.; Memorandum for Chief of Research, June 9, 1950, regarding visit to Bureau of Mines and Lewis Laboratory, May 24–25, 1950.
42. Bartlett, Walter A., Jr.: *Evaluation of End-Burning and Radial-Burning Solid Fuels in Ramjets Mounted in a Free Jet at Mach Numbers of 2.0, 2.2, and 2.3.* NACA RM L52I19.
43. Bartlett, Walter A., Jr.; and Dettwyler, H. Rudolph: *Flight Test of a Radial-Burning Solid-Fuel Ramjet.* NACA RM L52K03.
44. Bartlett, Walter A., Jr.: *Flight Test of an End-Burning Solid-Fuel Ramjet.* NACA L54B08a.
45. Bartlett, Walter A., Jr.: *Flight Test of a Solid-Fuel Ramjet With the Internal Surface of the Combustor Air Cooled.* NACA RM L56D24.
46. Seaberg, E. C., Memorandum for Chief of Research, July 31, 1952, regarding D109 acoustic seeker test vehicle.
47. Gardiner, R. A., Memorandum for Chief of Research, Dec. 6, 1950, suggesting that an AN/DAN–3 infrared seeker be borrowed for tests at PARD, behind different shapes.
48. Piland, Robert O.: *Preliminary Free-Flight Investigation of the Zero-Lift Drag Penalties of Several Missile Nose Shapes For Infrared Seeking Devices.* NACA RM L52F23.
49. Wallskog, Harvey A.; and Hart, Roger G.: *Investigation of the Drag of Blunt-Nosed Bodies of Revolution in Free-Flight at Mach Numbers From 0.6 to 2.3.* NACA RM L53D14a.
50. Piland, Robert O.; and Putland, Leonard W.: *Zero-Lift Drag of Several Conical and Blunt-Nose Shapes Obtained in Free Flight at Mach Numbers of 0.7 to 1.3.* NACA RM L54A27.
51. Zarofsky, Jacob: *System Analysis and Autopilot Design for Automatic Roll Stabilization of a Supersonic Pilotless Aircraft.* NACA RM L51E07.
52. Nelson, Walter C.; and Passera, Anthony L.: *A Theoretical Investigation of the Influence of Auxiliary Damping in Pitch on the Dynamic Characteristics of a Proportionally Controlled Supersonic Canard Missile Configuration.* NACA RM L50F30.
53. Passera, Anthony L.: *A Theoretical Investigation of the Influence of Autopilot Natural Frequency Upon the Dynamic Performance Characteristics of a Supersonic Canard Missile Configuration With a Pitch-Attitude Control System.* NACA RM L51H02.
54. Clements, James E.: *A Theoretical Analysis of a Simple Aerodynamic Device to Improve the Longitudinal Damping of a Cruciform Missile Configuration at Supersonic Speeds.* NACA RM L55H31.
55. Passera, Anthony L.; and Bridgeland, Thomas A., Jr.: *The Influence of the Control-Surface-Servo Natural Frequency Upon the Transient Characteristics of a Flight-Path-Angle Control System Incorporating a Supersonic Missile.* NACA RM L53J15.

56. Seaberg, Ernest C.; Geller, Edward S.; and Willoughby, William W.: *Theoretical Investigation Based on Experimental Frequency-Response Measurements of an Automatic Altitude Control in Combination With a Supersonic Missile Configuration.* NACA RM L54F04.

57. Zarofsky, Jacob; and Gardiner, Robert A.: *Flight Investigation of a Roll-Stabilized Missile Configuration at Varying Angles of Attack at Mach Numbers Between 0.8 and 1.79.* NACA RM L50R21. Reissued as NACA TN 3915, Jan. 1957.

58. Moul, Martin T.: *Flight Investigation of a Supersonic Canard Missile Equipped With an Auxiliary Damping-in-Pitch System.* NACA RM L52K14b.

59. Seaberg, Ernest C.; and Smith, Earl F.: *Theoretical Investigation of an Automatic Control System With Primary Sensitivity to Normal Accelerations as Used to Control a Supersonic Canard Missile Configuration.* NACA RM L51D23.

60. Passera, Anthony L.; and Nason, Martin L.: *The Effect of Control-Surface-Servo Natural Frequency on the Dynamic Performance Characteristics of an Acceleration Control System Applied to a Supersonic Missile.* NACA RM L53G23a.

61. Seaberg, Ernest C.; Sproull, Royce H.; and Reid, H. J. E., Jr.: *Flight Investigation at Supersonic Mach Numbers of an Automatic Acceleration Control Missile in Which Rate Damping is Obtained From a Linear Accelerometer Placed Ahead of the Missile Center of Gravity.* NACA RM L55G29.

62. Niewald, Roy J.; and Moul, Martin T.: *The Longitudinal Stability, Control Effectiveness, and Control Hinge-Moment Characteristics Obtained From a Flight Investigation of a Canard Missile Configuration at Transonic and Supersonic Speeds.* NACA RM L50I27.

63. Curfman, Howard J., Jr.; and Grigsby, Carl E.: *Longitudinal Stability and Control Characteristics of a Canard Missile Configuration For Mach Numbers From 1.1 to 1.93 as Determined From Free-Flight and Wind-Tunnel Investigations.* NACA RM L52F06.

64. Moul, Martin T.; and Wineman, Andrew R.: *Longitudinal Stability and Control Characteristics From a Flight Investigation of a Cruciform Canard Missile Configuration Having an Exposed Wing-Canard Area Ratio of 16:1.* NACA RM L52D24a.

65. Moul, Martin T.; and Baber, Hal T., Jr.: *The Longitudinal Stability and Control Characteristics of a 60° Delta-Wing Missile Having Half-Delta Tip Controls as Obtained From a Free-Flight Investigation at Transonic and Supersonic Speeds.* NACA RM L52H14.

66. Moul, Martin T.; and Baber, Hal T., Jr.: *A Flight Investigation at Mach Numbers From 0.67 to 1.81 of the Longitudinal Stability and Control Characteristics of a 60° Delta-Wing Missile Configuration Having an All-Movable Tail.* NACA RM L53G29.

67. Brown, Clarence A., Jr.; and Lundstrom, Reginald R.: *Flight Investigation From Mach Number 0.8 to Mach Number 2.0 to Determine Some Effects of Wing-To-Tail Distance on the Longitudinal Stability and Control Characteristics of a 60° Delta-Wing-Canard Missile.* NACA RM L52C26.

68. Purser, Paul E.; and Stevens, Joseph E.: *Exploratory Rocket Flight Tests to Investigate the Use of a Freely Spinning Monoplane Tail For Stabilizing a Body.* NACA RM L52I05a.

69. Purser, Paul E.: *Comparative Dispersion Data From Ground-Launched 2.25-Inch Rockets Equipped With Cruciform and Monoplane Fins.* NACA RM L55I06.

70. Martz, C. William; Church, James D.; and Goslee, John W.: *Free-Flight Investigation to Determine Force and Hinge-Moment Characteristics at Zero Angle of Attack of a 60° Sweptback Half-Delta Tip Control on a 60° Sweptback Delta Wing at Mach Numbers Between 0.68 and 1.44.* NACA RM L51I14.

71. Martz, C. William; Church, James D.; and Goslee, John W.: *Rocket-Model Investigation to Determine the Force and Hinge-Moment Characteristics of a Half-Delta Tip Control on a 59° Sweptback Delta Wing Between Mach Numbers of 0.55 and 1.43.* NACA RM L52H06.

72. Martz, C. William; and Goslee, John W.: *Rocket-Model Investigation to Determine the Hinge-Moment and Normal-Force Properties of a Full-Span, Constant-Chord, Partially Balanced Trailing-Edge Control on a 60° Clipped Delta Wing Between Mach Numbers of 0.50 and 1.26.* NACA RM L53I04.

73. Church, James D.: *Rocket-Powered Model Investigation of the Hinge-Moment and Normal-Force Characteristics of a Half-Diamond Tip Control on a 60° Sweptback Diamond Wing Between Mach Numbers of 0.5 and 1.3.* NACA RM L54C10.

74. Martz, C. William: *Rocket-Model Investigation of Hinge Moments on a Trailing-Edge Control on a 52.5° Swept Wing Between Mach Numbers of 0.70 and 1.80.* NACA RM L57F04.

75. Bland, William M., Jr.; and Marley, Edward T.: *A Free-Flight Investigation at Zero Lift in the Mach Number Range Between 0.7 and 1.4 of an Inset Tab as a Means of Aerodynamically Relieving Aileron Hinge Moments.* NACA RM L52K07.

76. Strass, H. Kurt; Fields, E. M.; and Schult, Eugene D.: *Some Effects of Spanwise Aileron Location and Wing Structural Rigidity on the Rolling Effectiveness of 0.3-Chord Flap-Type Ailerons on a Tapered Wing Having 63° Sweepback at the Leading Edge and NACA 64A005 Airfoil Sections.* NACA RM L51D18a.

77. Fields, E. M.; and Strass, H. Kurt,: *Free-Flight Measurements at Mach Numbers From 0.7 to 1.6 of Some Effects of Airfoil-Thickness Distribution and Trailing-Edge Angle on Aileron Rolling Effectiveness and Drag For Wings With 0° and 45° Sweepback.* NACA RM L51G27.

78. Schult, Eugene D.; and Fields, E. M.: *Free-Flight Measurements of Some Effects of Spoiler Span and Projection and Wing Flexibility on Rolling Effectiveness and Drag of Plain Spoilers on a Tapered Sweptback Wing at Mach Numbers Between 0.6 and 1.6.* NACA RM L52H06a.

79. Schult, Eugene D.; and Fields, E. M.: *Free-Flight Measurements of the Rolling Effectiveness and Drag of Trailing-Edge Spoilers on a Tapered Sweptback Wing at Mach Numbers Between 0.6 and 1.4.* NACA RM L14a.

80. Fields, E. M.: *Some Effects of Spoiler Height, Wing Flexibility, and Wing Thickness on Rolling Effectiveness and Drag of Unswept Wings at Mach Numbers Between 0.4 and 1.7.* NACA RM L52H18.

81. English, Roland D.: *Flight Investigation of an Aileron and a Spoiler on a Wing of the X–3 Airplane Planform at Mach Numbers From 0.5 to 1.6.* NACA RM L54D26a.

82. Gillespie, Warren, Jr.; and Dietz, Albert E.: *Use of an Aerodynamically Pulsed All-Movable Horizontal Tail to Obtain Longitudinal Characteristics of Rocket-Powered Models in Free Flight and Some Initial Results From an Arrow-Wing-Body-Tail Configuration.* NACA RM L52C10.

83. Gillespie, Warren, Jr.; and Dietz, Albert E.: *Rocket-Powered Model Investigation of Lift, Drag, and Stability of a Body-Tail Configuration at Mach Numbers From 0.8 to 2.3 and Angles of Attack Between ± 6.5°.* NACA RM L54C04.
84. Mason, Homer P.; and Gardner, William N.: *An Application of the Rocket-Propelled-Model Technique to the Investigation of Low-Lift Buffeting and the Results of Preliminary Tests.* NACA RM L52C27.
85. Mason, Homer P.: *Low-Lift Buffet Characteristics Obtained From Flight Tests of Unswept Thin Intersecting Surfaces and of Thick 35° Sweptback Surfaces.* NACA RM L52H12.
86. Mason, Homer P.: *Flight Test Results of Rocket-Propelled Buffet-Research Models Having 45° Sweptback Wings and 45° Sweptback Tails Located in the Wing Chord Plane.* NACA RM L53I10.
87. Henning, Allen B.: *The Effects of Wing-Mounted External Stores on the Trim, Buffet, and Drag Characteristics of a Rocket-Propelled Model Having a 45° Sweptback Wing.* NACA RM L54B19.
88. Mason, Homer P.: *Effects of Wing-Mounted Tank-Type Stores on the Low-Lift Buffeting and Drag of a Swept-Wing Airplane Configuration Between Mach Numbers 0.8 and 1.3.* NACA RM L55D27.
89. Mason, Homer P.: *Effect of External Store Mounting on the Buffet, Trim, and Drag Characteristics of Rocket-Powered Fuselage and Store Combinations Between Mach Numbers of 0.7 and 1.4.* NACA RM L53J22.
90. Mason, Homer P.; and Henning, Allen B.: *Effects of Some External-Store Mounting Arrangements and Store Shapes on the Buffet and Drag Characteristics of Wingless Rocket-Powered Models at Mach Numbers From 0.7 to 1.4.* NACA RM L54I20a.
91. Henning, Allen B.; and Brown, Clarence A., Jr.: *Flight Characteristics of a Wingless Rocket-Powered Model With Four Externally Mounted Air-to-Air Missiles at Mach Numbers From 0.6 to 1.6.* NACA RM L54K17a.
92. Gillis, Clarence L.; and Chapman, Rowe, Jr.: *Summary of Pitch-Damping Derivatives of Complete Airplane and Missile Configurations as Measured in Flight at Transonic and Supersonic Speeds.* NACA RM L52K20.
93. D'Aiutolo, Charles T.; and Parker, Robert N.: *Preliminary Investigation of the Low-Amplitude Damping in Pitch of Tailless Delta- and Swept-Wing Configurations at Mach Numbers From 0.7 to 1.35.* NACA RM L52G09.
94. D'Aiutolo, Charles T.: *Low-Amplitude Damping-in-Pitch Characteristics of Tailless Delta-Wing-Body Combinations at Mach Numbers From 0.80 to 1.35 as Obtained With Rocket-Powered Models.* NACA RM L54D29.
95. D'Aiutolo, Charles T.: *Low-Amplitude Damping-in-Pitch Characteristics of Four Tailless Swept Wing-Body Combinations at Mach Numbers From 0.85 to 1.30 as Obtained With Rocket-Powered Models.* NACA RM L54I10.

CHAPTER 10

BEGINNING OF HYPERSONIC RESEARCH PROGRAM: 1953

IMPLEMENTATION OF HYPERSONIC PROGRAM

On June 24, 1952, the NACA Committee on Aerodynamics adopted a resolution asking the NACA to increase its program dealing with problems of flight at Mach numbers from 4 to 10 in the upper stratosphere, and from Mach 10 to escape speeds into space (initiation of this research has been discussed in Chapter 9). Adoption of the resolution led to creation of a special team, consisting of C. E. Brown, W. J. O'Sullivan, Jr., and C. H. Zimmerman of Langley to study the problems and to prepare a report covering the various phases of a proposed program that would carry out the intent of the resolution. RA A73L95 was issued by NACA Headquarters on September 8, 1952, to cover a "Preliminary Study of Research on Space Flight and Associated Problems." The study was completed on June 25, 1953 (ref. 1).

The group lowered the upper limit of flight speeds to be studied from that of escape into space to that of satellite velocity of 26,000 feet per second, explaining their action with the statement that "It is, therefore, extremely difficult to give any adequate reason why any considerable amount of research effort should be devoted to projects having as their primary objective achievement of space travel." Their study regarding the problems of flight to satellite speeds, however, was quite broad and ended on a very optimistic note. While not proposing a complete overall research program, they did make some specific recommendations for immediate action.

The study team recognized the advantage of satellite vehicles in reconnaissance, weather prediction, astronomical observations, and worldwide television. They examined military as well as civilian uses for aircraft capable of hypersonic flight up to satellite speeds, and concluded that there were many far-reaching advantages of such aircraft. Accordingly, they recommended that research begin immediately on the problems expected to be encountered.

The findings of the study group may be summarized as follows:

1. There are no fundamental barriers to either ballistic or airborne flight at extreme altitudes at speeds up to orbital velocity.
2. Flight at these extreme speeds and altitudes offers great military and commercial advantages.
3. The outstanding problem is preventing structural failure from aerodynamic heating.
4. Research is required at Mach numbers, Reynolds numbers, and temperatures beyond the range of existing facilities.
5. Since orbital speeds are obtainable with existing chemical propellants, rocket-propelled models appear to be the most readily developable means for testing at the required conditions.

Before recommending an immediate program of research, the group examined the recommendations of D. G. Stone (see reference 10, Chapter 9), that the Bell X-2 research airplane be modified for high-altitude flight with the addition of two Sergeant rocket motors strapped to the outside to allow it to attain higher speeds and altitudes. They also examined the proposal of H. M. Drake and L. R. Carmen of Edwards, to construct a special supersonic high-altitude-launch airplane that would likewise extend the capabilities of the X-2 to the desired higher speeds and altitudes.

Of the two proposals, that of Stone appeared the more practical to the study team, and it was recommended as a first step, but with one modification, i.e., replacing the rocket engine in the X-2 airplane with one of much higher thrust, instead of adding the strap-on motors.

This recommendation was given additional engineering study at Langley in the following months, and the conclusion was reached that the X-2 airplane was too small for research as a hypersonic space-flight vehicle. The decision was made to embark on development of a completely new airplane to be designated X-15. Such an airplane with Mach 7 capabilities was proposed to the military services in July 1954 (ref. 2) but it was not to be until September 1959, almost 2 years after *Sputnik I*, that the airplane was to make its first powered flight (ref. 3).

The original proposal of Woods and the discussion and resolution of the NACA committee placed the greatest emphasis on the need for research in the problems of flight at Mach numbers from 4 to 10 in the upper stratosphere. The Brown-O'Sullivan-Zimmerman team, however, became so enthused over the results of their analysis revealing the very favorable possibilities of manned flight at orbital speeds, that their conclusions and recommendations had a definite orbital-flight flavor. Their studies indicated that a boost-glide manned vehicle operating from an initial near-orbital speed could not only be an effective, economical strategic bomber, but could be an economical passenger-carrier over long distances. For example, their calculations indicated that an airplane could travel from New York to Buenos Aires in one hour instead of the normal 36 hours, and for one-half the cost. This study excited interest at Langley for the development of a hypersonic boost-glide vehicle as a follow-on to the X-15. Research on the boost-glide vehicle later was to become known as Round 3 and, still later, as the NACA-USAF Dyna-Soar project (ref. 4).

The study group, in examining the facilities required to conduct research for the boost-glide vehicle, quickly dismissed wind-tunnel facilities as entirely inadequate, and strongly recommended an expanded rocket-model program. They recommended that Wallops Island be used as the launch base for models of boost-glide vehicles with reentry and recovery in the Sahara Desert! While this would require a major effort on the part of the NACA, it was believed to be the quickest, most dependable, and least expensive method. They concluded:

> The very great service that the (Wallops Island) facility has performed and still performs cannot be denied. It is believed that a similar service can be performed by extension of its activities to include research at near-orbital velocities.

During the period the study group was making its analysis and recommendations, PARD was preparing a hypersonic research program (ref. 5), which outlined the immediate possibilities of increasing the flight speeds of rocket models with existing rocket motors. The proposal for this program was submitted to Langley management on June 5, 1953, and became the basic reference document for the hypersonic research to be conducted during the next 2 years. In summary, the PARD proposal stated: "It is believed that the present state of the art of model testing is such that data to Mach number 10 can be obtained during the latter half of 1954." That this was a sound belief was to be evidenced by the successful launching of the first Mach 10 vehicle on October 14, 1954.

The proposed Mach number 10 vehicle contained two rocket motors that had not been previously used at Wallops, but which had been developed by the military services. The proposal called for a three-stage system with two Nike booster motors in tandem as the first and second stages, and a Thiokol T40 motor as the third stage. Later, it was found necessary to add a fourth stage, a Thiokol T55 motor, to reach Mach 10.

Although Mach 10 was believed to be possible with existing motors, the program proposed that this goal be approached in several easy steps. The following vehicles were proposed:

Vehicles	*Mach Number*
1. Triple Deacon-HPAG	5.5
2. Nike-Deacon	7.0
3. Nike-T40	8.0
4. Nike-Nike-T40	10.0

Increasing the Mach number of rocket models from the earlier maximum of about 4 to a new high of 10 introduced more problems than that of finding the proper launch vehicle. First, the range to impact would be increased from the existing 25-mile limit to 400 miles, for a ballistic trajectory. In view of the long-time opposition of the Atlantic Fleet to long-range firings from Wallops, the possibility of overcoming this obstacle was viewed with skepticism. Second, the instrumentation requirements for the Mach 10 vehicle required major improvements in both ground-based and airborne instrumentation. The range and instrumentation problems will be discussed in following sections of this chapter.

During preparation of the PARD hypersonic research program, it became obvious fairly early that combinations of rockets on hand (Deacon and HPAG) could extend the flight speed attainable to Mach 5; and on October 28, 1952, Langley requested authorization for "Preliminary Rocket Model Studies of Simple Body-Fin Combinations at Mach Numbers of 5 and above." RA A73L98 was issued by NACA Headquarters on November 5, 1952, to cover such studies.

A triple Deacon booster had been designed at Langley for the F23 program, and its first test was made on July 16, 1952. This was redesigned for use as a booster for a vehicle containing an HPAG rocket motor as the second stage. The first launch of the triple Deacon-HPAG vehicle, shown in figure 174, was made on August 20, 1953. A Mach number of 5.4 was reached in this flight, the highest Mach number attained at Wallops to this date.[1]

When the PARD hypersonic research program was transmitted to NACA Headquarters on June 5, 1953, a draft of a new RA to cover "Exploration of Problems of Flight at Mach Numbers of 10 and Above" was submitted for approval. This RA, A73L112, was issued on July 2, 1953. The vehicle envisioned in this program had a Thiokol T40 rocket motor as the final stage.

The Thiokol T40 was the first motor obtained by Langley with JPL polysulfide, cast propellant. The motor had been developed for the Army Redstone Arsenal by Thiokol Chemical Corporation for use in the Hermes missile program, and was a scaled-down version of the motor to be used in the Hermes A-2 solid-propellant guided missile. Flight tests of the motor over a range of initial motor temperatures had been made at Wallops in February 1952. (The tests are to be discussed in a later section of this chapter.) Although the T40 motor was never declared operational by Army Ordnance, its high performance made it so desirable for the PARD hypersonic program that PARD was willing to take the risk of using this experimental motor.

The T40 motor had about the same total impulse (20,000 pound-seconds) as the Deacon, but was considerably lighter (132 pounds, compared with 150 for the Deacon). Use of 103 pounds of propellant resulted in a propellant-mass fraction of 0.78, the highest encountered so far. The motor's main disadvantage in comparison with the Deacon was its stubby shape (8 inches in diameter and 4 feet in length) and its longer burning time and lower thrust (3,000 pounds of thrust for 6 seconds). The T40 had an internal-burning star-perforated grain, housed in a thin-walled steel case. Although the stubby shape and low thrust ruled out this motor for earlier rocket models, it was ideal for use as an upper stage in the hypersonic program, in which it would be operating under the low-drag conditions of high altitude.

For the first stage of the proposed Mach 10 vehicle, a rocket motor much larger than the Deacon or T40 was required. PARD had realized the need for larger booster rockets for some time. The F36 long-range ramjet missile required a large booster and the need to propel general aerodynamic models to higher speeds called for larger rockets. The immediate solution was to cluster Deacon motors to form, first, a double Deacon booster; then, a triple Deacon; and, later, a quadruple Deacon.

1. The first flight with an instrumented model to a Mach number greater than 5 was made at Wallops on March 17, 1953, by a Lewis air-launched rocket model powered solely by a Thiokol T40 rocket motor. The program will be discussed in detail in Chapter 11.

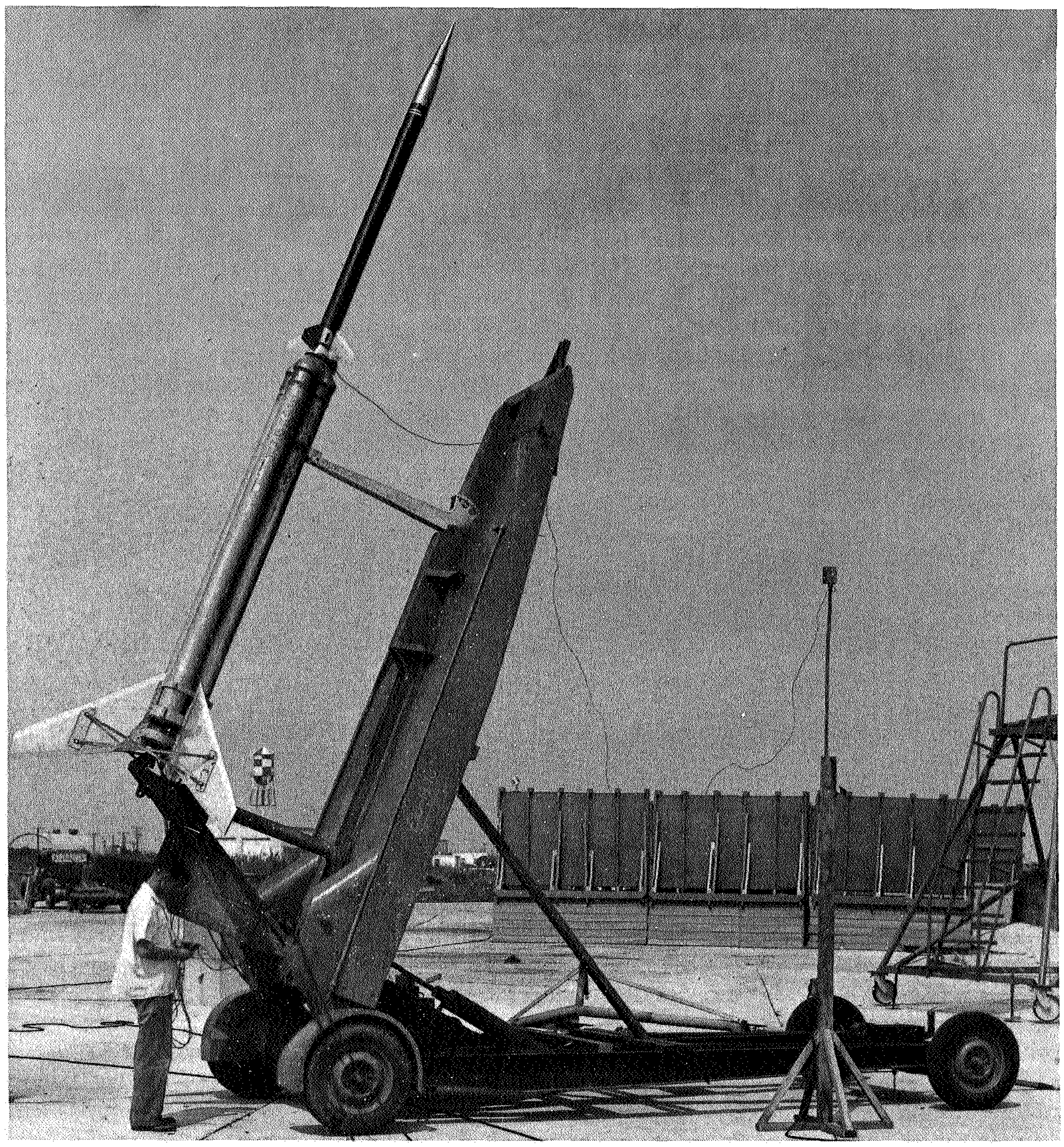


FIGURE 174. Technician Roy Hindle connects firing leads to triple Deacon-HPAG hypersonic test vehicle, August 20, 1953.

In July 1951, Langley asked Allegany Ballistics Laboratory for information about a large, lightweight rocket motor, 2.5-DS-54000, under development for the Navy Terrier missile.[2] This was the beginning of contacts with ABL that resulted in acquisition of several of these motors for trial firings at Wallops. The Nike booster motor was the Army's production version of this rocket, including modifications, which PARD was to purchase in large numbers in later years. The motor was equivalent in total impulse to about seven Deacons and was a definite step forward for use in the first or second stages.

In March 1952, PARD's rocket-motor expert, J. G. Thibodaux, proposed that the NACA cooperate with the Navy in development of a 60,000 pound-second solid-rocket motor (ref. 6). Such a motor was proposed for use in PARD's high-speed flight program. At this time, the larger Terrier or Nike booster was considered to be uneconomical for such applications. The proposed motor was to have a fineness ratio of 15. The motor also was desired for the NAMTC at Point Mugu, California, and meetings were

2. Letter from H. J. E. Reid, Langley Director, to Hercules Powder Co., Allegany Ballistics Laboratory, July 27, 1951, regarding information on Deacon rocket performance and lightweight Terrier booster.

held with the cognizant people from BuAer over the next year. An acceptable plan for development of such a motor was agreed upon, but it was never to be carried out. The Nike booster motor was eventually to fill this need as far as PARD was concerned.

The Nike booster was selected for the F36 ramjet missile, with the first launching planned for July 1953. (See Chapter 8.) In anticipation of this launching and other plans requiring trainable launchers, R. L. Krieger had initiated procurement of a special launcher to meet these needs. The first plan was to obtain a 90-mm antiaircraft gun mount and to convert it into a launcher. Late in 1952, Krieger visited the Erie Arsenal to discuss such a conversion (ref. 7). The plan was abandoned when it became evident that the conversion was too complicated to permit readiness by the time of the expected launching. Instead, a rather crude interim launcher was designed at Langley. In May 1953, however, Krieger learned that the Army had surplus launchers designed especially for the Terrier missile, and that they might be obtained for Wallops.

The Army had initiated an evaluation of the complete Terrier missile system at White Sands Proving Ground for possible adaptation to its antiaircraft missile program. It had procured a complete Navy fire-control system, including radars, Terrier missiles, and several dual launchers, but the project had been canceled. Krieger telephoned the Redstone Arsenal and verified the availability of one of the launchers. In fact, shortly after this, the Army offered to transfer the entire project to Langley, provided Langley would complete evaluation of the missile for the Army (ref. 8). While this would have been an excellent opportunity for Langley to obtain direct experience with a complete beam-rider guided missile system, Langley decided that such an undertaking was beyond the means of the laboratory. Steps were taken, however, to obtain one of the launchers. The launcher was shipped to Wallops and was to become the standard launcher for Nike boosters there. It is shown in figure 175. with the first Nike-Deacon vehicle at launch on November 19, 1953. (The first firing from this launcher at Wallops, also with a Nike-type booster, was made on October 23, 1953, as part of the North American Navaho missile program, to be discussed in a later section of this chapter.)

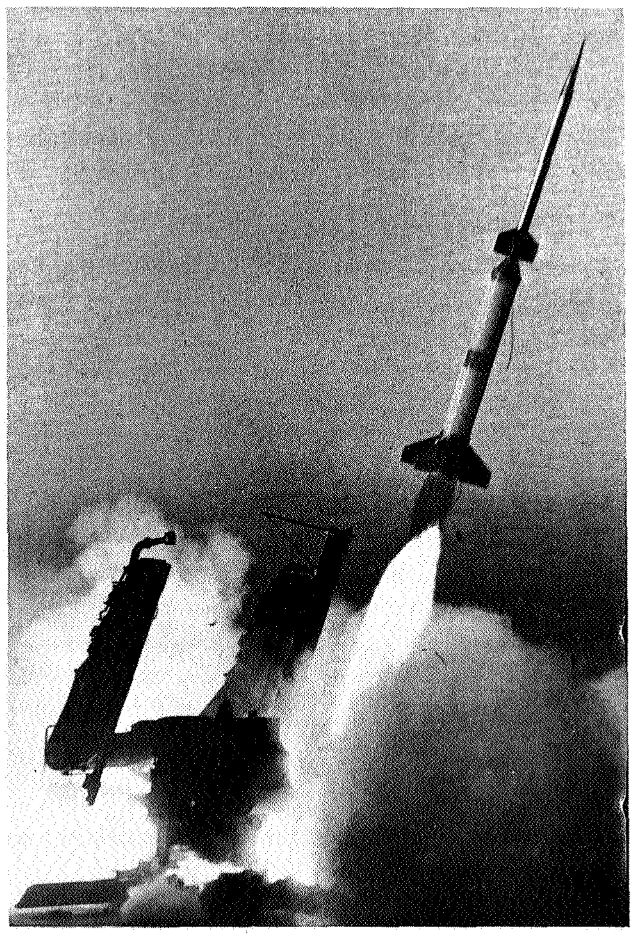


FIGURE 175. First Nike-Deacon vehicle lifts off from Army T−121 Terrier launcher at Wallops, November 19, 1953.

INSTRUMENTATION FOR HYPERSONIC SPEEDS

Development of instrumentation for use in the rocket-model program at Wallops was a continuing responsibility of the Instrument Research Division (IRD) at Langley. IRD tried to anticipate the needs of the programs and have required instrumentation developed by the time it was needed. The impact of the hypersonic research program, with its jump in speed from Mach 4 to Mach 10 in 2 years, plus corresponding increases in altitude, was so great that minimum improvements and a loss of accuracy had to be accepted for the first few years. It was to be several years, for example, before adequate tracking radars were installed.

IRD had achieved an enviable reliability record at Wallops through the application of quality control techniques and environmental testing with subsequent redesign of failed components. An analysis made for the years 1951 and 1952, for example, showed that of the 206 telemetered models flown at Wallops, with a total of 1,246 channels of information, useful data were obtained during 99 percent of the total flight time, and 97 percent of the data apparently contained errors of less than two percent.[3] One change had been made in the telemeter which contributed to this reliability; the entire assembly inside the model was shock-mounted to the frame. In addition, whenever possible, all electronic components were "potted" in plastic for greater ruggedness. By this time, the number of continuous channels available in the tray-type telemeter had risen to 10.

The higher speeds of the hypersonic program were expected to increase the temperature of the outer skin to be measured in heat-transfer programs, as well as increase the temperature inside the telemeter compartment. Greater range thermocouples had to be developed, and radiation shields and insulation had to be provided in extreme cases. Multiple-range accelerometers and pressure-pickups were needed to cope with the large changes in these measurements from sea level to altitudes as high as 100,000 feet. This was the beginning of an instrument development program for high-speed and high-altitude measurements that was to continue far into the space age.

A model 10C Doppler Velocimeter was acquired from Sperry with 1952 GOE funds ($133,981) and was delivered at Wallops in October 1953. This radar differed from the model 10A principally in that it was mounted on a gun mount that could be servoed remotely by the SCR-584 radar. The model 10C radar is shown in figure 176. Considerable difficulty was experienced with this radar; in fact, it was not accepted from the manufacturer until late in 1954.[4] The servomechanism introduced microphonics and leakage difficulties. The microphonics were eliminated but the leakage problem was never completely solved.

One change that had been made in the Doppler at Wallops was addition of a special filter, developed by the University of Virginia under a contract effort directed by Dr. L. R. Quarles. This filter extended the useful range of the radar and made possible the automatic counting of Doppler frequency, which reduced record reading time by 50 percent and later was to facilitate automatic data reduction.[5] The hypersonic research program called for an increase in Doppler frequency measuring capability and also an increase in range to the model. As long as the rocket stages were fired in close sequence, as was commonly done in the beginning, the Doppler was able to keep up with the needs. Later, however, when long coast periods were inserted between stages, the Doppler was no longer able to provide velocity measurements of the final stages. The less accurate system of integrating accelerometer data then had to be used.

The SCR-584 radar required a modification to extend the tracking rate in order to keep up with the models of higher speed. Extreme skill was required for the operator to transfer from a large target to a smaller one of higher speed, at the ignition of upper stages. Widening the gate so both targets could be seen at separation helped to solve this problem. Luke Jett was the most skillful of the many operators trained at Wallops, and his presence was demanded by the project engineers for the hypersonic firings.

3. Letter from NACA to Chief, BuAer, March 5, 1953, regarding experience related to missile reliability.
4. Letter from Langley to NACA Headquarters, June 30, 1954, regarding proposed meeting at Ballistic Research Laboratories to discuss problems encountered with Sperry Model 10C Velocimeter.
5. Letter from NACA to NAMTC, Point Mugu, California, June 9, 1950, regarding modifications to Sperry Velocimeter Model 10A.

FIGURE 176. Sperry model 10C Doppler Velocimeter at Wallops, June 1, 1954.

With the planned increase in ranges for models at Wallops, first the long-range ramjet models, and then the hypersonic models, the need for onboard beacon transponders was realized, if accurate tracking were required over the entire range. Up to this time, skin tracking alone had been used. Some preliminary evaluation of a beacon began in 1950 (ref. 9), but its size and weight prevented its use until 1955 when lighter versions became available. The first use of an S-band beacon was to be in the first Nike-Deacon sounding rocket launched at Wallops on April 8, 1955.

In June 1952, an improved radiosonde system was installed at Wallops, which was to provide atmospheric pressure and wind data over a greater altitude range. This was the Rawin equipment, procured with 1951 GOE funds for $35,000. The system operated on a frequency of 1,680 mc. For hypersonic flights to an altitude of 100,000 feet or more, extra-large balloons were used. Later, a ranging attachment was added, which eliminated the need for SCR-584 tracking.

NAVY AGREEMENT ON WALLOPS RANGE EXTENSION

Beginning in June 1950, as has been discussed first in Chapter 7 and then in Chapter 8, the Chief of Naval Operations (CNO) had effectively limited Wallops firings to a range of 25 miles, at the insistence of the Commander in Chief, Atlantic Fleet (CINCLANT). Fleet training exercises were conducted in the Warning Area offshore from Wallops, beyond 25 miles. Plans for increased range firings from Wallops were continually frustrated by the refusal of the Navy to share its range. This attitude was finally altered, however, in 1953 when the hypersonic research program became a reality. The change of attitude was as much a result of a change in personnel as a result of the expansion of the flight program. Nevertheless, it produced a very necessary and timely agreement.

The June 5, 1953, letter transmitting the PARD hypersonic research program to NACA Headquarters pointed out the need for the cooperation of the Armed Services when the proposed flights were to be made. Headquarters made informal contacts with the staff of CNO in Washington, D. C., and finding them receptive, asked Langley to prepare a draft of a formal request for assistance. Such a draft was prepared by J. A. Shortal, Chief of PARD.[6] It discussed the hypersonic research program with flights to Mach 10, and outlined the need for assistance in firings to ranges of 80 to 400 miles, beginning in July 1953 and occurring every four months. Such firings would be made into and over the fleet training areas. Search of the sea by the Navy was also requested.

Hugh L. Dryden, NACA Director, sent the official request to the Deputy Chief of Naval Operations (Air) on June 24, 1953, with the promise that such firings would be scheduled with the Navy

6. Letter from Langley to NACA Headquarters, June 19, 1953, enclosing draft of proposed letter to CNO regarding assistance in long-range rocket firings at Wallops Island.

in such a way as to avoid interference with Navy operations.[7] This time, CNO agreed to assist the NACA in such Wallops firings.[8] The reply from CNO stated "that the Commander in Chief, Atlantic Fleet, was to be directed to coordinate the schedule of naval operations so as to permit your firings during mutually satisfactory periods." He was also to be directed to coordinate provision of search aircraft. CINCLANT assigned responsibility for coordination of all such naval activities to the Commander, Air Force, Atlantic Fleet (ComAirLant).

Shortal and Krieger visited the Navy air operations office in Norfolk, Virginia, on July 16, 1953, to discuss detail arrangements (ref. 10). They met with Lieutenant Commander D. R. French, Assistant Operations Officer, and Captain T. H. Moorer, Plans Officer. Moorer had received a directive from CINCLANT "to assist NACA, coordinate other naval activities involved, and to publish such notices (to mariners, airmen, etc.) as were necessary." Captain Moorer was very cooperative and stated that no large problems were involved. He requested that Langley notify ComAirLant by letter 2 weeks in advance of any long-range firing, and describe all the services required. It was agreed that to minimize interference with Navy operations, the NACA would plan its firings for Friday afternoons, with Saturday as an alternate day. This plan worked well for the next year.

Langley tried to maintain good relations with the Navy by adhering to firing schedules as closely as possible. This was something new for Wallops firings, and it put an extra strain on operations people. The general plan was to prepare at least two models for firing and have them ready a few days in advance of the scheduled date. It was hoped that this plan would minimize cancellations of firings at the last minute. Of course, in cases of bad weather, cancellation was unavoidable. The plan worked so well that on one afternoon, October 14, 1954, three multistage, long-range firings were made successfully.

Although the cooperation of the Navy in long-range firings from Wallops was to continue, this "red-carpet" treatment of having ComAirLant coordinate such Navy activities for the NACA was not to last. Eventually, the firings were to be scheduled in accordance with procedures followed by all Navy units, through the Fleet Training Command. Under this plan, several months' notice was required.

NEW CONSTRUCTION

During 1953, three new buildings were completed at Wallops. The most valuable of these was a permanent structure to house the SCR-584 radar. The other two buildings were a paint shop and a service station. These buildings were financed from C and E funds appropriated for fiscal year 1952.

When the 1952 budget was prepared at Langley in the spring of 1950, funding was requested for a service station, a paint shop, and permanent buildings at the Mainland and Island Docks. Insufficient funds were appropriated for all of this work, and the buildings at the docks were eliminated. In October 1951, Williams, Coile, and Blanchard were selected as architects to design the paint shop and service station, under Project 1229. At about the same time, approval was requested of NACA Headquarters for the construction of a shelter for the SCR-584 radars, with financing to be obtained from GOE funds. Headquarters approved the request on March 11, 1952, in an amount not to exceed $57,000, but disapproved the GOE funding. Rather, they proposed C and E funding and made this building another part of Project 1229. Funds to cover the additional work were transferred from a Langley utilities C and E project. This building was officially designated Station 3 by NACA Headquarters.

The shelter for the SCR-584 radars was needed to replace the old trailers that had been in use at Wallops to house the radars and plotboard from the beginning. In the early days, having the radars in trailers made it possible to move the radars for better reception, if desired. Now that a permanent site for the equipment had been in use for a number of years, the time had come to provide a better home. The structure proposed was a cinder-block building 36 feet by 58 feet, with a concrete roof for mounting the radar antenna. Such a building would provide more room for maintenance of the

7. Letter from H. L. Dryden to Ralph A. Ofstie, Vice Admiral, USN, Office of CNO, June 24, 1953, regarding assistance of Navy in long-range firings from Wallops Island.
8. Letter from R. A. Ofstie to H. L. Dryden, July 6, 1953, regarding assistance of Navy in long-range firings from Wallops Island.

equipment and better protection from the weather. It would also ensure greater accuracy because the radar antenna could be firmly anchored in place. It was estimated that the errors would be reduced from about 1 mil to 0.2 mil.[9] The proposed building was constructed on the concrete pad already in use by the trailers at the radar site. It may be seen in figure 177.

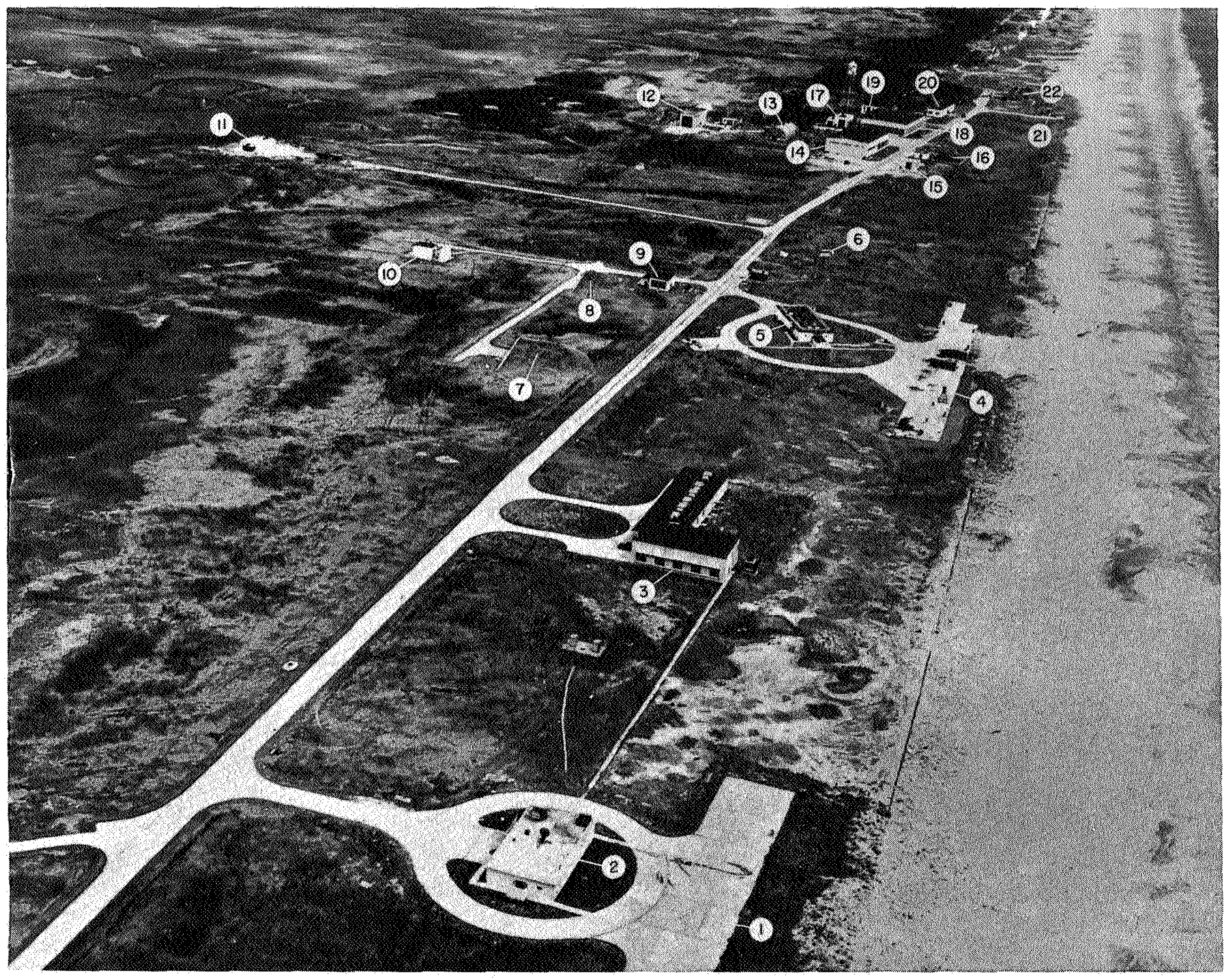


FIGURE 177. Aerial view of Wallops, April 1954. Numbers identify areas and buildings, as follows: (1) Launch Area 2, (2) Control Center 2, (3) Model Assembly Shop, (4) Launch Area 1, (5) Control Center 1, (6) Control Tower (Observation Tower), (7) Propellant Magazine, (8) Igniter Magazine, (9) Propellant Shop, (10) Rocket Test Cell, (11) Station 3, (12) Preflight Jet, (13) Standby Powerplant, (14) Instrument Laboratory, (15) Service Station, (16) Fuel Storage, (17) Paint Shop, (18) Utility Shop, (19) Heating Plant, (20) Administration Building, (21) Station 1, and (22) Service Building.

The service station was a two-bay building 32 feet square, located across the main road from the Instrumentation Laboratory near the fuel storage area. The paint shop was a building 45 feet by 43 feet, located just west of the Utility Shop. These buildings may also be seen in figure 177.

The Byrne Organization, Inc., was awarded contract NAw-6231 to construct the three buildings, and they were completed in October 1953. Before the project was closed, a bulk storage area, located near the paint shop, was added. This was an open building 15 feet by 30 feet, with a concrete floor and a shed roof. In addition, a dropped ceiling of acoustical tile was added to the radar station. These two additions were constructed by Wyle Maddox under contract NA1-2427.

9. Letter from Langley to NACA Headquarters, September 25, 1951, requesting approval for a shelter for precision radar-theodolite equipment at Wallops Island.

The total allotment for all of the new construction was $173,000, expended as follows:

Project Number	Title	Contract Number	Contractor	Amount
1229-A	Architects & Engineers		Williams, Coile & Blanchard	$ 3,800
1229-B	Paint Shop	NAw-6231	Byrne Org., Inc.	57,781
1229-B	Bulk Storage	NA1-2427	Wyle Maddox	6,909
1229-C	Service Station	NAw-6231	Byrne Org., Inc.	26,091
1229-D	Station 3	NAw-6231	Byrne Org., Inc.	76,646
1229-D	Ceiling	NA1-2427	Wyle Maddox	1,765
			Unexpended	8
			Total	$173,000

ASSISTANCE TO THE NAVY AT WALLOPS

By 1953, NAOTS operations on its end of Wallops Island were reduced to gun firings for the most part, with an occasional air drop. The Ammunition Test Facility, discussed in Chapter 8, was in operation, and sounds of the guns could be heard from the NACA area. Through a misunderstanding at Langley regarding approval procedures, permission had been given by Langley to NAOTS to construct this facility on the beach about one-half mile on the NACA side of the Navy lease line. A cold-box had been added to the facility to allow evaluation of aviation armament over a wide range of temperatures.

In October 1953, NAOTS was ready to proceed with construction of another gun facility termed a "plate test facility," which involved erection of a metal plate target downrange from a firing box, for evaluation of armor-piercing ammunition. Official request for permission was made on October 16, 1953.[10] This time Langley forwarded the request to NACA Headquarters for action. When Krieger learned of the request and noted that NAOTS wanted to construct this new facility on NACA property south of the existing Navy Ammunition Facility, he was quite upset. He prepared a document summarizing the situation, and recommended that the Navy be persuaded to use "a portion of the island already assigned to them." He pointed out that NAOTS was slowly using up all available land on the island, thereby preventing further expansion of NACA facilities. In particular, a blast facility under consideration for construction by the NACA would nearly coincide with the proposed Navy plate test facility (ref. 11).

Langley Director H. J. E. Reid endorsed Krieger's recommendation and sent it on to Headquarters. Before a decision was reached, Wallops personnel discovered that NAOTS had already poured a concrete slab for the new facility. This really brought things to a head. Krieger went to NACA Headquarters and, at a meeting in John W. Crowley's office on December 10, 1953, persuaded the Navy representatives to reconsider their plans and abandon the slab. In January 1954, permission was granted for them to add the plate test facility to their existing Ammunition Test Facility north of the proposed area. This incident ended NAOTS' encroachment upon NACA test areas.

NAOTS had another gun range on the upper end of the island, near the old Coast Guard station, which allowed overland firings. Observation stations paralleling the line of fire allowed studies of premature explosions and other fusing problems of ammunition. The Navy's use of Wallops as a guided missile range never amounted to much after Navy activities were curtailed in this field, as has been discussed in Chapter 5.

For guided missile testing, NAOTS had installed a number of phototheodolite stations and three tracking radar systems. Equipment included an SCR-584 and an MPQ-2A radar modified with data boxes and bore-sighted cameras, as used by the NACA on Wallops. NAOTS also had an Mk 25 radar with an Mk 37 director. Despite this, the NACA was asked by the Naval Air Development Center (NADC) to supplement NAOTS equipment in the tracking of some Gorgon V missiles NADC was

10. Letter from NAOTS to Langley, October 16, 1953, requesting permission to construct a plate test facility.

planning to drop over the ocean out from Wallops. Three members of the NADC crew assigned to NAOTS for these tests visited Wallops on April 7, 1953, to discuss their needs. Such assistance was provided by NACA crews on Wallops on July 15, 1953, November 17, 1953, and May 10, 1954. It took a while for the official paperwork to catch up with the project. NACA Headquarters approved the request for assistance and issued RA A22L186 on November 27, 1953. On one occasion, the NACA crew provided the only tracking information obtained because the drop was made after regular working hours and the NAOTS crew, having made no arrangements for overtime operation, had closed their station and gone home.

A different kind of support was provided a crew from the Naval Air Material Center (NAMC), Philadelphia, Pennsylvania. This was a crew being trained to fly a drone aircraft along a precise flight path while watching the track of the drone as shown on the plotboard at Wallops in real time. The request for such assistance was made after the success achieved by NADC in positioning the target drone for the D109 acoustic seeker tests discussed in Chapter 9. The NAMC crew were being trained for an operation in which the drone aircraft would be flown by remote control along previously selected paths near nuclear blasts in the desert. This training began at Wallops on November 18, 1953, and was completed on January 6, 1954. Successful operations were conducted at night as well as in the daytime. The drone aircraft were provided by NAS, Chincoteague.

RECREATION ON WALLOPS ISLAND

By 1953, the pattern of living on Wallops Island was well established. The Service Building, more often called the cafeteria, was the headquarters for all transients as well as the lunchroom for everyone. The cost per night for a bunk bed had risen to $1.00, and all meals were a la carte. An overnight visitor was assigned to a bunk in one of the sleeping rooms, but the meeting place was the lounge, which had been equipped with leather-upholstered furniture from the Langley Officers' Club surplus. This facility was operated as a branch of the NACA Exchange at Langley. C. A. Hulcher, PARD operations head, persuaded the Morale Activities Association at Langley to provide a television set for the lounge at Wallops. An antenna was erected atop a high pole to provide programs from Norfolk and Baltimore. These programs were supplemented by music and news from a Hallicrafter radio, obtained earlier from Army surplus. Hulcher also obtained ping-pong equipment and a set of horseshoes for recreation.

Many of the men from Langley spent their spare time in the shop area making sure that their model would be ready for firing the next day. The engineers worked right along with the Wallops technicians during the day and frequently would continue alone during the evening, if necessary. There was always a supply of magazines and paperback books in the lounge, and it was not difficult to arrange a card game if one was so inclined. None of the magazines were ever thrown out but were added to at regular intervals by PARD personnel, especially Paul Purser.

Some years after the wild ponies had been taken off the island, the horseflies almost disappeared, but the mosquitoes survived, despite regular spraying with DDT. Killing mosquitoes on the walls and ceiling of the lounge—or even on the wing—with an Aerosol bomb was a regular pastime. The seasoned visitor always cleared out his bedroom of any winged beasts before turning in for the night.

The waters around Wallops were well known for an abundance of fish. Before the NACA moved to Wallops Island, it was owned by the Wallops Island Association and was used as a private club for fishing, hunting, and swimming, as discussed earlier in this history. The Association members continued to use the island after the NACA moved into the southern end but had to leave after the Navy leased the remainder of the island. The clubhouse of the Association was abandoned and became the victim of beach erosion, winds, high water, and waves. It was in bad shape by May 1949, as shown by figure 178. Although local residents on the Eastern Shore would have welcomed the opportunity to use the clubhouse and the beach for recreation, both the Navy and the NACA preferred to restrict the island to official use, although it was used on occasion by employees for family picnics on weekends.

Fishing at Wallops Island was mostly by surf casting at night. The sport was enjoyed by transient visitors as well as by employees who cared enough to bring their own equipment. Fish were available throughout most of the year, but the run of channel bass or drum in the spring provided the greatest

FIGURE 178. View of Wallops Island Association clubhouse on north end of the island, showing damage from erosion and storms, May 1949.

sport. Such fish would weigh 35 to 50 pounds, and it was quite a job to land one. Success was achieved by Langley visitors R. L. Krieger and E. D. Schult, as shown in figure 179, and by J. B. Lee, pictured in figure 180. Local employees were equally successful, as evidenced by the catch of Sherwood Northam shown in figure 181. Northam was of slight build and was forced to sit on the beach and dig in his heels to keep from being pulled into the ocean by one of his fish.

Swimming at Wallops was as good as at any Atlantic beach resort. The water was clear, the beach was sandy, and there was usually plenty of wave action. Swimmers among the visitors, however, were generally in the minority. The usual time for a swim was just before breakfast or before dinner. There was not much time available in the late afternoon because the cooks, who also served as guards, were anxious to serve dinner as early as possible and usually had it ready by the time the last rocket firing was completed.

Three of the men who doubled as cafeteria workers and as guards—George Harmon, Harvey Thornton, and Charlie Young—were former Coast Guard employees and prepared the food in Coast Guard style, without any fancy trimmings. They were noted for their clam chowder and clam fritters. Fried chicken, fish, ham, and roast beef were served at lunch, with perhaps a steak for dinner. There was always mashed potatoes, canned vegetables, and plenty of coffee. The cooks made their home on the island and were available for yarn-telling in the lounge at night when they were not on guard duty.

Sherwood Northam was an indispensable member of the night force. He also lived in the cafeteria building, and his official job was that of night mechanic. It was his duty to get the air-storage spheres at the Preflight Jet pressurized at night and see that the heat exchanger was restored to its proper temperature in readiness for testing the following day. He was also available for any other mechanical work required at night, and operated the boats and trucks at night, if necessary.

It had been approved by Langley management that overnight visitors at Wallops could be taken by boat to the mainland after hours and be picked up on demand. This was to relieve some of the monotony of the isolated station. The only trouble with the plan, however, was that there was no place to go once the mainland was reached. Consequently, few people made use of this service. Occasionally, however, a few adventurous souls would explore the mainland area and perhaps purchase some beer. On some occasions, when Northam went to the mainland to pick up his passengers, fog would have set in and the return trip would be sometimes quite hazardous. This was particularly true at the time of some high tides when the channel and surrounding marsh were turned into a single large lake. On such rides, the visitor would wonder if his trip were really necessary.

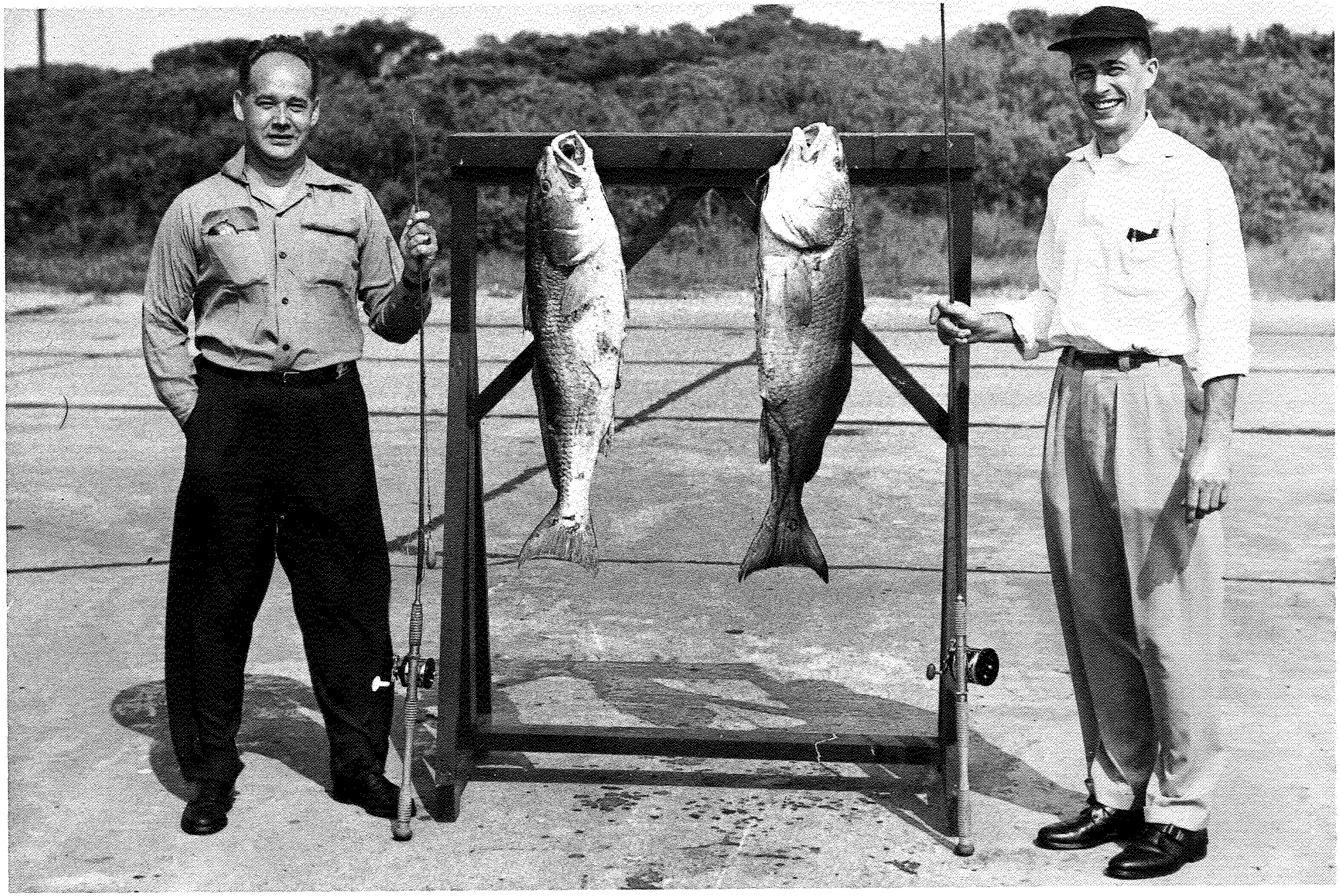


FIGURE 179. R. L. Krieger and E. D. Schult display channel bass, or drum fish, they caught off Wallops Island beach, May 1953.

FIGURE 180. Happy engineer and fisherman J. B. Lee, with channel bass he caught in surf at Wallops Island.

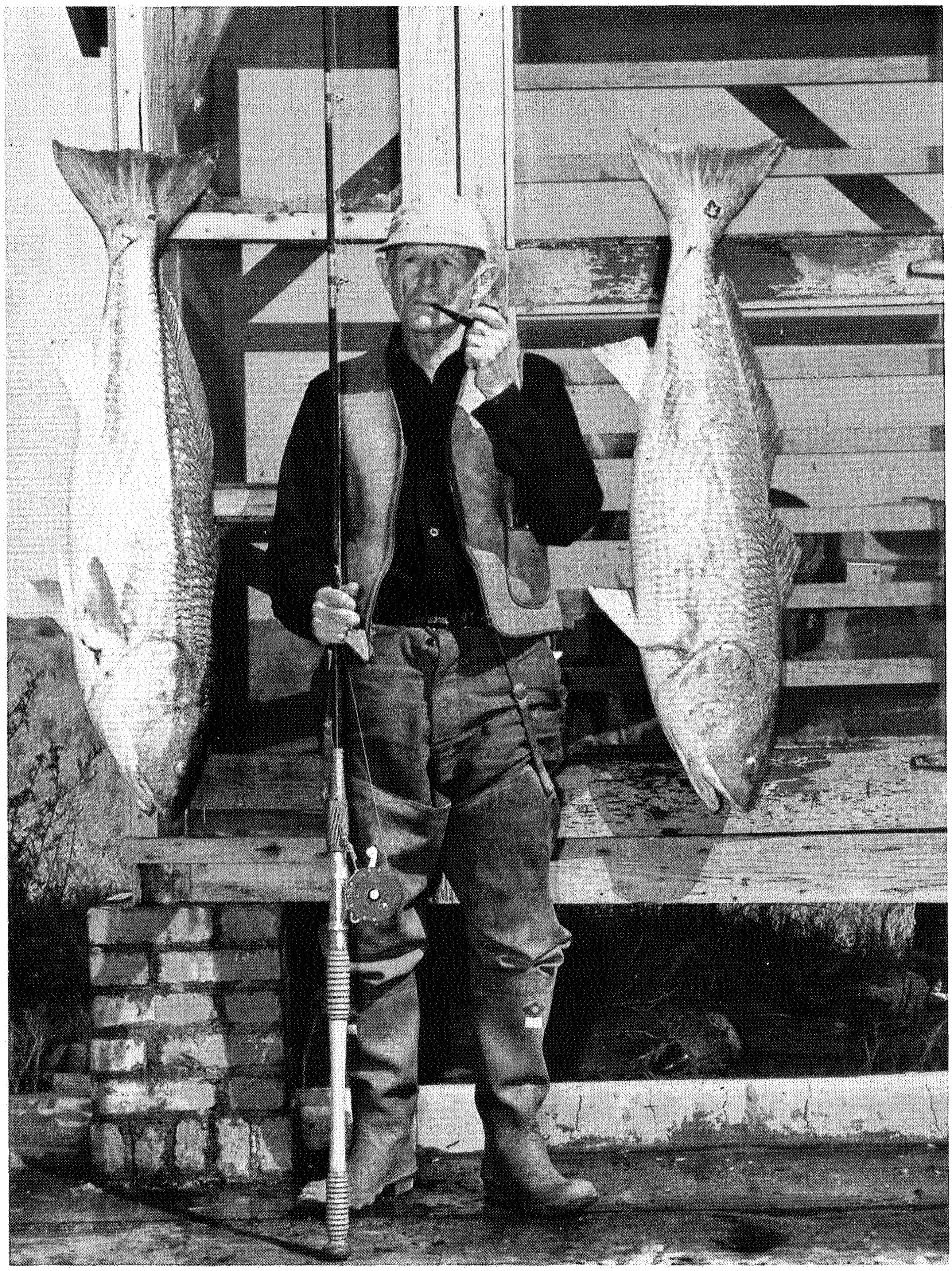


FIGURE 181. Wallops night mechanic Sherwood Mortham, with channel bass he caught in surf at Wallops Island.

Robert L. Hallett was another Wallops employee who made the island his home during the week. His home in Delaware was too far for commuting except on weekends. Hallett was the first professional employee in the launching crew at Wallops. He was thoroughly familiar with all the electronic instrumentation, although his specialty was the Doppler radar. The fine record achieved with this radar at Wallops was due to his ability and interest, and the painstaking care with which he maintained and operated it. Hallett was always available in the evenings, either in the lounge or in his room, for shop talk with visiting engineers; and he served as a tutor for young aerodynamicists from PARD in their quest for knowledge about the electronic phase of their rocket-model projects.

Despite the remoteness of Wallops, most engineers from Langley enjoyed temporary duty at the island, provided it really was temporary. Some engineers who were assigned to duty at the Preflight Jet and were required to be at Wallops several weeks in a row soon tired of the monotony and were eager to finish their project.

CRITICISM OF DELAYS IN MILITARY FLIGHT PROJECTS

In spite of the fact that specific flight projects for the military services were given high priority, the Air Force and its contractors, by 1953, were becoming critical of the length of time required to complete flight tests of rocket models. This was particularly true of the Hughes Falcon guided missile. Chapter 7 has discussed the proposal of Puckett of Hughes Aircraft Company that a PARD-type facility be constructed on the west coast to relieve the situation. The number of specific projects at Wallops had grown to 18 in 1952, with no sign of any decrease in the immediate future. Since some projects involved the launching of five or more models, a sizable backlog had accumulated by mid-1953. To make matters worse, the Air Force had assigned highest priority (1A) to six of its eight projects at PARD. The Air Force expected nothing to stand in the way of a 1A project. At the request of NACA Headquarters, J. A. Shortal made an analysis of the situation which was reported to Headquarters on August 31, 1953.[11]

It was found in the appraisal that the two major sources of delay were (1) the many months frequently spent in correcting inadequate construction, or revising the design in Langley shops; and (2) the lengthy time required to install instrumentation in the models.

To reduce the first source of delay, or at least to eliminate Langley as the cause of the delay, Langley management directed that all modifications to models were the responsibility of the contractor, who could either send men to Langley to perform the work, or have the model returned to his facility for correction. This directive was effective in reducing the number of such corrections. The only solution to the second problem at the time was increased effort by IRD on specific models. Any suggestion that such work be performed by outside contract was always met with a cold shoulder by IRD personnel. No outside firm was acquainted with the special NACA telemeter, and commercially available telemeters were far less accurate than the hand-tailored IRD system. The general research models were delayed in favor of specific models, although some relief was obtained by increasing the manpower assigned to the task. This type of research item was not suited for mass production.

The excessive backlog was finally eliminated by 1954, but it required a continuing effort to keep the models on an acceptable time schedule.

CONVAIR B–58 HUSTLER SUPERSONIC BOMBER

As a follow-on to the Boeing B-52 bomber, the Air Force held a competition for a supersonic bomber design having Mach 1.7 capabilities. The two major contenders were Convair (Fort Worth) and Boeing. Convair, with its MX-1626 design, won out over the Boeing MX-1712 proposal. The Air Force

11. Letter from Langley to NACA Headquarters, August 31, 1953, regarding progress on PARD programs for specific configurations.

requested rocket-model tests of both designs at Wallops. The Boeing models followed those of Convair, and will be discussed in a later chapter.

On July 30, 1951, the Air Force requested tests of 1/10-scale models of the Convair MX-1626, and NACA Headquarters issued RA A73L75 on September 17, 1951, to cover the program. The request was for the determination of drag, pod separation, stability, control, and buffet characteristics to Mach 2. At first, Convair was hesitant to become involved in a rocket-model program when they learned that such a program might require a year or more. Their representatives insisted that if they did not obtain the results within 6 months, the information would be of little value. Eventually, however, a program was agreed upon, and it is interesting to note that it extended over a 4-year period, mainly because of a radical redesign dictated by early results of the rocket-model program.

The MX-1626 design, which eventually became the B-58 Hustler, was the Air Force's first supersonic bomber. The unique performance requirements for the airplane led Convair to propose an unusual configuration. The fuselage was made in two sections, split along the horizontal centerline. Somewhat more than half of the fuselage made up the lower section, which was called a "pod" and which contained extra fuel required for the long-range mission. Upon approaching the target area, the airplane was to drop the pod and return home in the "clean" condition. The airplane had a 65-degree delta wing of 4-percent thickness, and was designed to be powered by two large jet engines contained within large outboard nacelles.

The 1/10-scale rocket models were 90 inches long and had a span of about 57 inches. This size of model was in the same class as the large E17 general research drag models, which were first discussed in Chapter 6, and which were powered by an internally mounted Deacon rocket motor. The MX-1626 design prevented the use of this type of propulsion, so a unique booster was developed. Figure 182 shows one of the models with the booster immediately after launch at Wallops. The booster consisted of two Deacon motors side by side but separated by about 12 inches. The model was placed upon the booster with the fuselage lying between the two motors. Thrust was transmitted to the model through horns extending into the lower surface of the wing, while stability of the system was provided by four small fins attached to a welded magnesium boxlike coupling at the rear of the booster assembly. Each Deacon had a canted nozzle designed for the thrust to pass through the center of gravity of the entire combination at takeoff. A small divergence flap on the outboard side of each motor assured that the booster would separate downward from the model at burnout of the motors. This was one of several "piggyback" or underslung booster systems to be used at Wallops.

Because of the urgency of the program, the first attempted flight was made with a complete and fully instrumented model. The attempt was made on July 8, 1952, with disastrous results. The rocket motor nozzles had been aligned improperly and, as described by John C. Palmer in the Wallops Daily Log, "apparently the twin Deacons fired normally, but as the model booster combination started to leave the launcher the nose of the combination dropped rapidly and the model booster combination executed three outside loops right in front of the launching area and hit the beach on the third loop which broke up the combination and parts went in all directions. The loops were an extremely tight maneuver, the combination probably not reaching an altitude of fifty feet."

Red-faced engineers from PARD rushed back to Langley and constructed a dummy model around some of the larger pieces, launching it successfully in less than a month—on August 6, 1952. This time, a special rig was used to assure proper alignment of the rocket nozzles. The model-booster combination was hung by its heels as a pendulum, and the nozzles were rotated until their axes passed through the vertical center of gravity as indicated by proper alignment of the main hangar rod with arbors inserted in each nozzle.

After the dummy test, successful tests of two instrumented models followed in rapid succession, on September 11, 1952, and October 30, 1952. One model was complete, while the other had its nacelles removed. Ten-channel telemeters transmitted data on longitudinal, lateral, and normal accelerations, pod and nacelle base pressures, and total and static pressure. Six pulse rockets, providing 60 pounds of thrust for 0.10 second, were located in the sides of the fuselage to disturb the model in flight at times controlled by time-delay squibs. Although these pulse rockets were positioned to impart a lateral

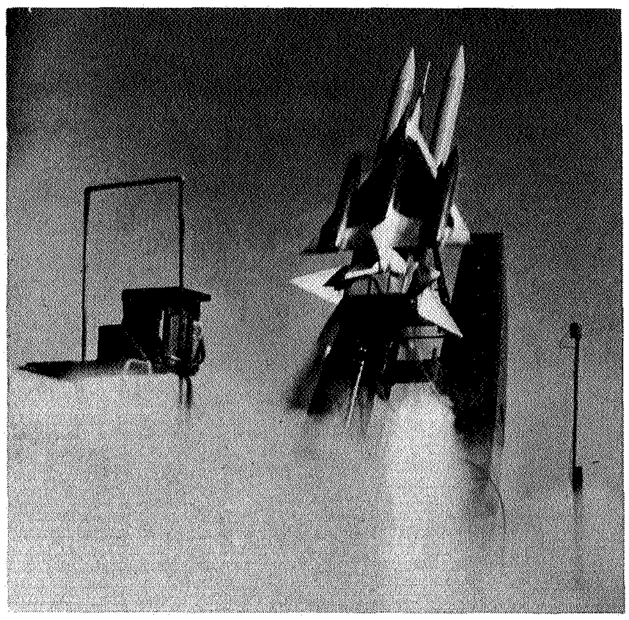


FIGURE 182. Launch of Convair MX–1626 model with underslung double Deacon booster at Wallops, October 30, 1952.

disturbance, their exhaust jets created a pressure field under the wing which caused substantial disturbances in pitch as well (ref. 12). Data were obtained, therefore, on directional and longitudinal stability as well as drag.

The drag measurements of the complete model were very upsetting to both the Air Force and Convair representatives. The peak drag coefficient at Mach 1.02, for example, was almost twice as high as that predicted. Convair representatives at first questioned the accuracy of the rocket-model data, but after a test of one of the same models in the Langley 16-foot Transonic Tunnel showed about the same drag rise, they conceded that the rocket-model data must be correct. In fact, the overall agreement between the rocket-model and tunnel tests of the same configuration was excellent.

An evaluation of the longitudinal area distribution of the configuration in accordance with the area rule of R. T. Whitcomb, along with tests of an equivalent body in the Helium Gun at Wallops, provided an explanation for the large additional drag. The results of the evaluation are given in figure 183. This figure shows not only the original MX-1626 configuration but also subsequent modifications. Figure 183(a) shows the original configuration planform, the longitudinal distribution of the cross-sectional area of the major components, and the drag coefficients measured with the body of revolution in the Helium Gun. Note how the wing, nacelles, and wheel fairings all added area to the maximum area of the fuselage and pod, creating a large total cross-sectional area. Note also the steep slopes in the total area curve that resulted from this placing of the components.

At about this time, independent changes were made in the full-scale airplane design which caused the drag rise to be even higher than that shown for the original configuration. The 65-degree delta wing of 4.0-percent thickness and an area of 1,200 square feet was changed to a 60-degree delta wing of 4.5-percent thickness and an area of 1,400 square feet; and the two large nacelles were replaced by four nacelles, in siamese pairs. The fuselage was lengthened from 900 inches to 1,051 inches, and the pod was modified in shape and size and was equipped with small delta wings, a canard fin, and vertical tails. The Air Force project number for the airplane was changed at this time from MX-1626 to MX-1964. The above changes resulted from unavailability of the originally planned large jet engines, and from changes in the function of the pod. The pod was now to be a complete air-to-ground missile system, even to be equipped with auxiliary propulsion. A 1/10-scale model of the MX-1964 design was flown on March 20, 1953, on the piggyback booster, but, unfortunately, a failure of the booster fins ended the flight.

It was concluded that the failure of the booster fins at burnout of the rocket motors resulted from the center of gravity of the combinations being too high above the thrust line of the canted nozzles at that time. An excessive angle of attack was induced, which led to the structural failure. The need for some intermediate cant angle at launch was indicated.

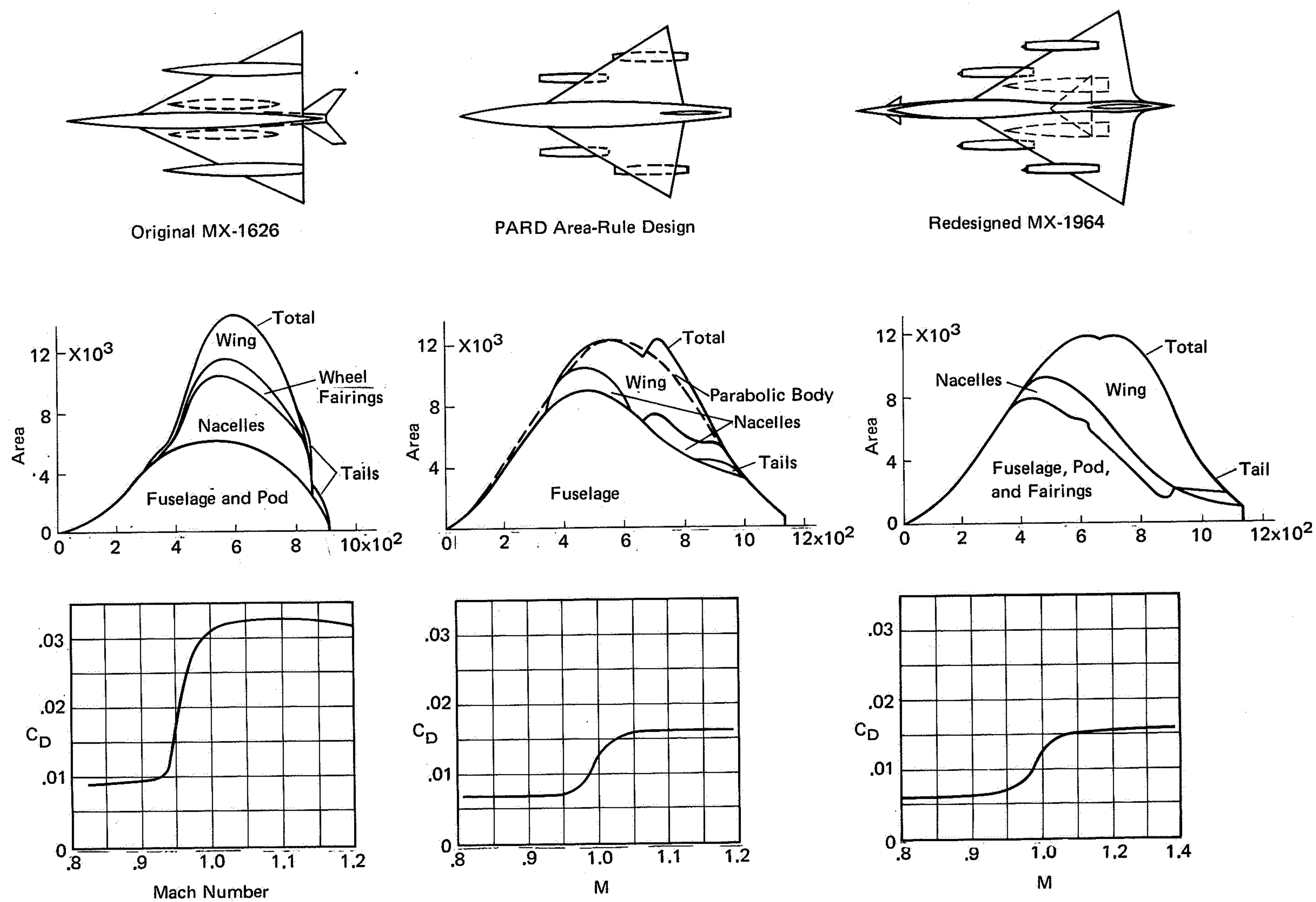


FIGURE 183. Graphs of data from flight tests of Convair B–58 supersonic bomber models, showing effect of area-rule redesign on area distribution and drag of equivalent bodies of revolution.

To add to the troubles with the B-58 program, the large rocket model used in the tunnel tests caught fire and burned while being modified in the Langley West Model Shop. Apparently a spark ignited magnesium chips during a machining operation.

PARD researchers R. N. Hopko, R. O. Piland, and J. R. Hall set out to find what a configuration designed by the area rule, and yet fulfilling the general requirements of the new MX-1964, would look like and what its drag rise would be. They started with a 3-percent-thick, 60-degree delta wing, modified by a 10-degree sweptforward trailing edge to form a sort of diamond planform, to provide a more gradual transition in the area progression. To this wing they added four separate nacelles staggered chordwise, and made the fuselage a body of revolution with an indentation to make the total area distribution of the configuration nearly identical to that of a good parabolic body. This design is shown in figure 183(b). The internal volume of this new design was made 60 percent larger than that of the MX-1964.

A 1/15-scale rocket model of the PARD design was constructed in the Langley shops and launched at Wallops with a single tandem Deacon booster on January 22, 1953, as shown in figure 184. The size of the model and the booster system were the same as those used in a new series of drag research models designated E25, to be discussed later in this chapter. This was the first complete airplane model designed by the area rule to be flown at Wallops. A Helium Gun model was also flown. Both tests showed a drag rise coefficient of only 0.010, less than half the original value for the MX-1626. These results were included in the first report on the B-58 model and were also published as a separate general report (ref. 13).

These data were shown Air Force and Convair representatives at a joint conference at Langley. The Air Force insisted that Convair give serious consideration to a redesign of the MX-1964 by the area rule, and Langley agreed to test corresponding equivalent bodies of revolution in the Helium Gun. Four such new Convair designs were tested. It was found that when the basic design was changed to provide a smooth area progression with minimum cross-sectional area, the drag rise was as low as that found in the PARD general E25 design (ref. 14). This is illustrated by the configuration in figure 183(c), with which Convair was able to do a somewhat better job at providing a smooth area distribution than had the PARD researchers. Convair engineers, in fact, became quite enthusiastic about these area-rule findings and extended their analyses to various supersonic Mach numbers as well as Mach 1.

The dramatic results achieved by the rearrangement of components for a given airplane provided an impressive illustration of the effectiveness of the Whitcomb area rule for which Whitcomb was awarded the Collier Trophy in 1954, the NACA Distinguished Service Medal in 1956, and the Arthur Fleming Award in 1956 (ref. 15). The indented fuselage was referred to as a "coke-bottle" or "wasp-waist," and sometimes as a "Marilyn Monroe" design.

The full-scale airplane was redesigned along these lines and several 1/15-scale models were flown at Wallops. One of the models of the redesigned airplane with the smaller pod missile is shown in figure 185. The flight of this model on October 22, 1954, was a failure, as was an earlier one in November 1953. A successful flight was finally made to a Mach number of 2 on December 14, 1955, with a Nike booster, as shown in figure 186. The revised B-58 model had four staggered nacelles beneath the wing, and an area-rule fuselage designed for Mach 2. Leading-edge camber was added to the wing to improve its drag characteristics under lifting conditions. The complete configuration, including the pod missile, was found to have a drag coefficient of 0.028 at Mach 2. The rocket-model results were in good agreement with wind-tunnel results under similar conditions (ref. 16). The full-scale airplane was first flown on November 11, 1956, and became the world's fastest nuclear bomber, exceeding Mach 2 in September 1957. The maximum speed was limited by aerodynamic heating of the structure rather than by drag.

The Air Force asked the NACA to assist in development of the B-58 pod missile by flight testing 1/7-scale rocket models of it, and RA A73L132 was issued by the NACA on May 25, 1954, to cover this phase of the investigation. Two models of the pod were flown in 1954 to investigate the drag, and one model was flown in 1956 with the canard control pulsed to measure control effectiveness and stability.

One of the drag models was propelled to a Mach number of 1.5 by a double Deacon booster; the second model had a Nike booster, shown in figure 187, to provide data to a Mach number of 2.5. The measured drag results were in good agreement with estimated values (ref. 17). The stability model was flown to a Mach number of 2.58 with a Nike booster. Extensive control and stability information was obtained (ref. 18).

Although the B-58 rocket-model program was beset with many difficulties, it culminated in development of a configuration which, through the cooperative efforts of Convair, the Air Force, and the NACA, met or exceeded its design objectives. In fact, the maximum specified speed of Mach 1.7 was exceeded by a good margin. The top speed of Mach 2.1 that was reached in flight was limited not by drag but by structural temperature. This was a considerable improvement over the original design, which probably could not have passed Mach 1.

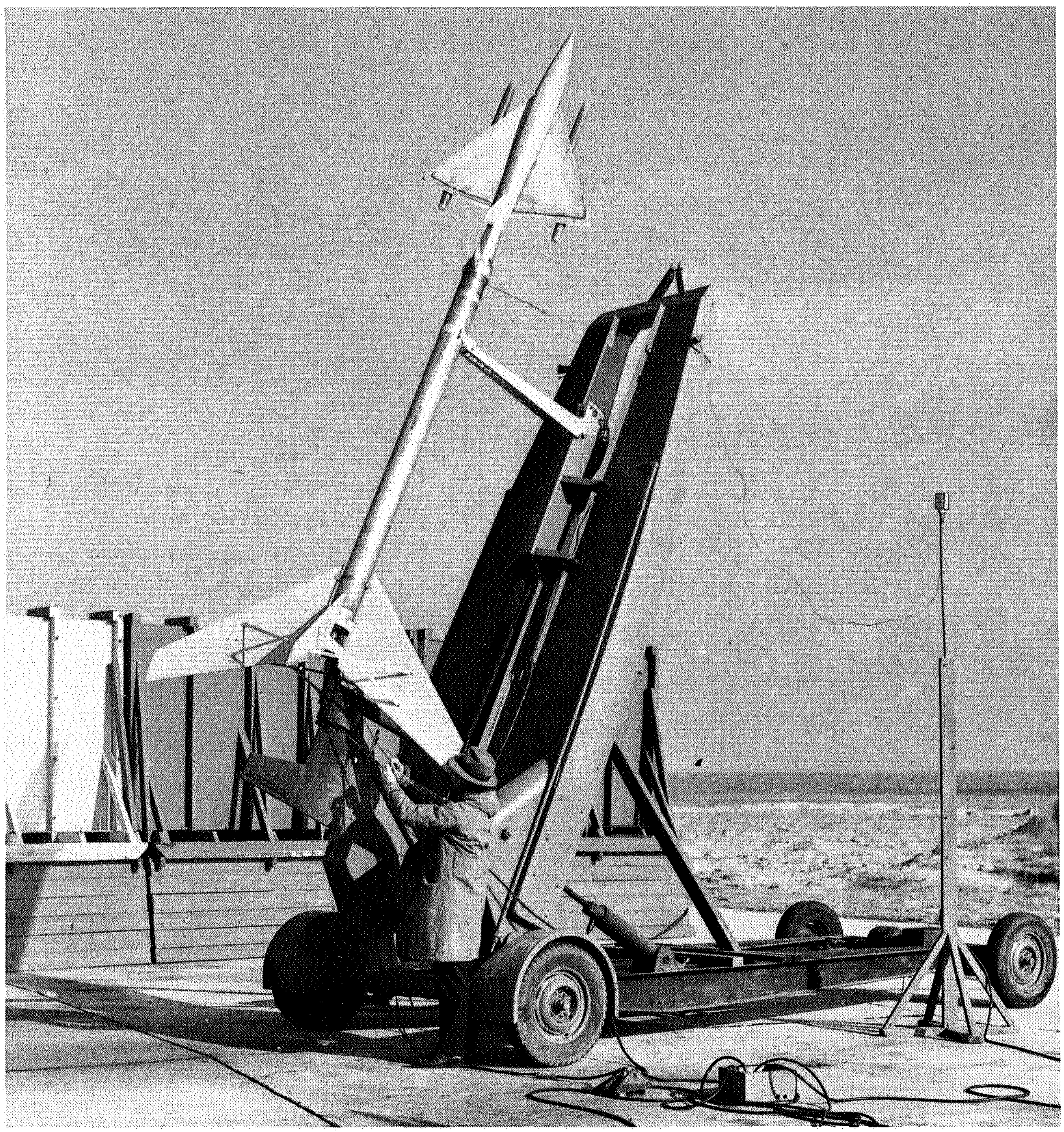


FIGURE 184. Engineer John C. Palmer connects firing leads to Deacon booster for bomber model designed by the area rule. Model is shown on its launcher, January 22, 1953.

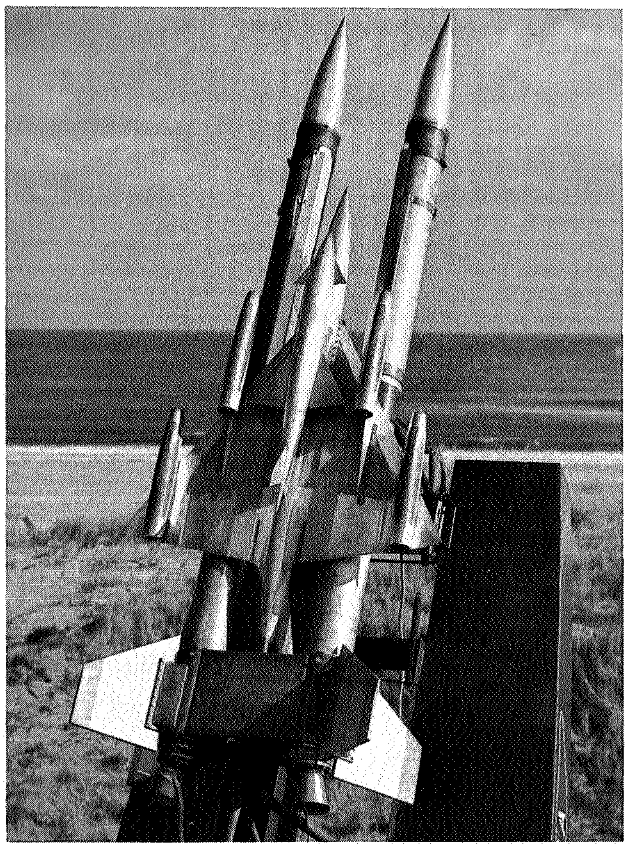


FIGURE 185. Model of redesigned Convair B–58 bomber mounted in inverted position on an underslung double Deacon booster. Model is shown on launcher at Wallops, October 22, 1954.

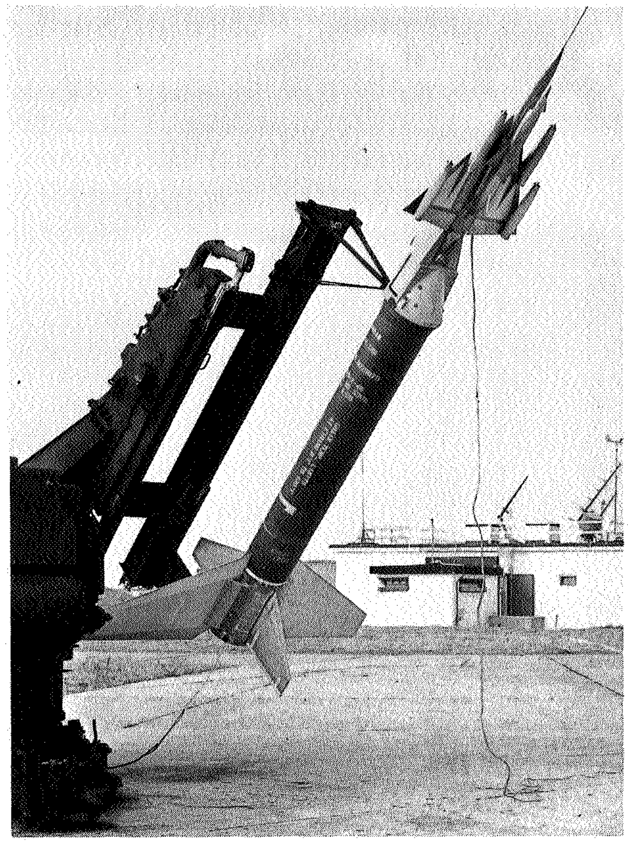


FIGURE 186. View of 1/15-scale model of Convair B–58 bomber with Nike booster, December 14, 1955.

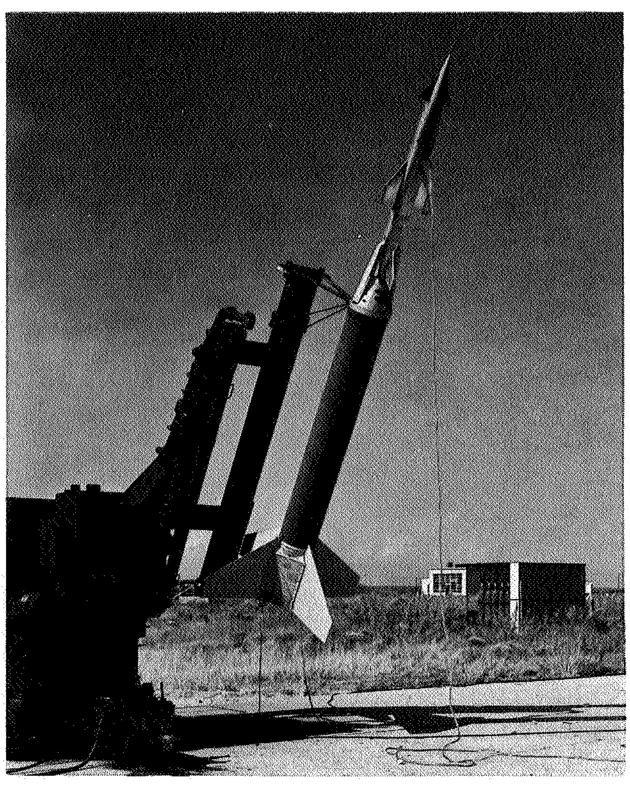


FIGURE 187. View of 1/7-scale model of Convair B–58 bomber pod with Nike booster, October 3, 1956.

NORTH AMERICAN NAVAHO GUIDED MISSILE

The Air Force's North American Navaho guided missile (designated SM-64 and later B-64) was a long-range ground-to-ground supersonic missile intended as a follow-on to the subsonic Snark. It was initiated at about the same time (1946) as the Snark and the Rascal. Although the Navaho achieved its objectives in prototype tests, it never reached deployment stage because by that time ballistic missiles were nearing a state of readiness. The Navaho was canceled in July 1957, but the development yielded great dividends from its guidance system and from its underslung booster whose liquid-rocket engine was to be used extensively in the ballistic missile program.

The full-scale Navaho program had two phases: a low-speed phase and the final supersonic phase. The final phase was powered by two ramjet engines in the missile, in addition to the single underslung booster mentioned earlier. Pending development of the ramjet engines and the large booster, flight tests were made of the low-speed Navaho configuration, which was powered with two turbojet engines and was designated X-10. Flights of the X-10 were made from Edwards Air Force Base, California.

In November 1947, North American asked the NACA for wind-tunnel assistance in developing a configuration having satisfactory stability over a Mach number range of 0 to 6.[12] By February 1950, a configuration had been decided upon, and Dale Myers, project aerodynamicist for North American, visited Langley and discussed the need for a rocket-model program. A series of six 1/10-scale models, to contain an internal HVAR motor and be boosted by a single Deacon, was agreed upon (ref. 19). Following official request from the Air Force on January 12, 1951, the NACA issued RA A73L54 on February 9, 1951, to cover the investigation.

The fuselage of the Navaho missile had the NACA RM-10 shape, the wings were of delta planform, and two large nacelles at the wing-fuselage juncture housed the powerplant. A delta canard fin was located well forward for longitudinal control, and twin vertical tails provided directional stability.

During preparations for the rocket-model program, the internal rocket motor was eliminated because of lack of room, and double Deacon boosters were proposed. A dummy model was flown successfully on March 19, 1952, and a complete, instrumented model was flown on May 22, 1952. This was a 0.12-scale model of the X-10 turbojet version of the Navaho. The canard controls were pulsed in a square wave pattern to provide data on longitudinal stability as well as drag. The model is shown in figure 188. This test was very successful and provided much-needed data to a Mach number of 1.7 (ref. 20). Good agreement with previous wind-tunnel data was obtained. The next flight, attempted on October 31, 1952, was a dismal failure. For some inexplainable reason, the model fell off the booster at ignition and landed on the pad right in front of the launcher. This ended the low-speed phase of the rocket-model program.

Concurrently with conducting the Navaho rocket-model program, PARD had become interested in the Terrier or Nike booster motor to replace multiple Deacon boosters and provide higher speeds (as discussed earlier in this chapter). Following completion of the first phase of the Navaho program, North American representatives expressed interest in obtaining similar data at higher speeds for the second phase of the program. Changing the booster to a Nike seemed to be the answer.

In January 1953, the NACA asked the Chief of BuOrd to furnish four 2.5DS-59000 rocket units, to be prepared from used metal chambers for use in the MX-770 tests.[13] These were the first Terrier or Nike motors to be obtained at Wallops. The motor had a diameter of 11 inches, was 134 inches long, and provided 45,000 pounds of thrust for 3.1 seconds. It weighed 1,180 pounds and contained 740 pounds of double-base propellant with internal burning, for a propellant-mass fraction of 0.63. Like the Deacon, these motors were developed by Allegany Ballistics Laboratory under the direction of Navy BuOrd. A full-scale dummy model was prepared with one of these boosters and was launched from the newly acquired dual Terrier launcher on October 23, 1953. (See figure 189.) Since this was the

12. Letter from L. L. Waite, North American, to NACA Headquarters, November 20, 1947, regarding need for wind-tunnel assistance on MX-770 missile.
13. Letter from the NACA to M. J. Schoeffel, Chief BuOrd, January 5, 1953, regarding rocket units for MX-770 tests.

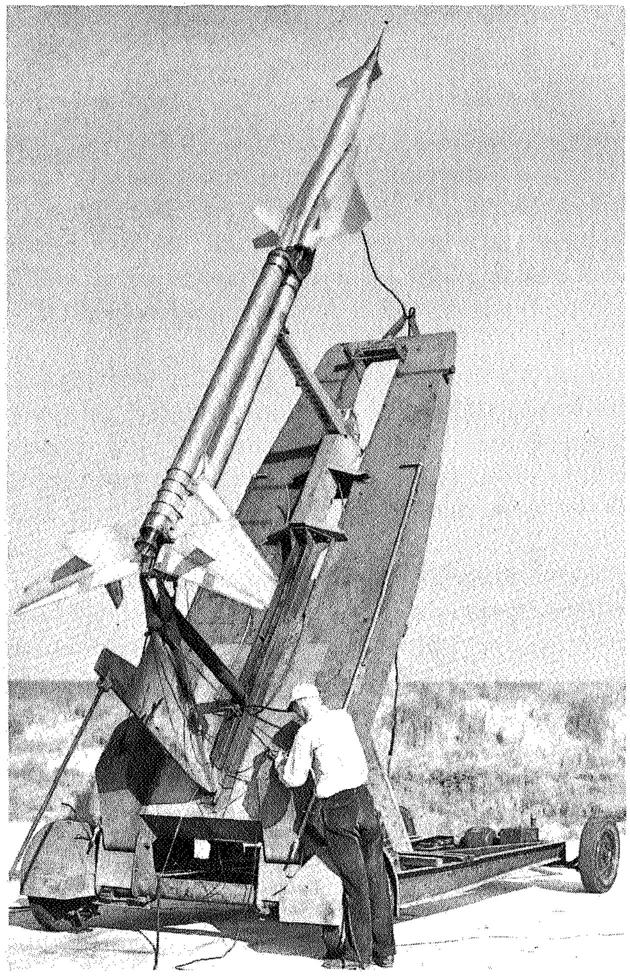


FIGURE 188. Technician Durwood Dereng connects firing leads to double Deacon booster for North American Navaho model, May 22, 1952.

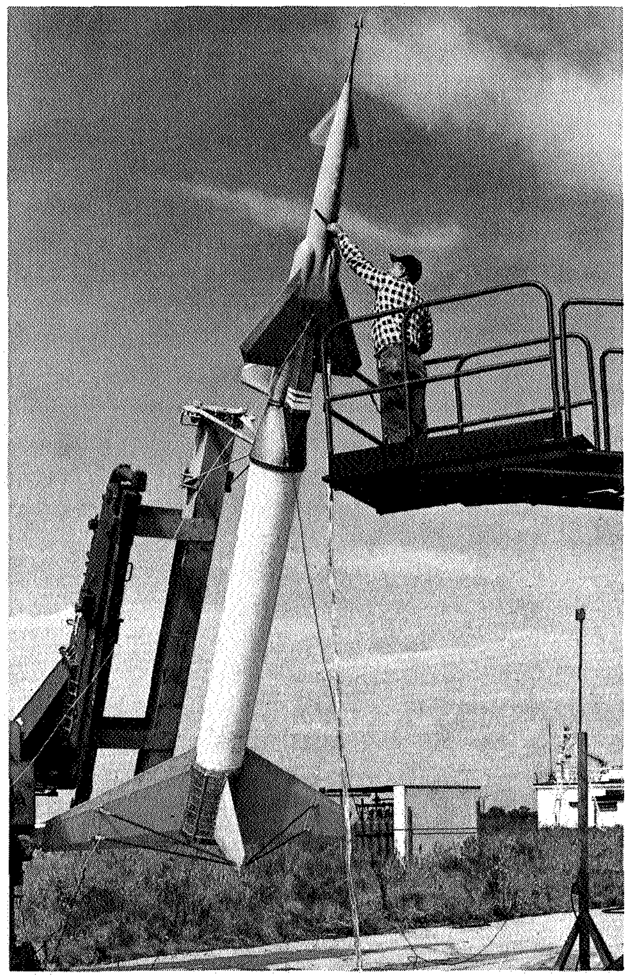


FIGURE 189. Technician Ed Matthews installs external-power plug in model of North American Navaho missile, shown on October 23, 1953, with first Nike booster used at Wallops.

first Nike booster to be launched at Wallops, some apprehension from a safety standpoint was felt about the pressure field and blast effects to be expected from this large motor. For safety, no personnel were allowed closer than 350 feet. The operation at launch went smoothly, as shown in figure 190, but 2 seconds after launching, the dummy model broke off from the booster, and the test was a failure.

A repeat test with a "boilerplate" dummy on February 3, 1954, was quite successful, and everything seemed to be in readiness for a series of high-speed tests with actual models. This was not to be—three attempts with complete models, made between March 1954 and September 1955, were all failures. In every case, the model broke off from the booster or broke up between 2 and 3 seconds after launch. The most logical explanation was aeroelastic divergence. The models simply were not designed to be boosted to speeds above Mach 2.

McDONNELL XF3H-1 AIRPLANE PROGRAM

A diversified and yet very successful series of rocket models was launched at Wallops for Navy BuAer to assist in development of the McDonnell XF3H-1 Demon shipboard fighter. Four complete models were tested, two to obtain dynamic response of the models to the action of extensible rocket racks, and two to obtain dynamic stability and control characteristics of modified versions of the airplane. A special F26-type wingless inlet model was tested, first in the Preflight Jet, for calibration, and then in flight. Four E5-type models with scaled wings and lateral controls were tested with different stiffnesses. Finally two D18-type flutter models were tested with scaled wing panels. All of the tests were successful.

The XF3H-1 airplane was the first of a series of airplane designs of McDonnell Aircraft Corporation that incorporated sweptback wings, twin side inlets, and a tail arrangement in which the vertical

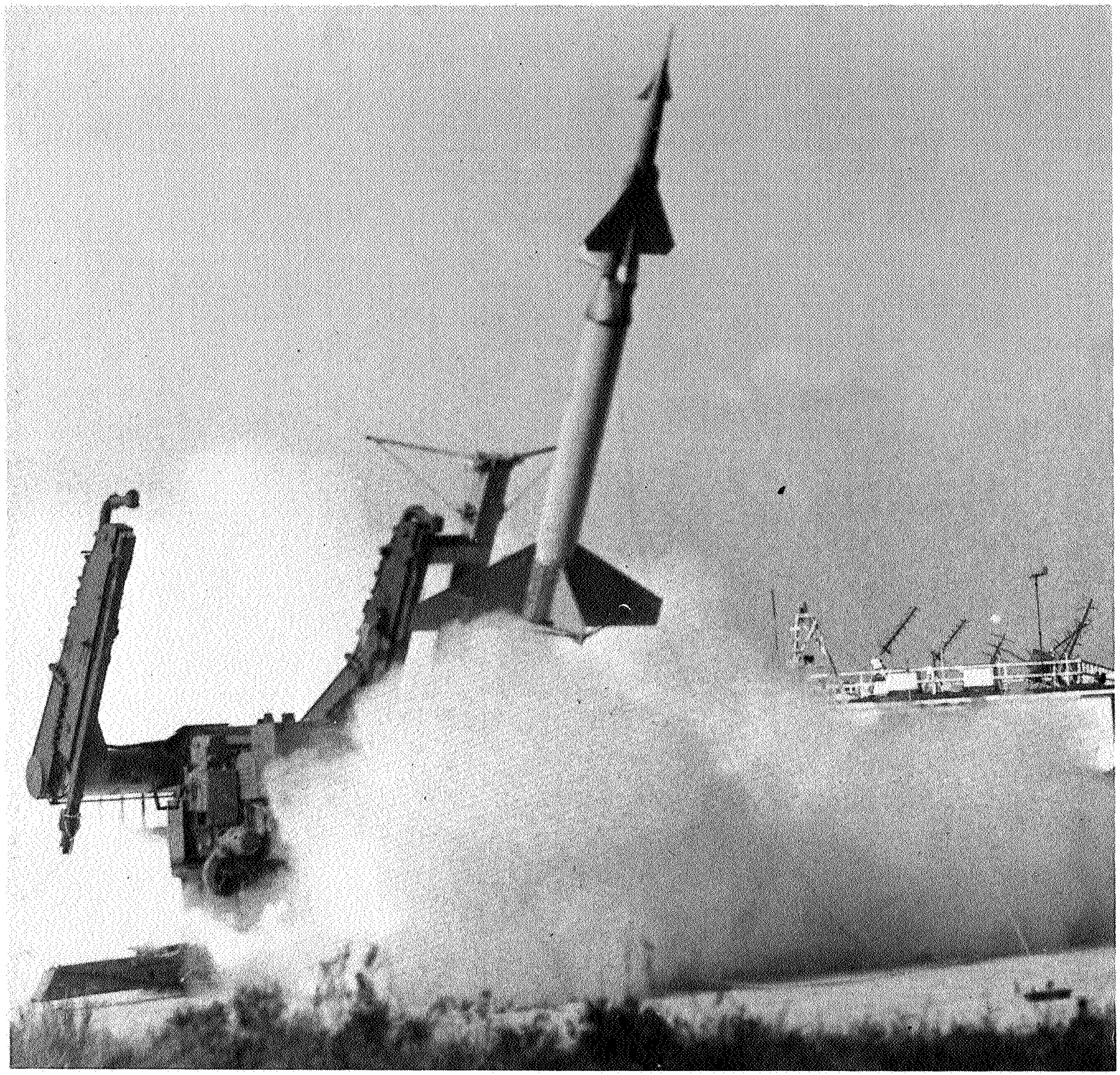


FIGURE 190. Launch of North American Navaho model with Nike booster, October 23, 1953.

and horizontal surfaces were mounted above the engine exhaust on a boom-type extension of the fuselage. Although the Demon did not see extensive service use, its development contributed to later airplanes of the same general type. One of the factors contributing to its lack of appeal probably was a result of its relatively thick wing, which varied from 9-percent thickness at the root to 7-percent at the wing tip.

The program of complete models was approved by NACA Headquarters on January 16, 1951, and RA A21L80 was issued to cover this phase. The models were 1/10-scale, weighed about 120 pounds, and were boosted to approximately Mach 1.4 by single Deacon boosters. Figure 191 shows one of these models on the mobile launcher at Wallops. Because of the unusual design of the fuselage and tail, a special shovel-type adapter was necessary to support the model on the front end of the booster motor.

The first two models were equipped with a hydraulically operated pulse system that extended and retracted the rocket racks from the bottom of the fuselage in a square wave pattern. The first flight test was made on March 5, 1952, and the second on June 10, 1953. A 10-channel telemeter was used in each case. The tests showed only minor effects from the extension of the rocket racks, but a pitch-up condition at high subsonic speeds was encountered, and some buffeting was observed (refs. 21 and 22).

FIGURE 191. Technicians Durwood Dereng and Roy Hindle make final preparations for launch of model of McDonnell XF3H–1 airplane model with Deacon booster, June 10, 1953.

The remaining two complete models were flight tested in 1955. They had been modified by removal of the extensible rocket racks, and by replacement of the wing, first, with one corresponding to that of the F3H-1N airplane, and then, with one like that of the F3H-2N airplane. A further modification consisted of adding a mechanism in the tail to pulse it as in the E15 general research program. The F3H-2N wing was thinner than the earlier wings. Data were provided by both models on longitudinal stability, lift, and buffeting at high angles of attack for these night and all-weather versions of the Demon (refs. 23 and 24).

The investigation of inlet performance of the XF3H-1 design was requested by BuAer on January 23, 1950, and was approved by NACA Headquarters by issuance of RA 1560 on February 9, 1950. The same personnel and techniques were used in this phase of the program as were used in the F26 general research program on inlets.

The XF3H-1 design afforded the researchers an opportunity to study a twin side-inlet arrangement. Side inlets were of interest because they decreased the distance between the inlet and the engine and left the nose of the airplane available for other uses. The boundary layer that built up along the fuselage ahead of the inlet, however, was known to be a potential source of energy loss. Inasmuch as the XF3H-1 inlets had no provision for removal of this layer, the test program evolved mainly into a determination of the losses associated with this factor over the transonic speed range.

The inlet model was essentially a standard F26 inlet-research model with the forebody a 1/7-scale model of the fuselage of the XF3H-1 airplane from its nose to a point behind the inlets. The inlets were led through a diffusion chamber into a duct exhausting at the rear. The duct contained a rotating shutter with which the mass flow was varied. Tests were made in the Wallops 27-inch nozzle of the Preflight Jet at a Mach number of 1.55, and also at a subsonic value of 0.7. The tests showed that, whereas the inlet had a pressure recovery of 0.94 at high subsonic speeds, the value dropped to an average value of only 0.70 at Mach 1.55. In addition, at the supersonic speed, extreme high-frequency oscillations in pressure were encountered. The oscillations were associated with unsteady flow, varying from an attached shock to separated flow. The pressure recovery near the fuselage was only 0.50, due to boundary-layer shock interaction (ref. 25).

Flight tests of the same model over a Mach number range of 0.80 to 1.45 verified the Preflight Jet results and, in addition, showed that the unsteady flow had a large effect on total drag as well as upon internal pressures. The need for changes in the design of the inlet were, therefore, clearly indicated (ref. 26).

Flight tests of rocket models to evaluate lateral control characteristics of the XF3H-1 airplane were also authorized by RA 1560. Scaled wings of the airplane were mounted on the standard E5 lateral control research body with fixed control deflections, and the standard E5 flight technique was employed. Two series of flight tests were made. In the first, three-panel E5 models were used in making an evaluation of the rolling effectiveness of a combination of an outboard aileron and an inboard spoiler (ref. 27). Later, another series of tests was made after the aileron-spoiler combination had been replaced by a midspan aileron design. In the latter tests, a two-panel wing with a four-fin free-to-roll stabilizing tail was used instead of the standard three-panel arrangement (ref. 28). Wings of different stiffnesses were flown in both series of tests to allow an evaluation of rolling characteristics of the actual airplane. With the first control design, the spoiler was the only part of the control that was effective at transonic speeds. The outboard aileron exhibited control reversal at Mach 1.0 due to aeroelastic effects. The revised design was considerably better, and while it suffered severe transonic aeroelastic losses at sea level, such losses at an altitude of 35,000 feet were considerably reduced.

The flutter characteristics of the wings of the XF3H-1 airplane were investigated by tests of two D18-type models flown at Wallops. The wings were scaled to represent the mass and stiffness of the wings of the full-scale airplane. On one of the models, a new technique was employed for evaluating wing damping at high frequency. Six small lead slugs were explosively fired at prearranged times after booster separation, during the period of low acceleration from a Mach number of 0.9 to 1.3. These slugs excited the bending mode of each wing and enabled an evaluation of damping. This technique was of value in assessing the susceptibility to flutter for cases in which flutter did not naturally occur. No flutter was encountered in the present tests (ref. 29).

NAVY BUAER GRUMMAN RIGEL FLUTTER TEST

The Rigel, a ground-to-ground long-range ramjet guided missile, was under development by Grumman Aircraft Engineering Corporation for the Navy's Bureau of Aeronautics. The ramjet engines on the missile were mounted on the tips of short, unswept wings. In order to provide an assessment of the validity of the methods used in the calculations of flutter for the ramjet and wing in combination, BuAer requested the NACA to conduct rocket-model tests on a dynamically scaled model. The request was made on December 27, 1951, and approved on January 30, 1952, with the issuing of RA C32L22. Three models were flown successfully between April and November, 1952, in a program conducted jointly by PARD and the Dynamic Loads Division.

A new test vehicle was needed for the Rigel test because a Mach number of 2 was desired. This new high-speed flutter research vehicle was designated D37 and is shown in figure 192 with the Rigel ramjets and wing ready for test. The test model was constructed with a Cordite rocket motor serving as the fuselage as well as the second stage. A nose section contained the telemeter, and the test wings were attached at the rear. Wiring from the wings was led to the telemeter through tubes strapped to the sides of the motor. A single Deacon booster accelerated the model to Mach 1.5, and the slower burning Cordite carried the model to Mach 2.0. For the sake of a conservative approach, the scaled wings were made less stiff than those of the full-scale design. In the flight tests, no evidence of flutter was found, providing assurance that the full-scale design would be flutter free (ref. 30).

NAVY BUORD EASTMAN KODAK DOVE GUIDED MISSILE

The Dove guided missile was a 1,000-pound bomb with control and guidance systems added; and its mission was high-altitude precision bombing. The missile was essentially a further development of the AZON bomb used in World War II. Eastman Kodak was the prime contractor for the Navy Bureau of Ordnance. Roll stabilization was provided by an AZON autopilot operating ailerons on the four tail fins. Pitch and yaw stabilization and flight-path control were obtained through an active guidance system in the nose operating four vanes or spoilers that could be projected forward from the nose. The vanes were approximate quarter-arcs of a circle.

Simulator studies of the guidance system were being carried out at the National Bureau of Standards, and flight development tests were being performed by NAOTS, Chincoteaque, at its Bullseye target in Chesapeake Bay. On August 21, 1950, BuOrd requested the NACA to obtain aerodynamic stability derivatives for use in the simulator study by dropping three instrumented bombs at Wallops. The NACA approved the request and issued RA 1584 on November 24, 1950. This RA was later changed to A21L88. BuOrd supplied the bombs and control system, while Langley was responsible for the instrumentation, testing, and analysis of flight data. The bombs were prepared at Langley and calibrated under the environmental conditions of the flight tests, including tests in a coldbox at −60° F. PARD had prime responsibility and was assisted by IRD and the Flight Research Division. The bombs were dropped at the Wallops range from the North American XF-82 airplane normally used for this type of test at Langley. One of the bombs is shown in figure 193.

Three Dove missiles were dropped from an altitude of 36,000 feet, the first on July 19, 1951, and the last on September 12, 1952. Good data were obtained in two of the tests. The tests were arranged to determine the effectiveness of the roll-stabilization system under the conditions of combined pitch and yaw attitudes obtained by simultaneous projections of the pitch and yaw vanes in the nose. The transient response of the missile in pitch and yaw to a series of programmed in-and-out movements of the nose vanes was measured and telemetered to ground stations as the missile traveled along its trajectory and accelerated from Mach 0.5 to nearly 1.0. These data were analyzed to yield the required stability derivatives for use in the simulator studies (ref. 31).

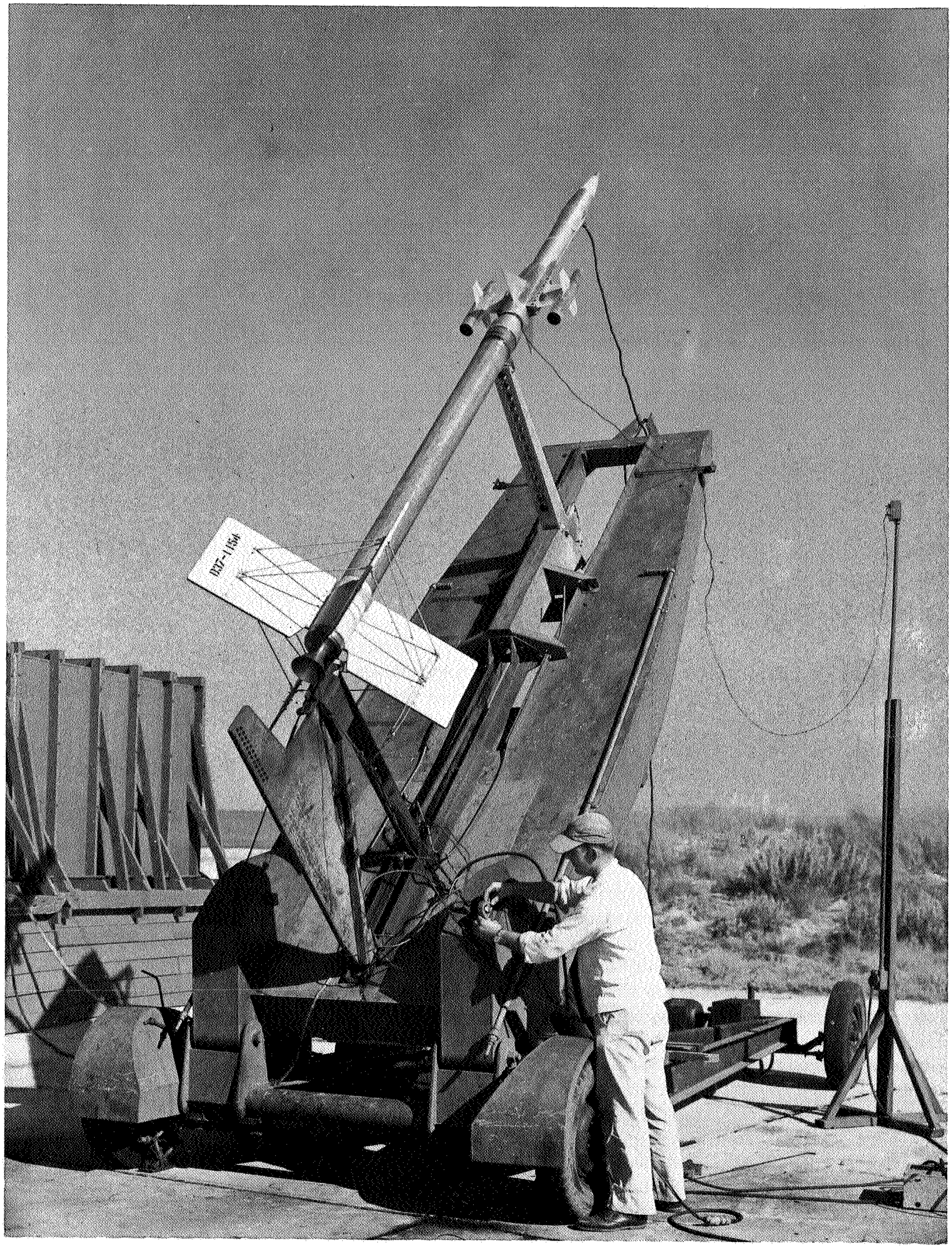


FIGURE 192. Technician George Cutler measures elevation angle of launcher for test of Grumman Rigel flutter model, September 5, 1952.

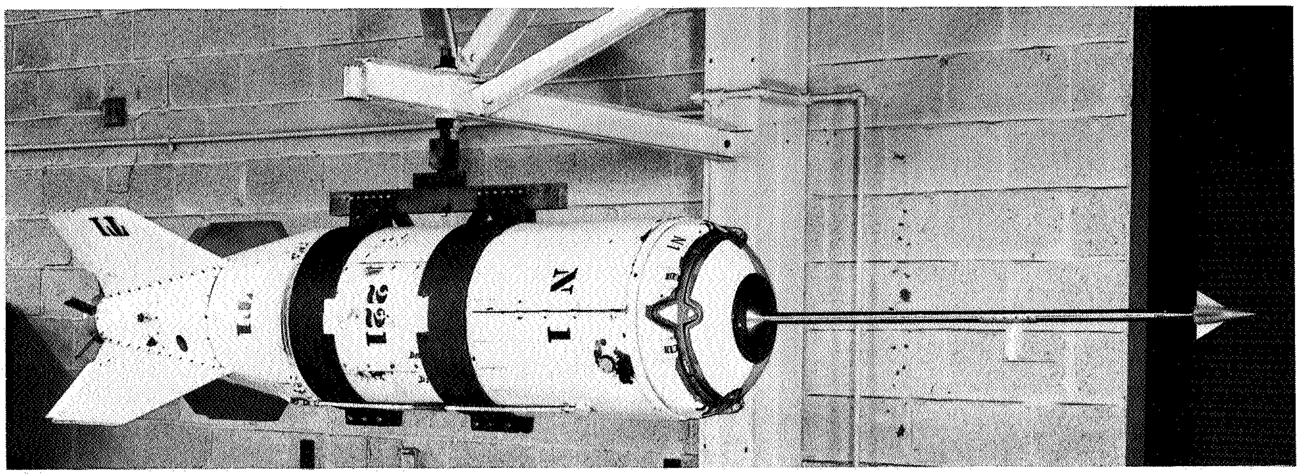


FIGURE 193. Eastman Kodak Dove bomb mounted in moment-of-inertia rig at Langley in preparation for drop test from high altitude at Wallops on December 4, 1951. A flow-angle indicator is sting-mounted for the test.

ASSISTANCE TO ARMY ORDNANCE HERMES PROJECT

Project Hermes of Army Ordnance was a broad research and development ballistic-missile project initiated in November 1944 with General Electric Company the prime contractor. The project was terminated at the end of 1954. The first flight phase of the Hermes program was the launching at White Sands Proving Ground of the numerous V-2 missiles captured from the Germans in 1945. A large number of German engineers and technicians from Peenemünde, headed by Wernher von Braun, were brought to the United States and assigned to Army Ordnance at Fort Bliss, Texas. This group, along with General Electric, conducted the V-2 firings. When these were completed in 1950, the Von Braun group were moved to the Redstone Arsenal, Huntsville, Alabama. Several ballistic missile designs were initiated, all bearing some form of Hermes identification. The NACA was requested to assist in the development of three of these through wind-tunnel and rocket-model tests. One was a liquid-rocket missile similar to the V-2 and designated Hermes A-3; another was a missile powered by a large solid-rocket motor and designated Hermes A-2; and the third was a proposed ramjet-powered missile designated Hermes II. Most of the contacts at Langley with respect to the A-3 and A-2 missiles were with General Electric representatives. The Hermes II ramjet missile, however, never got beyond the study stage and most of the contacts were directly with Von Braun's group.

The first contact with regard to assistance to Army Ordnance in the development of a ramjet was on October 20, 1948, when representatives from Army Ordnance, including Von Braun, visited NACA Headquarters to discuss the possibility of rocket-model tests of a Mach 3 two-dimensional diffuser (ref. 32). The program was agreed upon in later discussions, and an official request was made by Army Ordnance on July 19, 1949. RA 1545 was issued on August 4, 1949, to cover the rocket-model tests. Two Deacon rocket motors in tandem were used to obtain data to Mach 3. The two-dimensional inlet was located in the very tip of the nose cone, which also contained an eight-channel telemeter. This program was designated F101 by PARD. In figure 194, one of the models is shown at Wallops ready for launching. Four models were launched, beginning in August 1950. The first two had structural failures; but the last two, launched in August and September, 1952, were successful. Pressure recovery data were obtained from Mach 1.4 to 3.16 (ref. 33).

Assistance on the General Electric Hermes A-2 solid-rocket propelled missile was given to evaluate the flight performance of scaled models of the rocket motor at different initial motor temperatures. This work was a part of RA 1573 issued July 28, 1950, at the request of Army Ordnance. The 1/3.75-scale motors were designated T40 and have been discussed earlier in this chapter in connection with planning for the hypersonic research program at Wallops. The motors were made by Thiokol Chemical Corporation at Redstone Arsenal and were of internal-burning star-perforated design, with

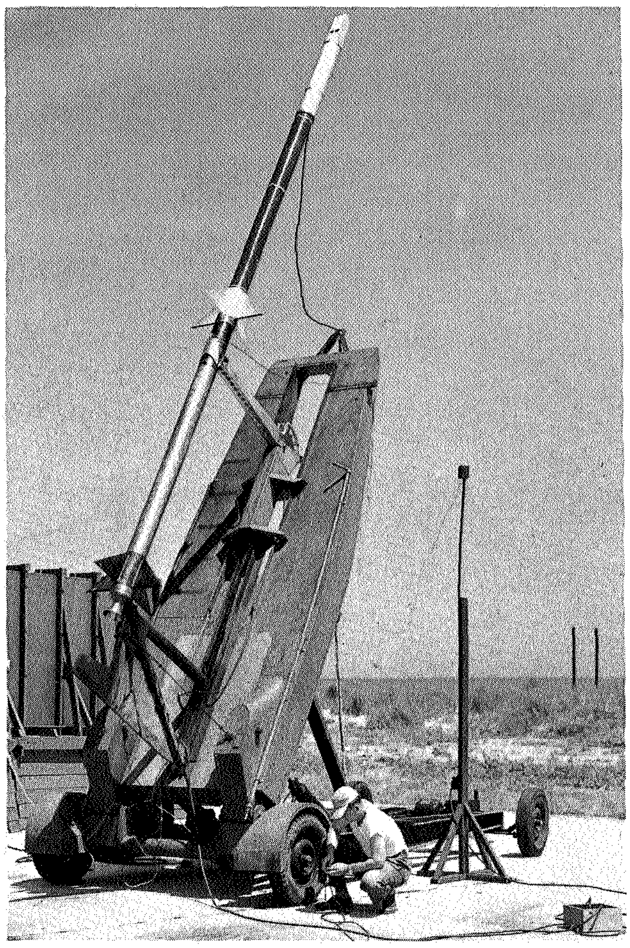


FIGURE 194. Technician George Cutler connects firing leads to tandem Deacon launch vehicle of Hermes II ramjet diffuser model, August 5, 1952.

polysulfide-perchlorate propellants. The motors had a thin steel wall with a domed-shaped head end. A special temperature-conditioning box was provided at Wallops for these tests. For the flight tests, a conical nose fairing was added to the motor, and stabilizing fins were strapped to the rear section. One of the models is shown in figure 195. Nine flights were made between February and May, 1952—three each at 70° F, 130° F, and −25° F. All flights were successful and indicated no serious effects of acceleration on the rocket-motor performance (ref. 34). Impulse measured in flight agreed well with earlier static tests. Although the Hermes A-2 was never flown as a guided missile, flight tests of the full-scale motor were made successfully by Army Ordnance at Cape Canaveral in February and March, 1953, in a program designated RV-A-10 (ref. 35).

Assistance to Army Ordnance on the General Electric Hermes A-3 liquid-rocket missile consisted of a flight investigation of the effects of rocket-motor operation on the drag and base pressures under RA 1573 (later changed to A72L9), and the investigation of longitudinal stability in flight under RA A21L176. This overall program with 1/5-scale models was designated E104 by PARD. Two versions of the Hermes A-3 were tested: a smoothly-faired shape, designated A-3A, and a combination cone and frustum of a cone, designated A-3B. Nine models were flight tested between April 1951 and May 1954, with six providing satisfactory data. Drag and base pressures with rocket motor operating were measured with three A-3A models and one A-3B model. Stability was studied with one model of each design. For the stability tests, pulse rockets provided the needed disturbance. A telemeter was located in the nose of each model.

The operating liquid-fuel rocket engine of the full-scale missile was simulated in the tests by a modified Cordite solid-rocket motor. A blast tube was fitted to the Cordite, and different nozzle sizes were used to approximate the jet-exit pressure ratios of the simulated liquid engine. A range of Mach numbers and altitudes during Cordite burning was obtained by using four different booster rocket

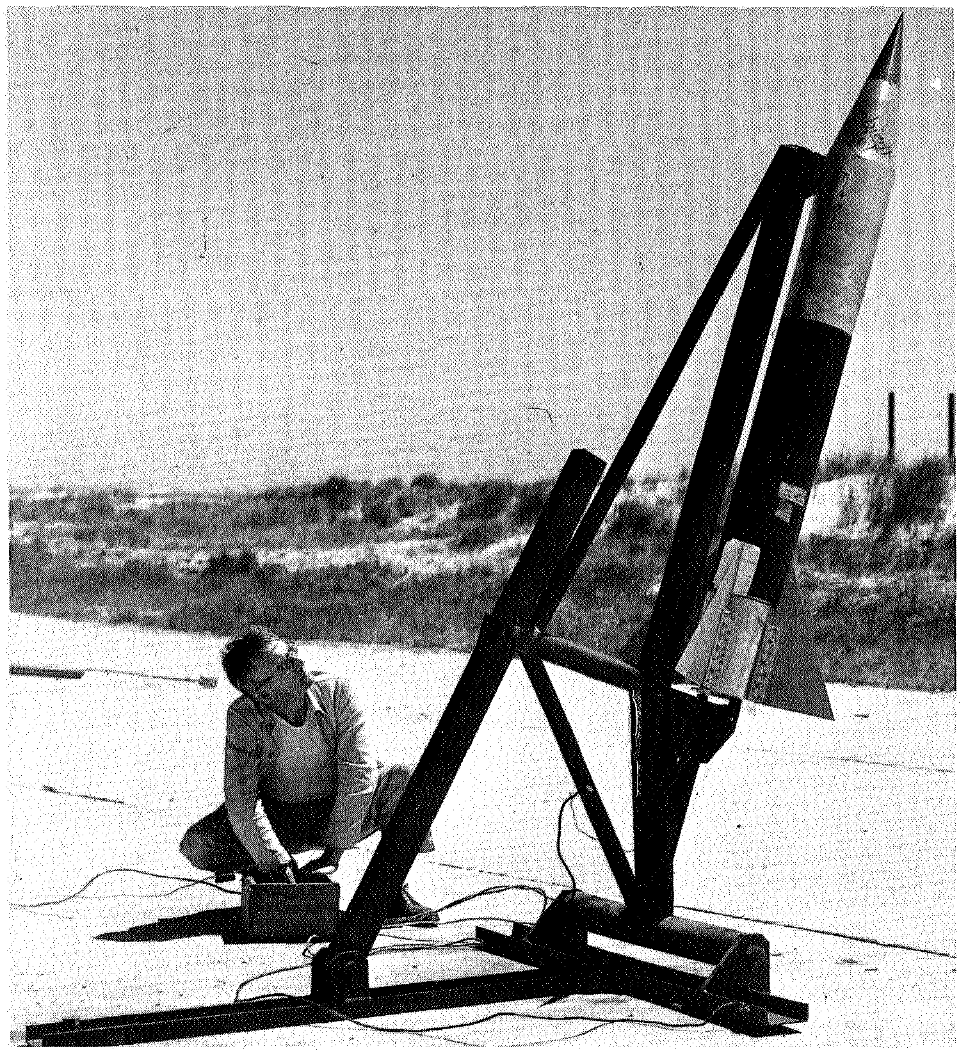


FIGURE 195. Technician Franklin Forbes checks wiring to T40 test motor, May 7, 1952, for test conducted as part of General Electric Hermes A–2 missile project.

systems: (1) 3.25-inch motor; (2) lightweight HVAR; (3) 65-inch HVAR; and (4) Deacon. The model of the Hermes A-3A missile with the lightweight HVAR booster is shown in figure 196. Data were obtained over a Mach number range of 0.6 to 2.0. Evaluation of base pressure and drag under engine operating conditions was desired for accurate prediction of range and performance of the full-scale missile. The stability models had no internal rocket motor but were boosted by 65-inch HVAR motors. Lift, drag, center of pressure, and damping were determined with the stability models for a Mach number range of 0.6 to 1.6 (ref. 36).

ARMY ORDNANCE 40-MILLIMETER SHELLS

Army Ordnance requested the assistance of Wallops in obtaining Doppler radar data from some special 40-mm shells fired from a gun. The Army's Ballistic Research Laboratory (BRL) had been experimenting with the reduction of drag of shells by burning a small amount of powder in the wake, but they were not satisfied with their own radar data. The request was approved by NACA Headquarters on September 26, 1952, and RA A72L100 was issued to cover the assistance. BRL furnished the gun, shells, and gun crew. Wallops supplied the range, radar units, and photographic coverage. PARD researcher C. J. Welsh was assigned the task of analyzing the test results.

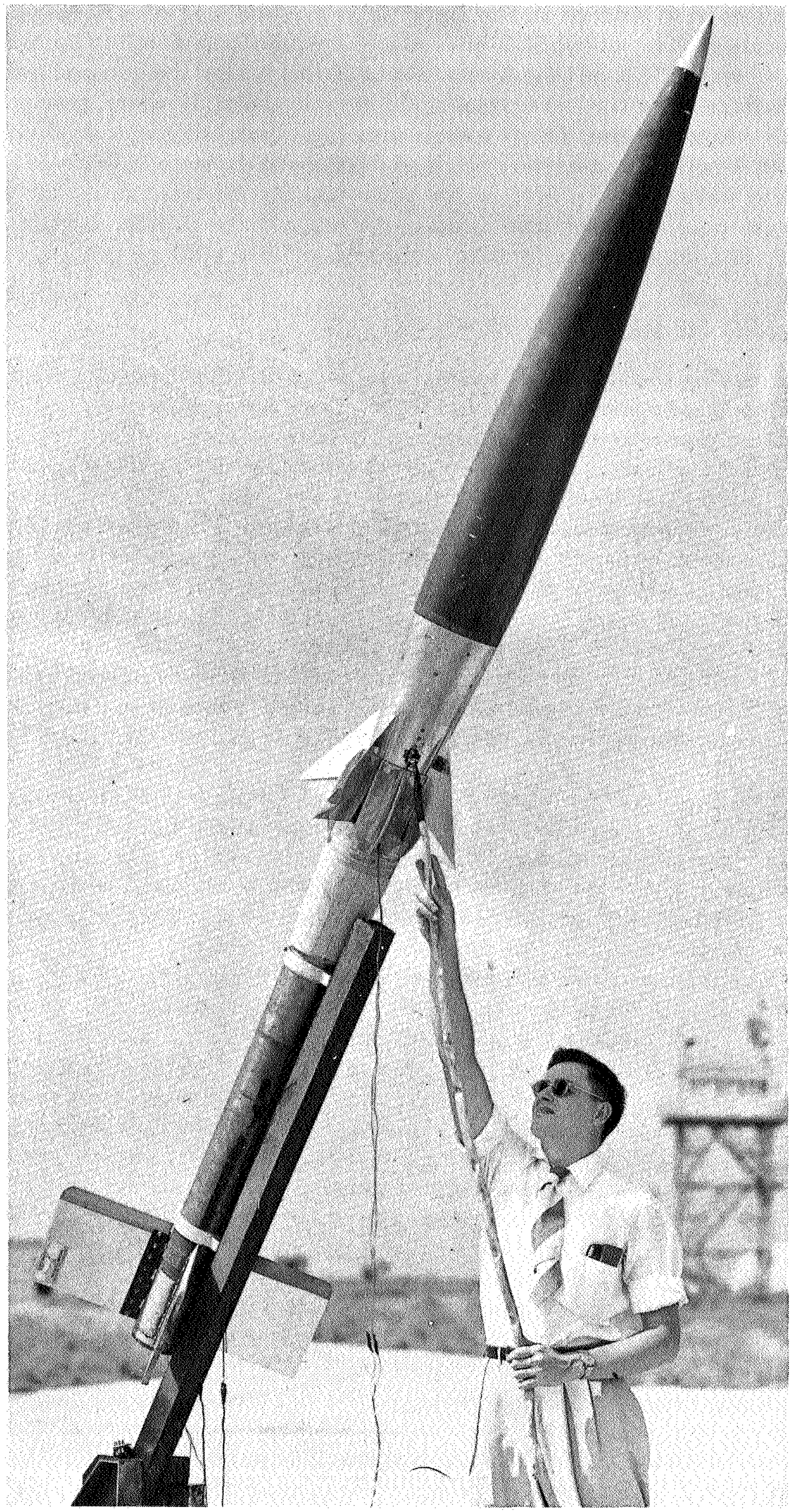


FIGURE 196. Engineer Herbert Jackson checks external cable to model of General Electric Hermes A–3A missile at Wallops, July 27, 1951.

The gun was moved to Wallops on September 29, 1952, and a number of rounds were fired with different radar locations. The mobile SCR-584 radar in its trailer was moved to the launching area, and it was found that when the SCR-584 was located about 60 feet behind the gun and was aligned with the flight path, the shells could be tracked to splash. The Doppler radar, however, gave poor results until it was moved to one side of the gun. Thirty rounds were fired under different conditions, the last series on October 2, 1952. Good radar data were obtained from ten of the rounds, five cold and five equipped for burning in the wake. This burning in the wake was also referred to as an "external ramjet."

Analysis of the data indicated that in only one test did the powder burn externally for any appreciable time; but, in this case, a drag reduction of about 20 percent was noted (ref. 37).

VAPOR COOLING OF REENTRY NOSE CONES

The problem of ensuring the survival of reentry nose cones of ballistic missiles was given attention at Langley almost as soon as meaningful measurements verified the existence of a really serious problem. Aerodynamic heating posed two types of problems. The first was connected with continuous operation at hypersonic speeds. The heat in this case would continue to pour into the skin until an equilibrium temperature was reached, at which the rate that heat was radiated from the surface equaled the aerodynamic heating rate unless some cooling method was used. The second problem was connected with reentry of an intercontinental ballistic missile nose cone. Here the heating was a transient condition for the nose cone began slowing down at the same time that heating began. The solution was to absorb the total heat transferred to the skin during the time of reentry. A breakthrough occurred in 1952 when H. J. Allen of NACA Ames laboratory showed that the total heat transferred to a body would be drastically reduced if the slender cones being considered were replaced by a very blunt shape. In fact, it was found that during the brief reentry period a thick copper shield could absorb this amount of heat without melting the surface. Later, the ablative type of heat shield was to be found more efficient.

In 1952, Convair was working on a slender nose cone for the Atlas ICBM. It was assumed that this was the proper shape, and research was underway to solve the reentry heating problem. One proposed solution was that of transpiration cooling, a man-made simulation of the sweating phenomenon. Some success had already been achieved with such cooling of rocket nozzles. Some exploratory tests of cooling of nose cones and wing leading edges were conducted in the Wallops Preflight Jet over the next several years. All of these are discussed here for continuity.

In March 1953, exploratory tests of a combination of transpiration and film cooling of an 8-degree cone were made in the true-temperature Mach 2 Preflight Jet. Figure 197 shows the test model mounted in front of the 8-inch B jet. In this test, water was forced through a porous section a short distance back of the nose. It was found that in this airstream of 550° F stagnation temperature, the metal skin back of the porous band was kept at about 125° F through absorption of the heat by evaporative cooling. Water consumption was 2.7 pounds per square foot per minute (ref. 38). This was a simpler system than the one in which the entire surface was porous, and was surprisingly effective. The cone ahead of the porous band, however, remained a problem.

In August 1954, the efficiency of water, nitrogen, or helium ejected through a completely porous surface was investigated with the same shape of cone (ref. 39). Helium was found to be much more efficient than nitrogen. Water cooling with the completely porous surface was slightly more efficient than the film cooling method tested earlier.

Research on the problems of survival of structures and various materials was greatly expanded over the next several years, and ground-based facilities that simulated hypersonic flight were developed. At first, the exhaust of a liquid-rocket engine was used at Langley, followed by a ceramic-pebble heated air jet, and then by electric-arc heated jets. At Wallops, the B jet was modified by the addition of a 12-inch-diameter ramjet, burning ethylene. The jet exhaust provided conditions of more than 3,000° F and Mach 2. This facility will be described in more detail later. One of the projects in the facility was a continuation of transpiration cooling research under these more severe conditions.

The first of these tests in the Ethylene Jet was made with a wedge-shape airfoil having an included leading-edge angle of 40 degrees. The gas was forced through a flat section of porous stainless steel of

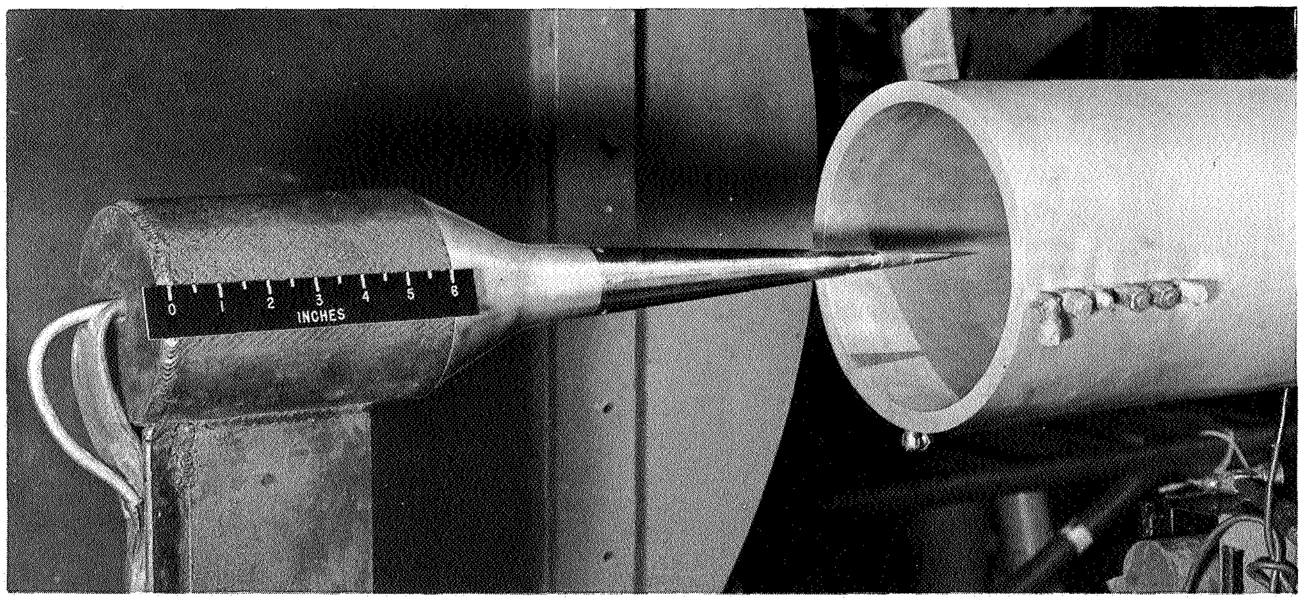


FIGURE 197. Water cooling test of 8-degree cone in Preflight Jet at 550° F stagnation temperature, March 1953.

1/8-inch thickness. The results of these tests were in general agreement with the earlier tests at lower temperature, and again showed helium to be four or five times as efficient as nitrogen because of its higher heat capacity (ref. 40).

The second test was of a water-cooling scheme that would protect not only the sides of a cone but the tip as well. This model consisted of an 80-degree total-angle cone. Water was ejected from the apex of the cone from behind a small umbrella-shaped nozzle or from a simple axial nozzle. The test was proposed by the General Electric Company in March 1957 for possible ICBM application. The model was constructed by GE after official approval had been received from the Air Force. This system, while providing good cooling of the nose, was more wasteful of water than the earlier transpiration system by a factor of 2.5 (ref. 41).

CONTINUATION OF LANGLEY F23 RAMJET FLIGHT PROGRAM

The early success of the F23 ramjet flight test program at Langley in 1950 has been discussed in Chapter 7. Six more flights were made through 1953, but with less success. In fact, out of the six flights there were four failures from various causes, including failure of booster fins and failure of the burner. The flight tests were augmented by considerable testing in the Preflight Jet. All of these models had the B engines (design Mach number of 2.13). One of the successful flights was made with a double Deacon booster and gave good performance over a Mach number range of 1.76 to 2.61, except for some combustion buzz near Mach 1.8, which was not serious (ref. 42). An overall fuel specific impulse of 1,246 seconds was calculated from the flight results.

PARD researchers continued their study of the problems of adapting the F23 ramjet system to long-range missiles. Thrust control of such engines was obtained by varying the fuel rate and thus the fuel-air ratio. Control of the fuel-air ratio alone was not sufficient to avoid engine instability, and additional devices which could compensate for changes in free-stream temperature, pressure, and Mach number were required. M. A. Faget proposed a system for controlling ramjet thrust that was activated by the ratio of total pressure to diffuser exit pressure (ref. 43).

A successful flight test of the Faget system of thrust control was made on June 25, 1953. A triple Deacon booster was used, as shown in figure 198. Before flight, the two engines were mounted side by side in the 12-inch nozzle of the Preflight Jet for an evaluation of the control system under a Mach 1.8 condition. For the flight test, a canard fin was installed in a retracted position in the nose of the vehicle

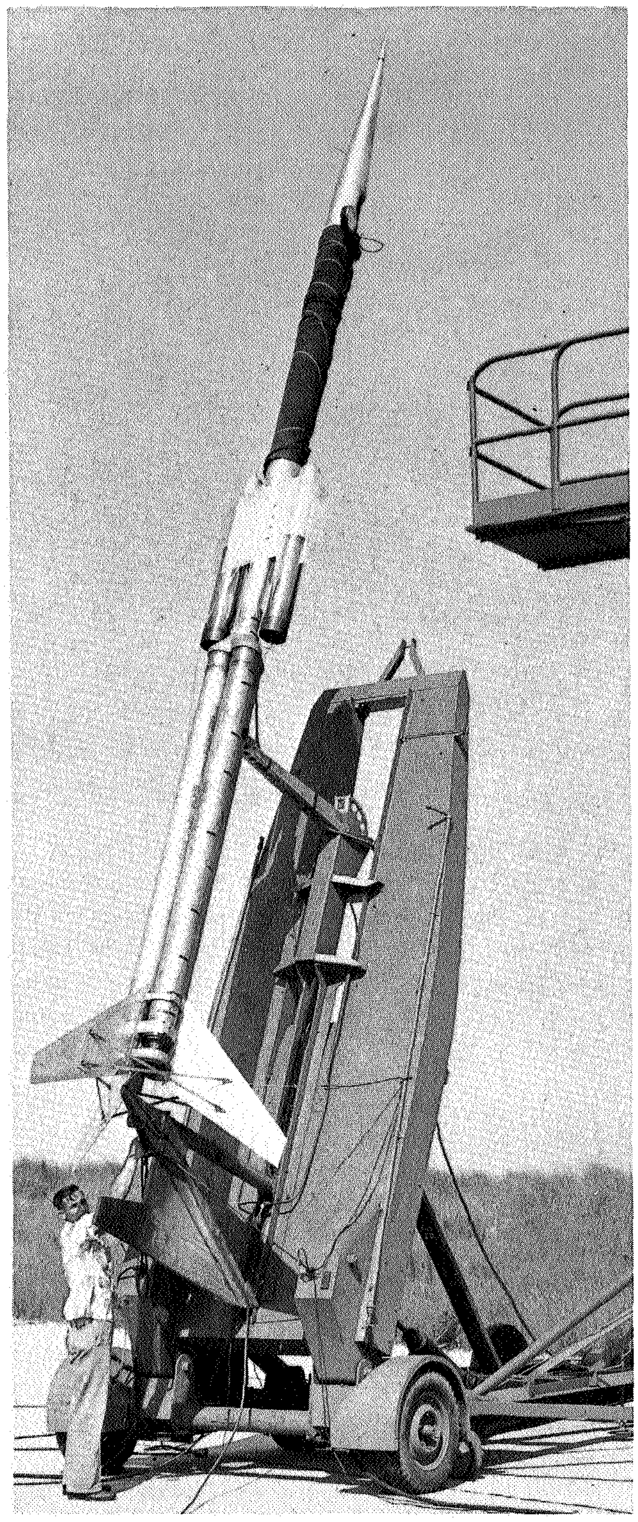


FIGURE 198. Technician Roy Hindle connects firing leads to triple Deacon booster of F23 ramjet test vehicle, June 25, 1953. The temporary insulation around the vehicle body was used to prevent excessive pressure buildup in the fuel tank and was removed before launch.

and was set to be extended at 70 seconds after launch to induce pitch-up and structural disintegration for range safety purposes. This was an attempt to abide by the Navy CNO's directive that the NACA limit its firings to a 25-mile range. In flight, the engines operated satisfactorily to a maximum Mach number of 3.14 and a maximum altitude of 67,950 feet (ref. 44). The vehicle coasted to an altitude of 135,000 feet and the canard fins were extended at 70 seconds as planned, but it was not determined whether the range was curtailed. The fact that the telemeter continued to operate to splash for a record 8.5 minutes indicated that perhaps the vehicle did not break up but instead trimmed at a high angle of attack and floated to earth in the fashion of a windmill.

COMPLETION OF LEWIS AIR-LAUNCHED RAMJET FLIGHT PROGRAM

The initiation of the Leiws air-launched ramjet flight program was described in Chapter 6, and its continuation through 1949 has been discussed in Chapter 7. In the early flights, the ramjet engine was ignited before release from the airplane and accelerated to its maximum speed under the combined action of gravity and engine thrust. In order to obtain high Mach numbers at high altitudes and to study engine operation at higher speeds, a solid-rocket motor later was added to the engine and used as a booster. The first such rocket motor was the Aerojet 14AS1000, providing 1,000 pounds of thrust for 14 seconds. In later flights, the Thiokol T40 motor was used. The rocket motors were placed inside the ramjet combustion chamber on rails. At ignition of the rocket motor, a restraining pin was sheared by the rocket thrust; after burnout of the rocket, the empty case was then forcibly ejected by pressure from the burning ramjet engine.

On October 21, 1949, plans for the use of a rocket-motor booster were discussed between W. V. Gough, Jr., of Lewis, and Langley personnel. For safety, Langley recommended that the rocket motor be ignited after release of the ramjet model from the airplane. Ignition would be achieved by means of a delay squib igniter energized at release through a long break-wire circuit in a manner similar to the maypole circuit used to ignite the second stage of a rocket model at Wallops. A 4-second delay squib was recommended to allow a minimum clearance of 250 feet between the carrier airplane and the model at ignition. PARD agreed to develop the required delay igniter and to handle all details connected with rocket-motor installation. At this time, instrumentation was handled by IRD at Langley, and it was reasonable to install the rocket motor at Langley after instrument preparation. An electric heater was recommended to keep the rocket motor near 100° F prior to firing (ref. 45).

The first flight test with such a rocket was made on January 24, 1950, and by mid-1950 the rocket-boosted ramjet system was in use in most drops. In November 1950, plans were completed to transfer all of the operations to Cleveland. Now the models would not only be constructed at the Lewis Laboratory but the telemeter and rocket systems would be installed there and the airplane with the test model would be flown directly from Lewis to Wallops for air-launching. Howard Kyle of Langley IRD was designated as Langley coordinator, and Scott H. Simpkinson of Lewis was designated the responsible person for rocket handling there.[14] From mid-1951, this system was used. It was the first time anyone besides Langley personnel was given responsibility for the NACA telemeter. Langley agreed to the proposal because it would release engineers and technicians for work on Langley rocket models.

The first ramjet engines air-launched by Lewis incorporated a single-oblique-shock inlet designed for a Mach number of 1.8. These were designated series A, B, C, or D, differing in the Mach number at the combustor inlet. With the addition of the rocket-motor booster, a new engine was constructed for operation at a Mach number of 2.4. This was a double-oblique-shock inlet with cone half-angles of 22 degrees and 35 degrees. The engine was designated series F and was about a foot longer than the earlier models. It was launched from a position under the center panel of the F-82 airplane as shown in figure 199. A T40 rocket motor was used to boost this model. A practice bomb may also be seen under each outer wing panel. These were dropped over Wallops for orientation prior to the test model.

Three such models were launched during 1952—with only one successful flight, on March 21, 1952. In the other two flights, January 30, 1952, and August 26, 1952, the T40 rocket motor did not ignite. In the successful flight, the rocket ignited 6 seconds after release and at burnout had accelerated the model to Mach 1.55 at an altitude of 32,000 feet. After ramjet ignition, the model continued to accelerate to Mach 2.2 at 18,000 feet, at which time a fuel system failure initiated explosive destruction of the model (ref. 46). Diffuser pressure recovery with the double-oblique-shock inlet in engine F approached the theoretical value of 0.93 at a Mach number of 2.10. A thrust coefficient of 0.82 was measured at this same Mach number.

The technique of rocket boosting these models was developed with series C engines, pending construction of the new F engines. The C engines were boosted by the Aerojet 14AS1000 motor to Mach 1.2, and the ramjet then extended the speed to Mach 1.6.

14. Letter from Abe Silverstein, Chief of Research, Lewis, to Langley November 20, 1950, with proposal concerning ramjet missile drop operations originating at Lewis Laboratory.

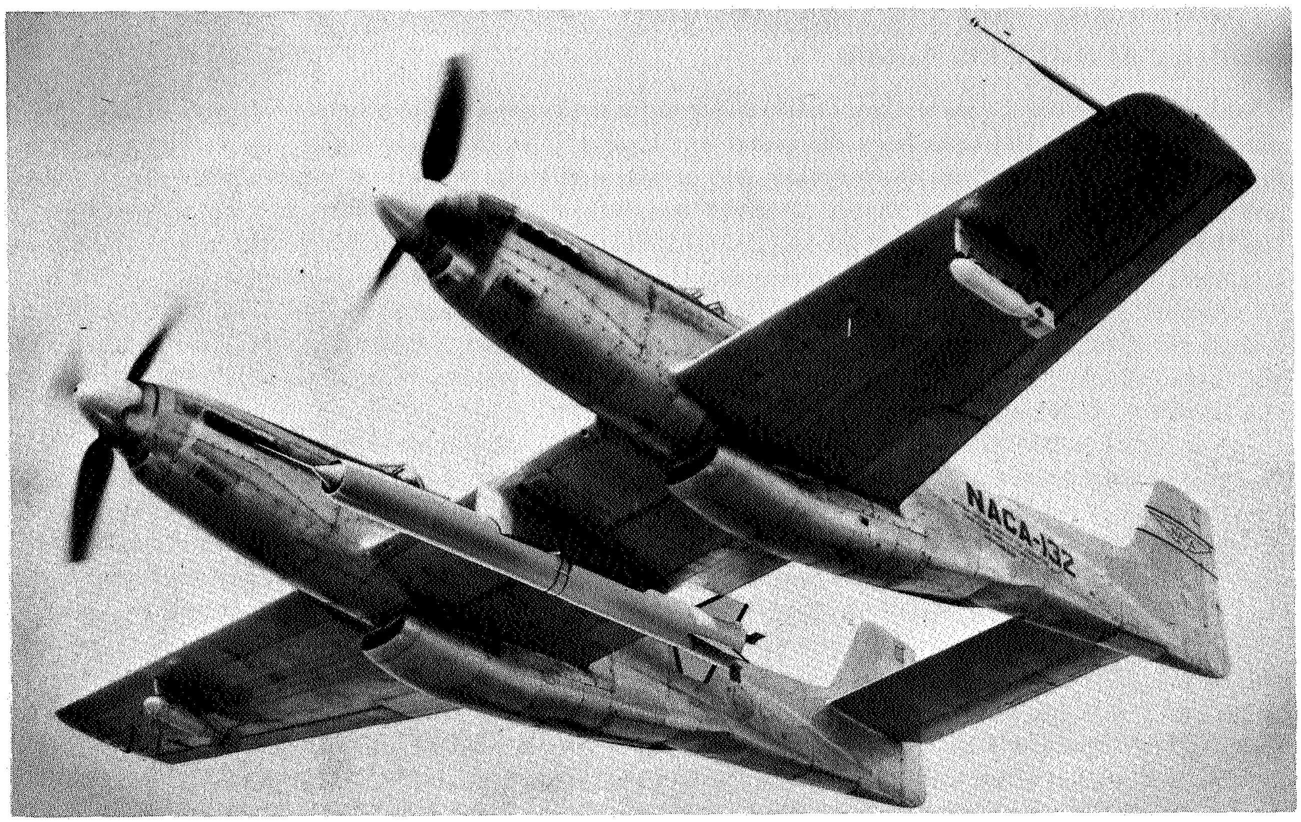


FIGURE 199 North American F−82 airplane carrying Lewis 16-inch ramjet test vehicle with internal rocket booster and double-oblique inlet. Vehicle is ready for air-drop over Wallops, March 1952.

The drag of the model with series F engine was evaluated from a special rocket-boosted test with inoperative ramjet. In this test, 30 different measurements of pressures and acceleration were obtained with a 10-channel telemeter by means of a switching unit. On June 3, 1953, the T40 rocket motor accelerated this drag model to a Mach number of 1.87 at an altitude of 33,000 feet (ref. 47).

Drag of the models with series C engines was likewise evaluated. Four such models were air-launched and then boosted to Mach 1.43 with Aerojet 14AS1000 motors (refs. 48 and 49).

Significant gains in performance from the use of high-energy fuels in ramjets were indicated by theoretical analyses and by laboratory tests at Lewis. In July 1953, Navy BuAer requested the NACA to conduct a flight test of such a fuel (pentaborane) as part of Project Zip. A 9.75-inch engine was used in this test instead of the standard 16-inch engine used in the gasoline-fueled program. The engine was generally similar to the D series flown earlier. The flame holder was developed in connected-pipe tests and consisted of eight radial wedge-shaped airfoils. The model was 140 inches long and weighed 156 pounds including 8.79 pounds of fuel. It was launched from the center panel of an F-82 airplane over Wallops on February 12, 1954. (See figure 200.) A Mach number of 1.45 was reached in flight before a failure in the combustion chamber occurred. The results indicated a potential gain in range of 70 percent with pentaborane over that calculated for JP-3 fuel (ref. 50).

In a second flight, on May 5, 1954, the ramjet was operated with pentaborane fuel at lower fuel-air ratios, at Mach numbers up to 1.74. Even better performance of the fuel was indicated with a calculated increase in potential range of 96 percent above that with JP-3 fuel. Much of this gain was the result of higher cumbustion efficiency (ref. 51). In a third flight, on October 12, 1954, a maximum Mach number of 2.04 was reached from the use of an improved fuel-spray bar. Again, the outstanding superiority of pentaborane was shown (ref. 52).

On February 23, 1956, a fourth test with pentaborane fuel—the last of the Lewis air-launched ramjet series—demonstrated the satisfactory operation of pentaborane at Mach numbers up to 3.02.

The inlet of the engine had been changed to a double-oblique-shock type with a design Mach number of 2.4, and the sonic exits used in the earlier tests had been changed to a convergent-divergent supersonic exhaust nozzle. A Thiokol T55 solid-rocket motor was added internally to boost the speed of the vehicle to a supersonic value prior to ignition of the ramjet. As before, the rocket case was expelled through the exit nozzle after burnout. The general arrangement of the flight model is shown in figure 201. A McDonnell F2H-2B airplane was used in this test to allow launching at a higher altitude (42,000 feet) (ref. 53).

FIGURE 200. Lewis engineer Scott H. Simpkinson examines 9.75-inch high-energy ramjet engine on North American F–82 airplane prior to flight to Wallops for air launch on February 12, 1954.

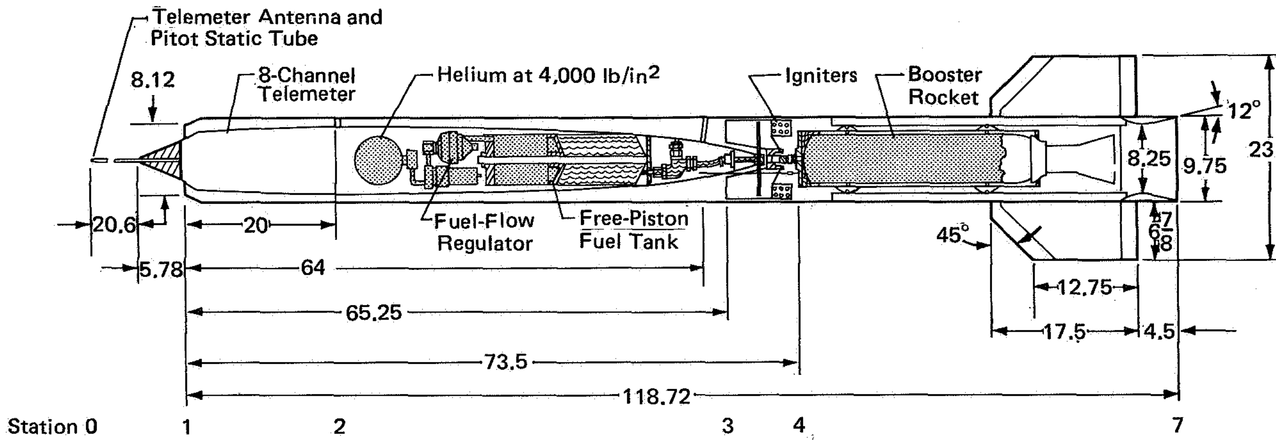


FIGURE 201. Sketch of rocket-booster 9.75-inch-diameter ramjet with convergent-divergent exhaust nozzle. (All dimensions are shown in inches.)

TRANSONIC INLET RESEARCH: F26

The initiation of the F26 rocket-model program to evaluate inlets in the transonic range has been discussed in Chapter 7. The first tests were made with instrumented models containing a rotating shutter to vary the mass flow. With this type of model, a large amount of information was obtained with a specific inlet shape, but considerable time was required to construct and instrument these fairly complicated models. Project leader R. I. Sears wanted to study a variety of different shapes and was willing to sacrifice some of the data in exchange for the ability to test a large number of different models with a given effort. To this end, he developed a technique by which the drag of inlets could be determined with simple uninstrumented models at Mach numbers above 1. A separate model was required for each mass flow studied. Total drag was determined from ground-based radar, and the internal drag was computed from the geometry of the configuration and the assumption of choking flow at a minimum area section just behind the inlet and at the exit of the model. This choking was assured by proper sizing of these stations and was verified by calibration models. The simple models were boosted by either a 65-inch HVAR or an HPAG rocket motor to a Mach number of 1.5. Figure 202 shows one of the models on a rail launcher.

From the initiation of the F26 program in January 1950 through 1954, 50 models were flown. Of these, 39 were of the simple type described above; 7 were of the more complicated, instrumented type; 3 were basic bodies without inlets for comparison; and 1 was a special fin-flutter test model. An enviable record of successful flights was made, with only one failure out of the 50 launchings.

The first series of simple models was flown to evaluate the normal-shock type of inlet in the transonic and supersonic range. Inlet shapes were found that were superior to the best of the high-critical-speed, NACA 1-series inlets above a Mach number of 1.1. The feature contributing to this reduction in drag was the replacement of the rather full shape of the 1-series cowling with a thin, sharp-lipped shape (ref. 54).

Above a Mach number of 1.5, the normal-shock inlet was known to suffer a loss of pressure recovery in the inlet, and the Ferri external-compression conical-shock inlet was favored. In order to evaluate the drag of this type of inlet over the speed range, a series of such inlets was flown as the second part of the simple F26 flight models. These models were propelled to a Mach number of 2.0 by Deacon boosters.

The models also included a new series of standard booster fins. These were sweptback fins of constant thickness, with thin, flat, crossed braces. The fins were cut from aluminum honeycomb panels, with the leading and trailing edges beveled by having the honeycomb crushed and then covered with sheet aluminum cuffs. This was one of the many special construction techniques developed in the Langley sheetmetal shop.

The flight tests of the conical-shock inlets showed the same effect of cowling shape as had the normal-shock inlet tests. The lowest drag was obtained with thin, sharp-lipped cowls (ref. 55).

FIGURE 202. Technician Franklin Forbes measures elevation angle of HPAG booster for F26 inlet model on rail launcher, July 18, 1951.

In tunnel tests, sharp-lipped nose inlets were found to be subject to undesirable losses in pressure recovery at angles of attack, because of flow separation behind the sharp edge. One possible solution to the problem was use of an asymmetric inlet, i.e., one in which the inlet face was skewed 45 degrees so that the top overhung the bottom. Tests of such an inlet over an angle-of-attack range were conducted in the Preflight Jet. Figure 203 shows the inlet model in front of the 8-inch B jet. The model in this test was mounted on its side, and angle-of-attack changes were made by rotating the entire model about a vertical axis. Tests were made at two supersonic Mach numbers, 1.42 and 1.84. A symmetrical, thin-lipped inlet was also tested for comparison. The symmetrical inlet showed large losses in pressure recovery at angles of attack of 20 degrees and greater, whereas the skewed inlet showed only slight losses up to a 35-degree angle of attack (ref. 56).

Since the nose of the airplane was not always available for an air inlet because of the use of the nose for radar or other equipment, the inlets were often located back from the nose. One such installation on

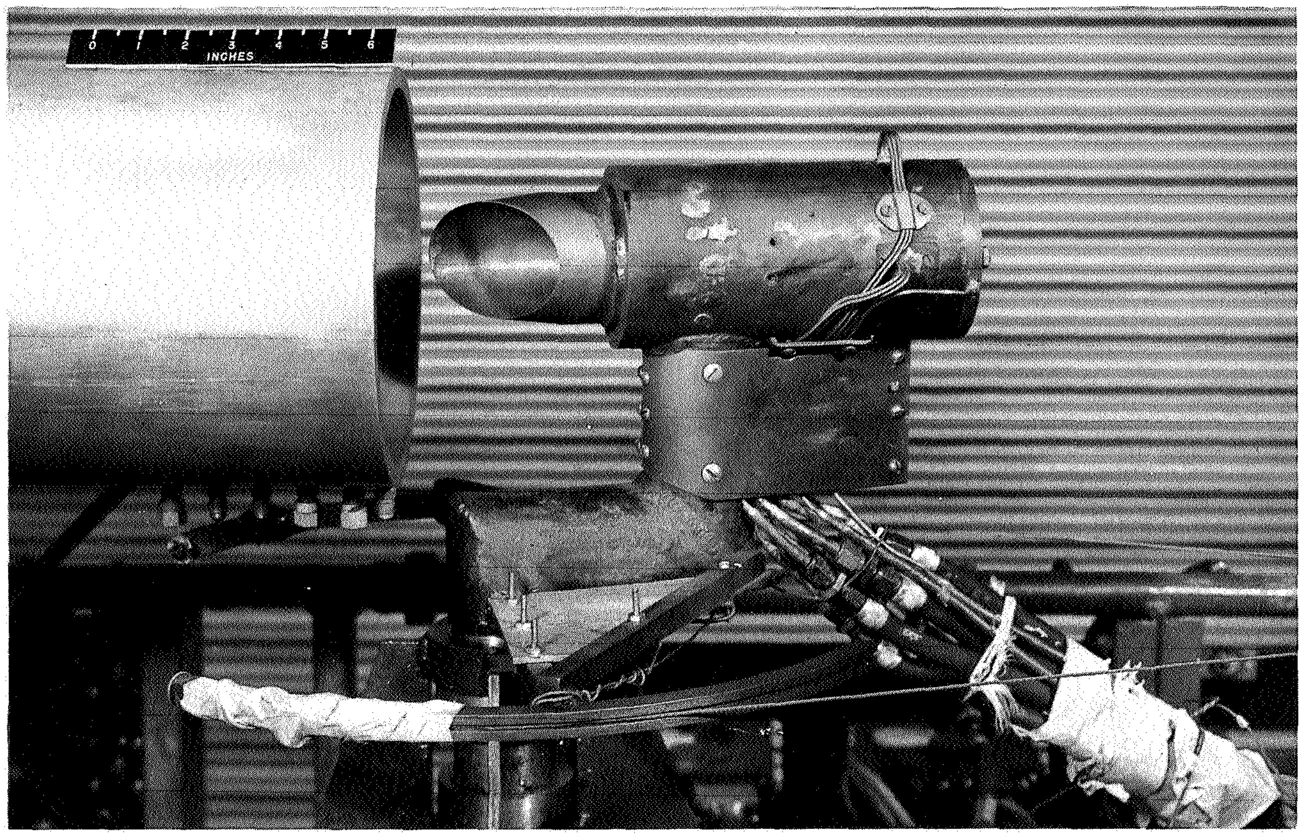


FIGURE 203. Asymmetric nose inlet in B jet at Wallops for pressure-recovery tests at angles of attack, October 24, 1952.

the McDonnell XF3H-1 airplane has been discussed earlier in this chapter. It will be recalled that large pressure losses resulted from the fact that the fuselage boundary layer entered the inlet. A general research application of a single underslung circular inlet was investigated as part of the F26 program. This inlet was located about a body diameter aft of a pointed nose, and was spaced slightly away from the bottom of the fuselage to allow the boundary layer to flow around the inlet. Tests were made in the Preflight Jet over an angle of attack range at a Mach number of 1.42, with the pointed nose and with two amounts of rounding (ref. 57). A flight test then was made with the pointed-nose model at speeds to Mach 1.6 (ref. 58). All of the tests showed this to be a very promising inlet arrangement. Angle-of-attack effects were small, the drag was no greater than that of a faired body alone, and the pressure recovery was greater than that behind a normal shock, being 0.95 at Mach 1.6.

The inlet data discussed so far, combined with high-speed wind-tunnel data, were presented in a paper by R. I. Sears at a conference on the aerodynamics of high-speed aircraft, held at Ames laboratory in 1953 (ref. 59).

While the forward scoop inlet was found to be a good design, it was a long distance from the normal engine location in the rear of the fuselage. Two additional models having scoop inlets located at the maximum diameter of the fuselage were flight tested early in 1954. One was a circular inlet with a boundary-layer diverter, while the second was a semicircular wraparound design with a boundary-layer splitter plate. The drag of the bodies with these inlets was somewhat greater than that of the basic body, and the pressure recovery was less than that found with the forward scoop, being about 4 percent less than that behind a normal shock (ref. 60). For a full-scale application of these results, the losses of the longer ducting required for a forward location would have to be weighed against the otherwise higher performance.

The successful prosecution of an inlet program at Wallops prompted the Subcommittee on Internal Flow of the NACA Committee on Aerodynamics to hold its meeting of October 10, 1952, at Wallops, and to inspect the facilities there. In figure 204, the visitors are shown in the photographic

FIGURE 204. NACA Subcommittee on Internal Flow, photographed at its meeting at Wallops, October 10, 1952. Front row: O. P. Pracher, General Motors, Allison Div.; W. J. O'Donnell, Republic Aviation Corp.; P. A. Colman, Lockheed Aircraft Corp., Chairman; J. Flatt, WADC; C. L. Zakhartchenko, Naval Ordnance Experimental Unit; J. V. Becker, Chief, Compressibility Research Div., Langley; W. Davis, Ames Laboratory; and Maj. R. S. Wolfson, USAF R and D Command. Rear row: J. A. Shortal, Chief, PARD; D. D. Wyatt, Lewis Laboratory; E. O. Pearson, NACA Hq.; J. Stack, Assistant Director, Langley; P. R. Wood, Navy BuAer; L. A. Geyer, Grumman Aircraft and Engineering Corp.; Comdr. R. L. Duncan, Navy ONR; J. A. Drake, Marquardt Aircraft Corp.; H. H. Hoadley, United Aircraft Corp.; and R. L. Krieger, Engineer-in-Charge, Wallops.

room of the Assembly Shop. In preparation for this visit, as was done for visits of other committees, an array of rocket models at Wallops for flight test was displayed in the main shop area for use in an illustrated talk about Wallops' activities of interest to the committee.

APPLICATION OF AREA RULE TO WING AND BODY DESIGN

An earlier section in this chapter has discussed the outstanding reduction in drag achieved over the transonic speed range through application of "area-rule" principles to the redesign of the B-58 Hustler supersonic delta-wing bomber. Researchers quickly set about to determine the extent of application of the rule, and its limitations. Rocket models were especially useful in this effort because they covered a much wider speed range than did the transonic wind tunnels.

One of the first general research programs was conducted with transonic wing C on an ogive-cylinder fuselage. In some cases, the fuselage had an indentation; in others, it did not. This was the same configuration studied by Whitcomb in the transonic tunnel (ref. 61). A body of revolution equivalent to the basic wing and body was also tested. Near Mach 1.0, the rocket-model results as well as the wind-tunnel results showed large drag reductions. In fact, at Mach 1.0 exactly the wing and indentation had the same drag rise as the original body without any wing. Above Mach 1.0, however, the results were disappointing—reductions in drag from indenting the fuselage were limited to speeds below Mach 1.18. In fact, above this speed large increases in drag were caused by the indentation (ref. 62). Another disappointing finding was that the equivalent body had only about 60 percent as much drag rise as its corresponding wing and body. These models were of the F25 type discussed earlier.

An analysis of the drag of six complete airplane models and their equivalent bodies of revolution confirmed that the drag of the equivalent body of a configuration with a sweptback wing was substantially less than that of the complete rocket model, whereas the drag of equivalent bodies representing configurations with straight or delta wings came within 15 percent of those of the complete models (ref. 63).

A similar F25 study was made with a thinner wing having more sweepback and a higher taper on a parabolic body of revolution, as shown in figure 205. The beneficial effects of the indentation in this case extended to Mach 1.35. As before, the pressure drag of the wing was canceled by the indentation at Mach 1. Above Mach 1.35, however, the wing and indented body had higher drag than the wing and original body.

By this time, R. T. Jones of the Ames Laboratory proposed that at supersonic speeds the area distributions should be examined by cutting the wing-body combination along Mach planes at different roll angles instead of the simple normal plane used at Mach 1 (ref. 64). Such an analysis of the area distribution for the present wing and indented body at Mach 1.5 revealed that the indentation was incorrect and did not provide a smooth equivalent contour (ref. 65).

In other general research programs, other applications and limitations of the transonic area rule were examined. Two of these were an extension of the E2-drag-research program and sought answers to the question of whether the drag could be reduced by actually adding bumps or gloves to existing wing-body combinations, if such additions improved the area distribution. Such a bump added to the fuselage behind a straight wing on an ogive-cylinder to fair out a sharp discontinuity in the area distribution did no good. In fact, at speeds above Mach 1.0 such a bump increased the drag (ref. 66).

Greater success with the addition of gloves or bumps was obtained with a sweptback wing on the same ogive-cylinder body. Gloves added ahead of, as well as behind, the wing reduced the pressure drag as much as 20 percent. The difference between this and the unsuccessful application to the unswept-wing combination was attributed to the lower local slopes to the protuberances required in the case of the sweptback wing. Thus another limitation of the area rule was established—local physical slopes should not be severe, actual values undetermined (ref. 67).

An attempt to explain the lack of agreement between the drag of swept-wing-body combinations and their equivalent bodies of revolution was made with a series of E25 models differing in wing size.

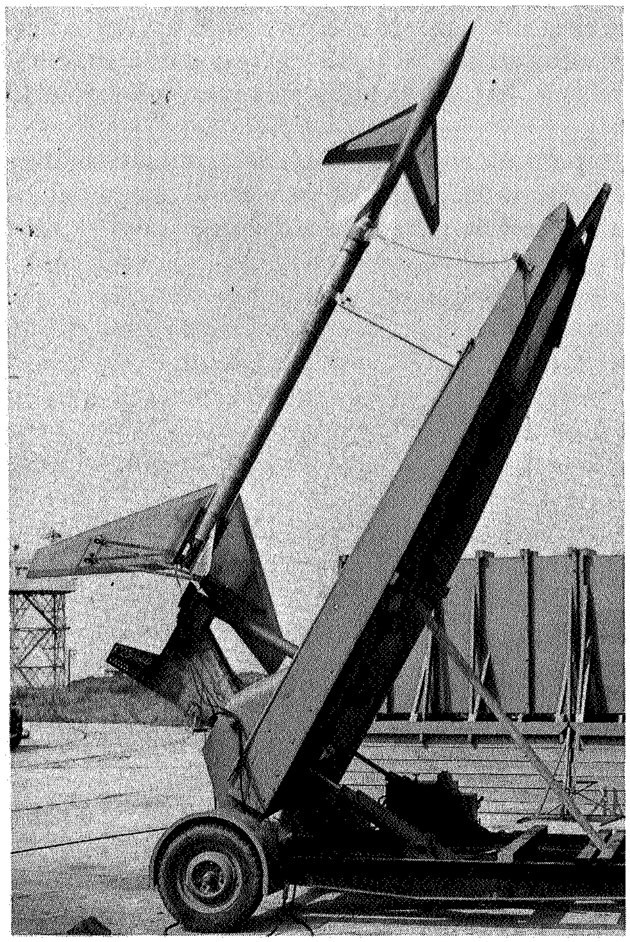


FIGURE 205. General research drag model with sweptback wing and indented area-rule body, shown with Deacon booster, July 15, 1953.

The E25 program was similar to the F25 program except that it was handled by a different branch of PARD. Empirical factors relating the drag of the wing-body to that of its equivalent body were established in these tests, but the large disagreement remained (ref. 68).

Application of the transonic area rule to ducted nacelles was studied with a series of E30 models launched from the Helium Gun. The question under study was how much of the duct area should be considered. Two F26 inlet models differing in mass-flow ratios were selected for the study. Equivalent bodies to represent these models were constructed by subtraction of the entering free-stream tube area from the external contour. The drag rise of these E30 models was in good agreement with that of the original F26 rocket models, providing confidence in this approach to the area rule concept for ducted bodies (ref. 69).

The effectiveness of the Jones supersonic area rule was investigated by two F25 rocket models consisting of unswept wings on parabolic bodies indented for Mach numbers of 1.1 and 1.4., and flown over the transonic speed range. Both indentations reduced the pressure drag of the basic configuration at transonic speeds, with the greater reduction being obtained with the Mach 1.1 indentation. Neither indentation was as good as the original configuration above Mach 1.4. An appendix to the report on the results (ref. 70) gave the short method developed by M. A. Faget for determining the average area distribution at supersonic speeds.

The transonic area rule and linearized theory were used to examine the interference drag of pylon-mounted external stores on a parabolic body, for comparison with tests of such arrangements in a series of F25 models. Half-submerged stores and the cavities alone were also tested. Linear theory was found to predict the interference drag of the pylon-mounted stores quite well (ref. 71).

Calculations of pressure drag of various wing-body combinations, as well as that of bodies and wings alone, were made by R. L. Nelson and C. J. Welsh of PARD by linearized theory and the Jones supersonic area rule, and were then compared with rocket-model test results, to explore the limitations of the area rule (ref. 72). Comparison showed that the area rule concept was very good for thin wings near Mach 1.0. Above Mach 1, the area rule gave misleading results for some configurations. Indentations to bodies, in accordance with the supersonic area rule, did not yield the dramatic reductions in drag achieved by the transonic area rule at Mach 1.0.

Thin delta wings were of considerable interest for supersonic airplanes. Sometimes it was desirable, from structural or volume considerations, to thicken the wing ahead of or behind the point of maximum thickness. A series of E25 rocket models was tested to evaluate the drag penalties of such modifications. In addition, the tests studied the penalty for rounding the leading edge to obtain lower drag under lifting conditions. The wings were of 60-degree delta planform with 3-percent thickness. The models had 3.25-inch internal rocket motors for the second stage of propulsion, and either HPAG or Deacon boosters to give maximum Mach numbers of 1.5 or 1.9. No internal instrumentation was used. The test results showed that leading edges of 60-degree delta wings could be rounded with no drag penalty up to Mach 1.9. Thickening the wing by blunting the trailing edge seriously affected the drag. A wing with a trailing edge of full thickness had almost three times the drag of the normal wing (ref. 73).

The effect of section modifications on sweptback wings was determined in another series of general research models. The series utilized E25 and E17 types of models, and, in addition, introduced a new series of simple wing-drag models designated E34. One of these is shown in figure 206. Thirty-five models of this type were flown at Wallops in the current period. The E34 models were especially designed to evaluate wing drag by minimizing the fuselage. A pointed steel rod 1.25 inches in diameter and about 4 feet in length served as the fuselage. Two small vertical tails completed the model except for the wing. No internal instrumentation was used and propulsion was by booster only (ref. 74).

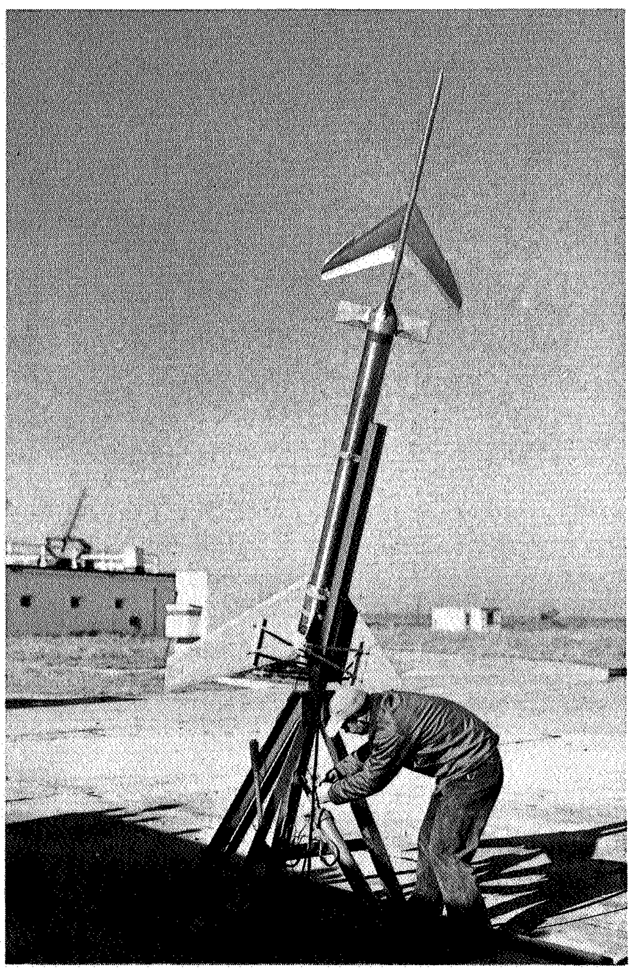


FIGURE 206. Technician George Cutler checks launcher for one of the E34 series of wing-drag research models, December 17, 1952.

By adding pulse rockets to provide a series of transient pitching oscillations, researchers expanded the technique of obtaining drag with E25 rocket models to include drag under lifting conditions. A four-channel telemeter was added in the nose of the model. One such test was made with a 60-degree delta wing, of 3-percent thickness. Disturbances of 6 degrees in angle of attack were excited. Lift-curve slope, static stability, and damping-in-pitch were obtained from the test, as well as drag due to lift. Only a small amount of leading-edge suction was measured for this thin delta wing (ref. 75).

William E. Stoney made a most comprehensive collection and analysis of data obtained from free-flight investigations at Wallops regarding the drag of bodies of revolution (ref. 76). Data from 48 different rocket models and 129 Helium-Gun models were compiled. Many of the models were equivalent bodies of revolution of complete airplane configurations not previously available.

In the course of the investigation of drag characteristics of models of airplanes in wind tunnels and in flight, questions continually arose regarding the reliability of the absolute measurements and the estimated drag reductions obtained by extrapolating the data to the full-scale airplane with its higher Reynolds numbers. Paul E. Purser made a comparison of drag data at transonic speeds for eight complete airplane configurations. Of the eight, full-scale flight data were available for all but one. The results showed surprisingly good agreement between the three methods when the slight differences in configuration were taken into account, and when comparisons were made for identical conditions of such things as lift coefficient, inlet mass flow, and control setting.

This finding was surprising for two reasons. First, wind-tunnel researchers had never claimed infallibility in their measurements of total drag, because of such things as tunnel and model-support interference effects, differences in model surface condition, and tunnel flow conditions. Second, most airplane designers had assumed that at full-scale Reynolds numbers, the total drag would be reduced because skin friction drag for a smooth surface theoretically decreased under these conditions. In the examples with which it was possible to examine pure Reynolds numbers effects at constant Mach numbers, Purser was unable to show any such reduction. Apparently the surfaces of the full-scale airplanes were sufficiently rough to nullify the expected reductions in friction drag (ref. 77). This finding was to lead to extensive measurements of roughness of existing airplanes, and considerable additional research in wind tunnels on roughness effects.

CONTINUATION OF AIRPLANE LONGITUDINAL STABILITY RESEARCH

General research continued during 1953 on longitudinal aerodynamic characteristics of complete airplane configurations. Although the results of these rocket-model tests were of greatest interest to stability experts, some of the data obtained contributed to a better understanding of wing and fuselage loads, for use in structural design. On some of the E15 models, the wing was mounted on an internal balance to measure the load on the exposed wing surface; the total lift load was determined from normal acceleration measurements.

One of the E15 models flown had wing H of the transonic program (aspect ratio 6, 45-degree sweepback, taper ratio 0.6, and 65A009 wing section). This wing of high aspect ratio, shown in figure 207, was expected to have serious pitch-up characteristics because of its geometry. To offset this, the horizontal tail was modified in accordance with wind-tunnel results which indicated that a low horizontal tail with negative dihedral would be beneficial. The tail, as flown, had 20-degree negative dihedral and was located slightly below the fuselage centerline. Incidentally, this was to be the horizontal tail arrangement used for the McDonnell Phantom F4H-1 fighter. In the rocket-model tests with a single Deacon booster, a maximum Mach number of 1.24 was reached with this 148-pound model. Only a slight amount of pitch-up was observed, and this could be controlled easily by tail deflection. Losses in lift-curve slope due to aeroelasticity were about 12 percent, even with a solid aluminum wing. Trim changes were small, but some zero-lift buffeting from this wing of 9-percent thickness was encountered near Mach 1.1 (ref. 78).

Wing H was also selected as the one to use in a canard design. Such a combination was promoted by C. W. Mathews of Langley, as has been discussed in Chapter 8, because of its expected more favorable supersonic stability and control characteristics, and because it allowed the wing to be located in the more

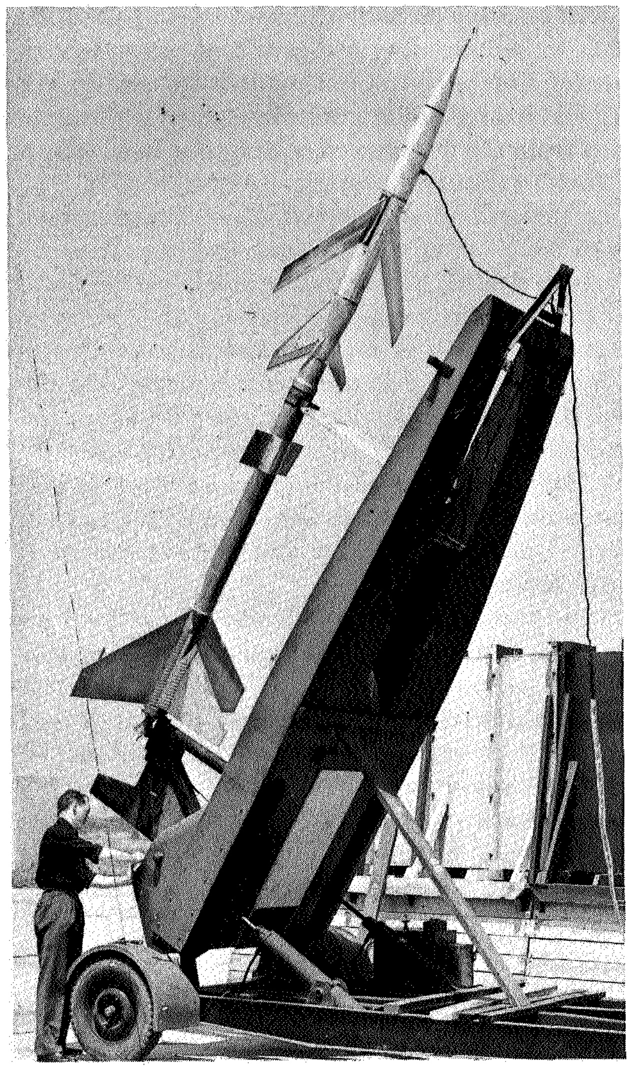


FIGURE 207. Engineer John C. McFall measures elevation angle of launcher for test of E15 stability research model, May 16, 1952.

favorable aft position. A rocket model of this design, shown in figure 208 on its launcher at Wallops, was flown to evaluate the transonic stability. The model was similar to those in the E7 program in that pulse rockets were used to excite disturbances in pitch, and a two-stage propulsion system was used. A maximum Mach number of 1.4 was reached with this 83-pound model.

In the E15 model with wing H and the aft tail, the aerodynamic center was found to move rearward in the transonic range from a position at 45 percent of the wing chord to about 85 percent. It was expected that the canard arrangement would not have such a large rearward movement. In the flight test, it was found that, instead, there was a large forward movement of the aerodynamic center from about the 10-percent station ahead of the leading edge of the reference chord to the 70-percent station ahead of the leading edge. The canard, therefore, changed the aerodynamic shift from a rearward movement of 40 percent of the chord to a forward movement of 60 percent of the chord. Either one posed a problem in providing trim. The pulse rockets used to provide angles of attack during the test disturbed the model less than 3 degrees, an amount insufficient to allow a study of pitch-up characteristics at high angles of attack (ref. 79).

In a continuing evaluation of possible airplane configurations, a rocket model in the E15 series was flown with a wing of 3-percent thickness, aspect ratio 3, and diamond planform. In this test, a double Deacon booster was used to provide a Mach number of about 1.8. The low horizontal tail with negative dihedral was located in the conventional tail-aft position. The pitching moment curves for this configuration were quite linear at all positive angles of attack, with no evidence of any pitch-up tendency. At large negative angles, a pitch-down tendency was encountered at a Mach number of 0.95, but this would not be expected to cause any trouble in normal flight operations (ref. 80).

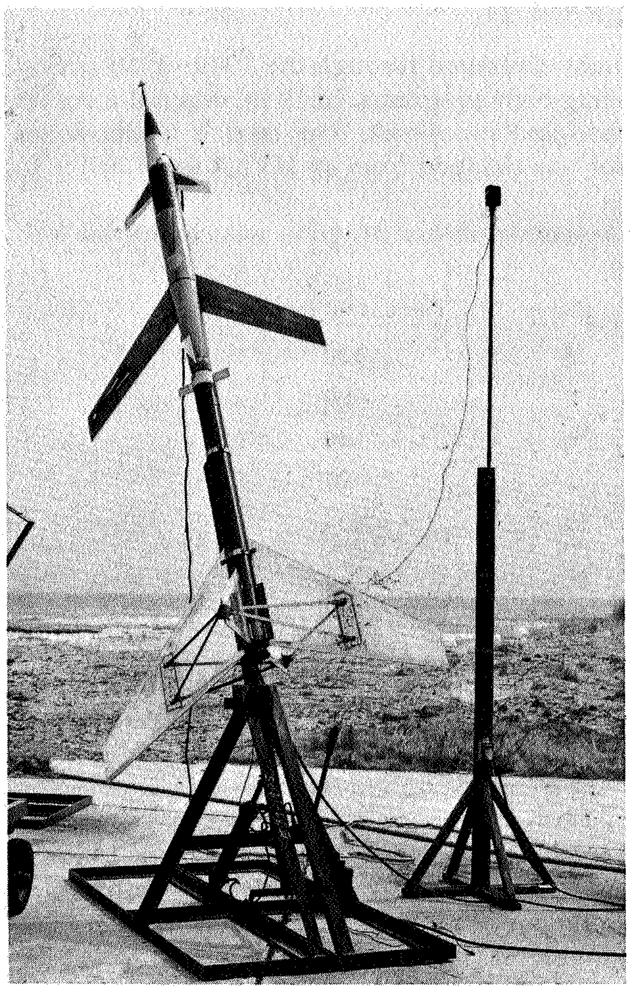


FIGURE 208. Canard stability research model on rail launcher at Wallops, March 26, 1954.

The last configuration in this series was a 52.5-degree delta wing of 3-percent thickness on the standard E15 body having the low horizontal tail with negative dihedral. A good general view of the area on the day of this launching may be seen in figure 209. In the test, the horizontal tail was pulsed to allow a study of lift, static and dynamic stability, control effectiveness, and drag at lifting conditions. A very complete set of data was obtained between Mach numbers of 0.79 and 1.83, with no indication of any undesirable characteristics (ref. 81).

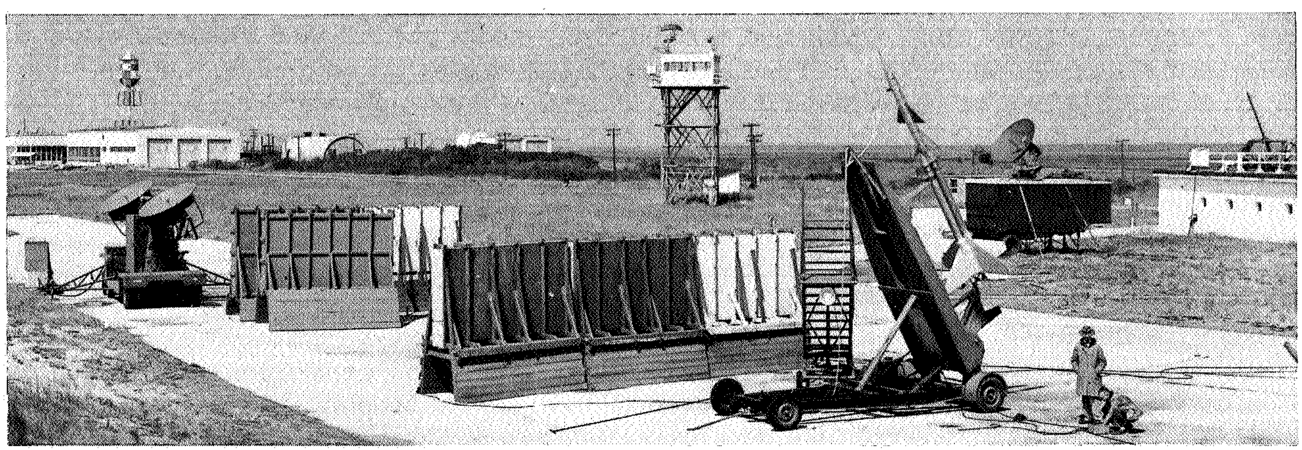


FIGURE 209. Engineer John C. Palmer and technician Franklin Forbes check firing circuit to E15 research model on mobile launcher, March 19, 1953. Seen in the background are the Control Center (at left) with telemeter antenna on roof, the movable SCR–584 radar, and the Control Tower with search radar. The safety barricades and Doppler radar are in position on the launch pad.

CONTINUATION OF WING FLUTTER PROGRAM

The experimental evaluation of wing flutter in free flight continued through the 1949–1956 period with the use of additional rocket-model and freely falling body programs. In 1949, nine FR-2 rocket models were flown, with wings of different aspect ratio and sweepback. The models in this series differed from the earlier FR-2 models in that the motor was changed from an HVAR to a Cordite to reduce the longitudinal acceleration.

All flights were successful. In fact, the entire rocket-model flutter program was conducted with high operational reliability, as shown by the following:

Type of Model	Number Flown	Failures	Percent of Success
FR-1	5	0	100
FR-2	20	2	90
FR-3	2	0	100
D18	19	1	95
D37	9	0	100
Total	55	3	95

Out of 55 firings, only three failures to gather data.

The nine FR-2 models were rather crude, as shown by figure 210. The test wings were clamped to the Cordite motor case, an ogive nose containing a two-channel telemeter was attached to the head of the motor, and four tail fins were fastened to the rear of the motor for stability. A maximum Mach number of 1.45 was obtained with these 55-pound models. The wings had sweepback angles from 0 degrees to 60 degrees and aspect ratios from 2.2 to 7.3. All wings were untapered.

The wings were arranged in three groups. The first two wings were unswept and had an aspect ratio of 7.3 to provide additional information on the type of flutter detected with an earlier FR-1 rocket model (as discussed in Chapter 5). In this type of flutter, wing bending coupled with the pitching motion of the complete model to provide a destructive type of flutter of rather low frequency. The second group of four wings had equal panel lengths but were sweptback by pivoting the panels about the juncture of the leading edge with the fuselage to form wings with 0-, 30-, 45-, and 60-degree sweepback. The unswept wing had an aspect ratio of 5.6, and the others were successively lower. The third group had 0-, 30-, and 60-degree sweepback formed by shearing the wing sections straight back while maintaining a constant aspect ratio of 3.3. It was hoped that these tests would settle the question of sweep effects as far as flutter was concerned.

Only two of these nine wings fluttered in the classical manner. Two of the wings traversed the speed range with no indication of flutter or failure. Three of the wings, two with 0-degree sweep and one with 30-degree sweep failed from aeroelastic divergence. Two of the high-aspect-ratio wings failed from a coupling between wing-bending and model-pitching modes and provided additional data for this type of flutter. This mode of flutter was later found to be associated with conditions in which the inertia of a wing in bending was large in relation to the inertia of the complete model in pitch.

Flutter was encountered with the remaining two wings. One had 30-degree sweepback and an aspect ratio of 5.6. The flutter speed was Mach 0.78, 10 percent greater than the calculated flutter speed. The other wing had 60-degree sweepback and an aspect ratio of 3.3, and fluttered at a Mach number of 1.01, 37 percent higher than the calculated speed (ref. 82).

In the calculation of flutter speed for these wings, a new approach proposed by J. G. Barmby, H. J. Cunningham, and I. E. Garrick was used (ref. 83). In this method, two-dimensional, incompressible, aerodynamic coefficients were used as before, but the velocity component at right angles to the leading edge of the wing was used to account for the sweepback effect in a manner analogous to the approach taken by R. T. Jones in analyzing the effect of sweep on drag rise. The bending and torsion modes and mode shapes were used in the calculations. This new method gave results more in line with experimental data on sweptback wings than had the previous method.

In a continuation of research on the effect of sweepback on flutter, two solid-metal, untapered wings were tested on a large freely falling body. One wing was made of magnesium with 4-percent

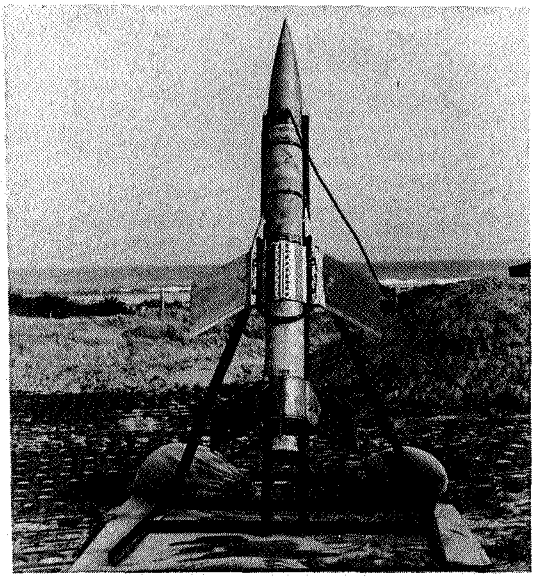


FIGURE 210. View of FR–2 flutter model with internal Cordite rocket motor. The model is shown on its rail launcher at Wallops, June 21, 1949.

thickness, while the other was made of steel with 3-percent thickness. This time, the calculations of flutter speeds were modified by use of compressible-flow, unsteady, aerodynamic coefficients. Something was obviously wrong with the calculation procedure, however, because no flutter was encountered over the speed range, which extended to a Mach number of 1.23. The calculations had indicated flutter at Mach 0.8 (ref. 84).

Variations in flutter speed for an unswept, high-aspect-ratio wing were obtained in the freely falling body program by equipping two bodies with such wings and then dropping the bodies from two different altitudes. The one released at high altitude reached transonic speeds at a higher altitude and, thus, a lower air density and higher flutter speed, both calculated and experienced. One model fluttered at Mach 0.85 for a flutter-speed ratio of 1.08, while the other fluttered at Mach 1.07 for a flutter-speed ratio of 1.23. This provided further evidence of the existence of a knee in the flutter-speed-Mach number curves at a Mach number near 0.9 (ref. 85).

In 1950, a new rocket-model flutter vehicle was introduced and designated D18. It was a two-stage system—a booster propelled the model to near the expected flutter speed, and then an internal Cordite motor provided the energy to traverse the test-speed range at a low acceleration. The D18 was essentially a complete airplane configuration with a fuselage and tail surfaces. The test wings were attached at their roots to a casting which formed the center section of the fuselage and which was slotted along the sides to receive wings of different chords as required. One of these models is shown in figure 211. Normally a nine-channel telemeter was used to transmit accelerations, angle of attack, and strain-gauge readings in the wings. The D18 vehicle was designed for use in an extensive general research program, and a number of such vehicles without wings were procured by outside contract. By 1953, however, the transonic blowdown tunnel at Langley had been converted for general flutter research and took over most of the general research (ref. 86). The main use made of the D18 vehicles, therefore, was in flight tests of scaled models of specific airplane wings, which will be discussed with other tests of the particular airplane, as has been done for the McDonnell XF3H-1 airplane earlier in this chapter.

The first D18 vehicles were used to gather additional data on the general subject of flutter of sweptback wings. One wing had an aspect ratio of 8.01, a taper ratio of 0.54, and sweepback of 45 degrees. The other had an aspect ratio of 4.25, a taper ratio of 0.54, and sweepback of 60 degrees. In the flight tests, both wings fluttered but neither failed structurally. The flutter speeds were Mach 0.89 and 1.09, just 5 percent above the calculated flutter speed. In these calculations, incompressible aerodynamics were again used (ref. 87). Apparently, the theory held better for these high-aspect-ratio wings than it had for the ones of lower aspect ratio discussed in the above series of nine FR-2 wings.

During 1953, flutter tests were made of three low-aspect-ratio, highly tapered, sweptback wings at speeds to Mach 2.0. These tests made use of the new simplified rocket vehicle designated D37 and discussed earlier in this chapter in connection with flutter tests of the Rigel missile. One of the models is

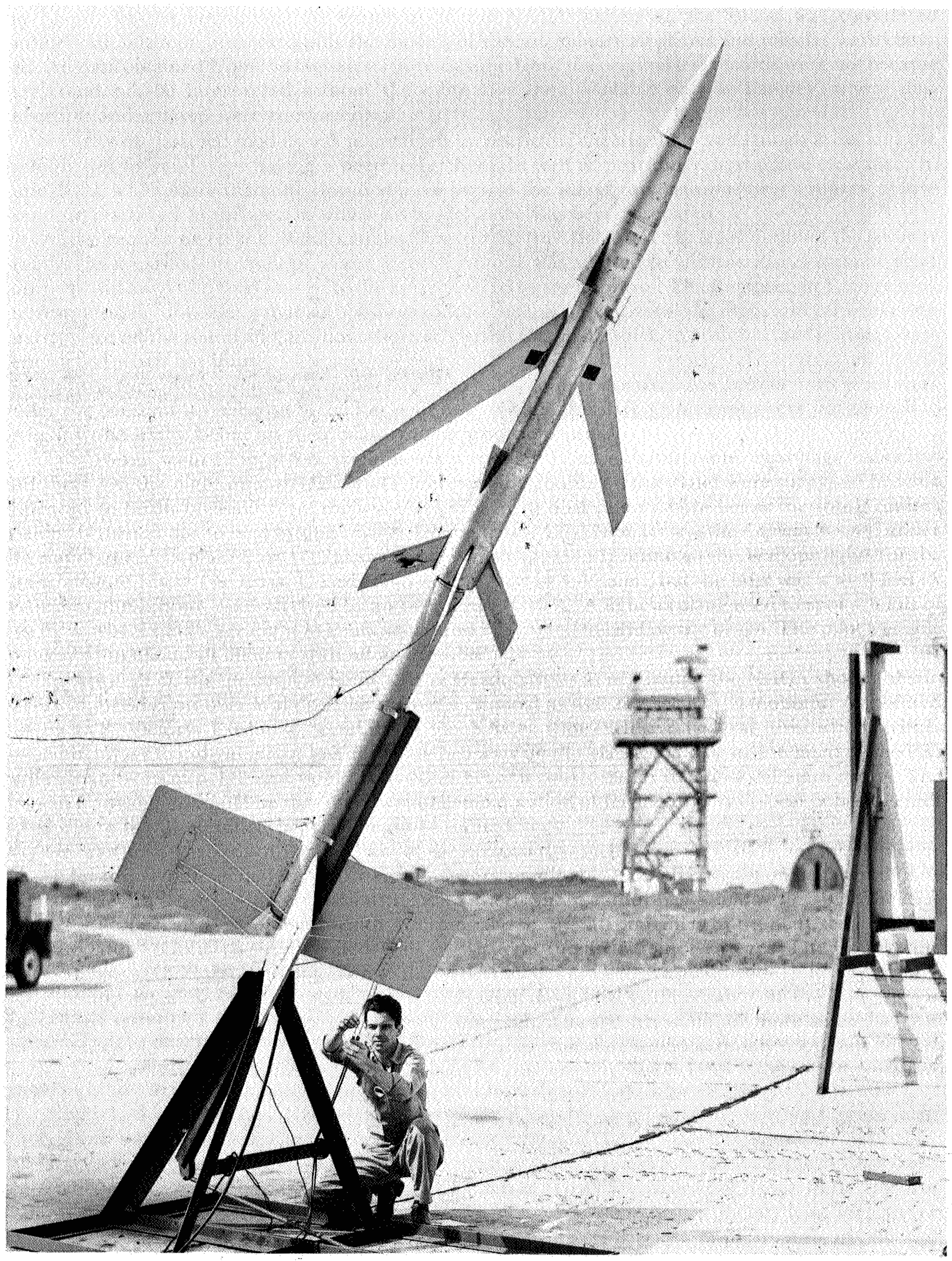


FIGURE 211. Engineer Burke O'Kelly examines firing leads to the booster of a D18 flutter research vehicle, May 16, 1952.

shown in figure 212. In this test, a 65-inch HVAR booster was used to reach Mach 1.0, and then an internal Cordite motor accelerated the model to nearly Mach 2.0. In addition to the 60-degree delta wing shown in figure 212, the tests included two wings having aspect ratios of 3.0, taper ratios of 0.2, and sweepback angles of 45 degrees and 60 degrees, respectively. All three wings started to flutter near Mach 1.0 and continued to the highest speed reached without failure. Calculated flutter speeds were close to those measured when effects of sweep were included, and when, in addition—for the 60-degree sweptback wing of aspect ratio 3.0—a third mode was included in the calculations. For this wing, the third mode involved bending of the outer one-fourth of the span, and was of lower frequency (148 cycles per second) than the torsion mode (197 cycles per second). The flutter frequency measured in flight was near that of the third mode, 120 to 160 cycles per second. The delta wing fluttered at random modes of varying frequencies between the second and third modes (ref. 88).

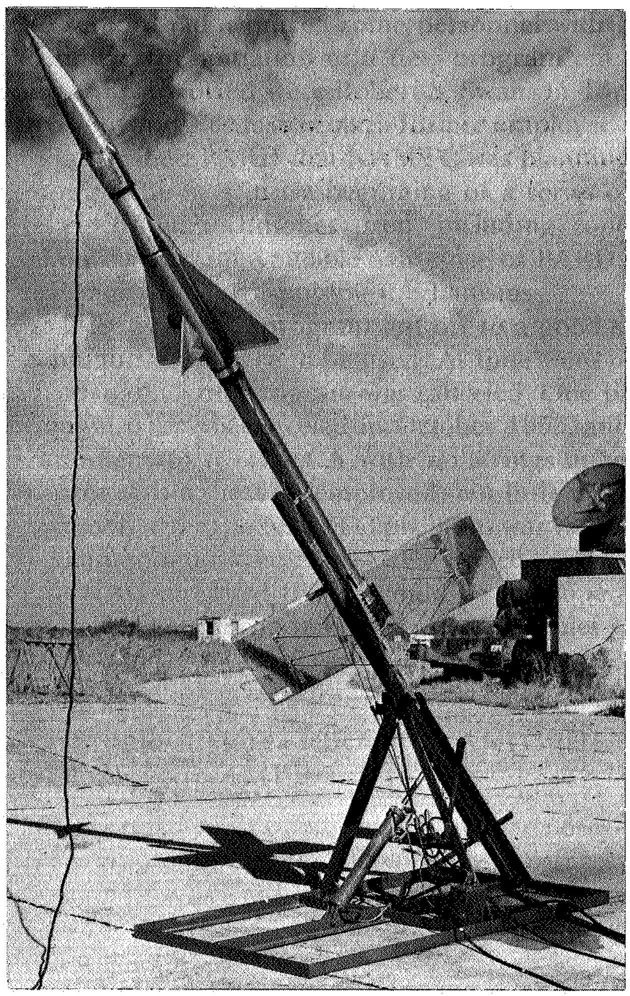


FIGURE 212. View of D37 high-speed flutter research vehicle on rail launcher, November 3, 1953.

After the first few years of experience at Wallops, flutter did not often interfere with the objectives of rocket-model flight tests. Occasionally, however, flutter did cause structural failure. One instance occurred during a series of tests of E5 lateral-control rocket models to determine aeroelastic losses for aileron and for spoiler-type lateral controls. Destructive flutter was encountered with the spoilers on the weakest wing but not with the wings having normal ailerons in a deflected state. H. Kurt Strass, project leader, was convinced that he had discovered a new phenomenon associated with spoiler controls. Two special models of these wings and spoilers were instrumented for flutter measurements and flight tested. The wings had 45-degree sweepback and an aspect ratio of 4.0, with a taper ratio of 0.6. Both models demonstrated destructive flutter of the bending-torsion type, starting at a Mach number of 0.90, 5 percent above the calculated value for this type of flutter for these wings (ref. 89). Despite this excellent agreement with a theory that did not include any consideration of the spoiler, Strass was not convinced that the spoiler did not have some influence on the results.

Another instance of destructive flutter was failure of a wing of a model of the Convair XF-92 prototype. The incident took place at Wallops on March 24, 1950. This 60-degree delta wing was constructed of mahogany with an aluminum insert along the chord plane near the trailing edge. Flutter began at Mach 1.11 during the deceleration phase, and failure occurred shortly thereafter (ref. 90).

A second 60-degree delta wing also fluttered during a series of tests of F25 models designed to study the drag of various nacelles on delta wings. A wing without any nacelles did not flutter during the acceleration phase to Mach 2.3, but fluttered without failure from Mach 2.3 down to 1.08 in the deceleration phase. At the highest speeds, flutter was close to the third mode or pure torsion frequency, 148 cycles per second; but near Mach 1.7, the frequency dropped sharply to about 80 cycles, halfway between the first and second modes. This wing was also made of wood, but the aluminum insert covered the entire wing along the chord plane (ref. 91). In a repeat test with the wing stiffened by aluminum sheets as surface inlays on the top and bottom of the wing, flutter was again encountered without failure as the model decelerated from Mach 2.1. This wing was basically stiffer in the area covered by the inlays, but the thin trailing edge and tip areas were not stiffened, and it was believed that the flutter obtained was associated with motions predominately in those areas (ref. 92).

In flight tests conducted at Wallops as part of the E17 large-scale wing-drag program, five additional wings having pointed tips experienced similar nondestructive flutter at Mach numbers to 1.95. Again, it was concluded that the trouble lay in weak construction of trailing-edge and tip areas (ref. 93).

To summarize the situation with regard to flutter of wings in the transonic and supersonic range during the 1950–1955 period, several findings were significant. For straight wings, existing two-dimensional incompressible-flow theory provided a satisfactory prediction of flutter speeds to a Mach number of 0.90. Above this Mach number, such a theory became increasingly conservative. For sweptback wings, the use of the component of flow velocity normal to the leading edge of the wing likewise gave satisfactory predictions of flutter speeds, but the extent of application was increased to about Mach 1.1 for 60-degree sweep. A nondestructive type of flutter encountered with sweptback wings extended into the supersonic range. Nondestructive flutter at high frequencies was also encountered with thin, pointed wings and was associated with local structural weakness.

On April 14, 1958, a D18 airframe was used to study the effectiveness in flight of a pulse rocket fired sideways from the fuselage above an unswept tapered wing as a flutter-exciting device. Although a D18 airframe was used, the model was given a D3 designation because longitudinal stability was also measured in the flight test. A maximum Mach number of 2.1 was reached in this test, with use of a double Deacon booster. The tests indicated that the pulse rocket induced a normal force on the wing from 5 to 8 times the value of the direct thrust. It was concluded that pulse rockets offered a simple and effective means of exciting wing oscillations for flight flutter testing without affecting the wing response (ref. 94). Although effective, this scheme was not pursued further.

AERODYNAMIC HEATING AND FLUTTER OF STRUCTURAL PANELS

The 27-inch, Mach 2.0 nozzle of the Preflight Jet at Wallops, with its true temperature and sea-level pressure conditions, had a unique capability for structural tests of models of actual wing panels at supersonic speeds. From March 24, 1952, until July 31, 1956, it was used extensively for this purpose by the Langley Structures Research Division with the assistance of PARD personnel at Langley and Wallops, pending construction of the 9-foot by 6-foot Thermal Structures Tunnel at Langley.

This new facility, designed with the benefit of experience with the Preflight Jet, was likewise a blowdown facility, but it had greater testing capabilities with its closed test section of larger size and higher speed. It was under the direction of Douglas H. Foland, who, as head of the PARD Preflight Jet section at Langley, had had the overall responsibility for the Preflight Jet and had been closely associated with the structures tests there. Foland was transferred to the Structures Research Division on November 28, 1955, to work on the 9-foot by 6-foot facility and became its head in December 1956.

The project involving tests of typical wing panels in the Preflight Jet was proposed by R. R. Gilruth in 1951, after he had been promoted to Assistant Chief of Research with cognizance over the Structures Research and Dynamic Loads divisions as well as PARD. R. R. Heldenfels was selected to head this project, in view of his interest in the effects of aerodynamic heating on structures, as evidenced by his calculations of such effects (ref. 95). The Dynamic Loads division had been involved with flutter testing in flight at Wallops for some time, and with this new structures project in the Preflight Jet, Gilruth now had all of his research divisions using the Wallops facilities.

Prior to Gilruth's promotion, the Structures Research Division had made studies of experimental facilities required for the study of problems associated with aerodynamic heating, particularly under transient conditions.[15] The studies were mainly a result of a resolution of the NACA Subcommittee on Aircraft Structures at its meeting on March 8, 1951. The subcommittee was concerned about the small amount of research being done on elevated temperature problems and about the lack of experimental facilities for such research. It recommended that the NACA study the problem and present a proposal at the next meeting.

Under the direction of Samuel Batdorf, a budget proposal was prepared in June 1951 for construction of a "High-Temperature Structural Research Laboratory." It was to be a subsonic blowdown facility with air stored under pressure in two large spheres and heated by a heat exchanger as the air flowed from the spheres to the closed test section. The test section was to be 20 feet wide and 8 feet high. Heating of the test models was to be accomplished by the use of radiant-heating panels to supplement the heating from the heated air flowing over the model at subsonic speeds. Structural loading of the test model was to be applied through insulated support links connected to external loading elements. The proposal was sent to NACA Headquarters in August 1951 and was accepted as part of the NACA budget for fiscal 1953. In mid-1952, approval was obtained for construction of the facility.

Gilruth had not been involved with the preliminary planning of this high-temperature structures facility, and he was not satisfied with its subsonic speed and external loading feature. Recognizing that it was impossible to obtain the correct conditions in such a facility, he set about to give the laboratory true speed as well as true temperature. In addition, he felt that Structures Division personnel needed experience in a heated facility prior to designing a large laboratory and, with this in mind, initiated the project in the Preflight Jet mentioned earlier.

Batdorf resigned from Langley in the Fall of 1951 and left the Structures Division without a project leader for the new facility. Progress in converting the design to one meeting the ideas of Gilruth was slow. In fact, E. E. Lundquist, Chief of Structures, delayed the appointment of a successor to Batdorf on the project. Gilruth and Thompson were dissatisfied with Lundquist's approach to this very urgent problem, and established a separate unit to supervise design of the new facility.[16] This unit was designated the Structures Research Facility Unit in the Office of Chief of Research, and John E. Duberg and Richard R. Heldenfels were transferred to this unit from the Structures Division on February 14, 1952 (ref. 96). This unit was given an office in the PARD building at Langley across the hall from the Preflight Jet section, and was assigned the job of supervising the design of a suitable supersonic structures facility. A preliminary layout of a Mach 3 heated facility, very similar to the one finally constructed, was presented by Heldenfels on March 20, 1952.

When the first structural panel tested in the Preflight Jet at Wallops failed dramatically on March 24, 1952, under simulated flight conditions, the time for changes in management of the Structures Division had come. The situation regarding the need for correct simulation of flight conditions was aptly summarized in the report on this first test (ref. 97):

> The test clearly demonstrates that there is much to be learned about the individual and combined effects of aerodynamic heating and loading on aircraft structures and that, when the effects are not simultaneously considered, factors which vitally affect the structural integrity of an aircraft may be overlooked.

15. Author's interview with R. R. Heldenfels, Langley Research Center, September 3, 1968, and notes by Heldenfels, October 3, 1968.
16. Author's interview with Floyd L. Thompson, Hampton, Virginia, December 21, 1968.

On April 4, 1952, 11 days after this test, Duberg and Heldenfels were transferred back to Structures, and Duberg was appointed Chief of the division. Lundquist was placed in charge of a Theoretical Structures Group in the Office of Chief of Research (ref. 98).

Another indication of the rapid shift in emphasis on high-temperature structures research was the number of professionals in the Structures Research Division engaged in such research. Whereas, prior to 1951, an average of 2 men out of 47 were engaged in high-temperature research, in 1952 the number jumped to 11, and, by 1957, 50 out of 62 professionals were so engaged.

The wing that shook up the Structures Research Division is shown in figure 213 as it appeared before the test, and, in figure 214, as it looked afterward. The wing panel had a chord and a span of 40 inches and was mounted at 0-degree angle of attack downstream of the 27-inch Mach 2 nozzle of the Preflight Jet at Wallops. The root of the wing was clamped in a bracket and the tip was secured with four guy wires, as shown. The jet was started with no mishap until 7.5 seconds later. At that time, a vibratory motion began, and the model was destroyed in about 2 seconds. The test was designed to investigate transient temperature distribution; the dynamic failure was a complete surprise.

Analysis showed that the flutter was initiated by a buckling of the skin from unequal external and internal temperatures resulting from aerodynamic heating. The phenomenon observed was a chordwise type of flutter (flag waving) brought on by a reduction of structural stiffness due to thermal stresses. The dramatic high-speed motion picture film of this failure, along with others, was shown to thousands of people across the nation and awakened the interest of the aeronautical community in this new structural problem.

The transient temperatures of the skin and interior structure of this first wing were calculated by several methods involving different degrees of approximation, and were found to be in good agreement with the experimental temperatures when proper account of heat conduction was taken. An NACA Conference on Aircraft Loads, Flutter, and Structures held at Langley March 2–3, 1953, afforded an excellent opportunity to present these data (ref. 99).

Six additional wing panels were tested in the first series in the Preflight Jet. Following the first test, the wing size was reduced to 20-inch chord and span for all succeeding models. The wing root was clamped as before, but the wing tip was not unsupported, as shown in figure 215. Two wings of the same general construction as the first failed in a similar manner following unequal heating, distortions,

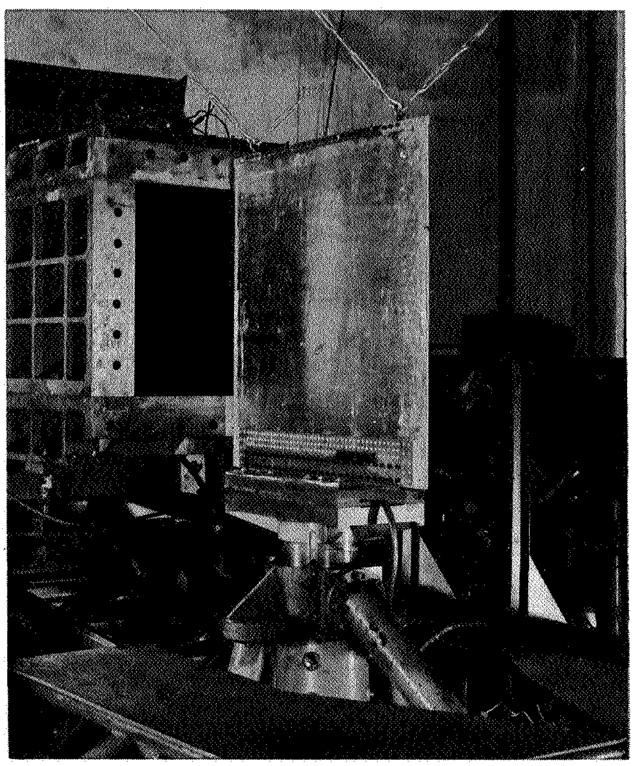


FIGURE 213. Structures research wing of 40-inch chord and span, shown in 27-inch Mach 2 nozzle of Preflight Jet, March 24, 1952.

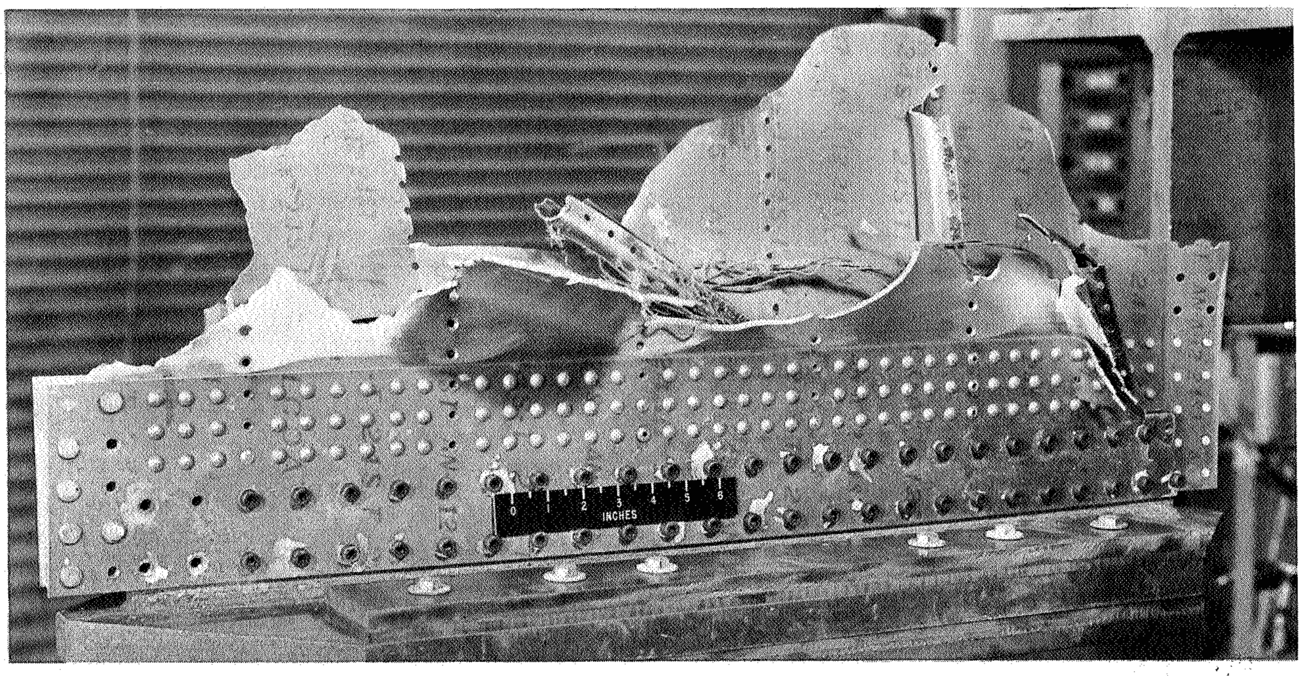


FIGURE 214. Remains of 40-inch-span structures research wing after failure in Preflight Jet, March 24, 1952.

and a destructive, flag-waving type of flutter. Failure was prevented for four wings by increasing the thickness of the skin, by adding chordwise ribs, or by using steel instead of aluminum in the construction (ref. 100).

This marked the beginning of a continuing program of tests of actual structures in the Preflight Jet, and represented one of many new uses to be made of the facility.

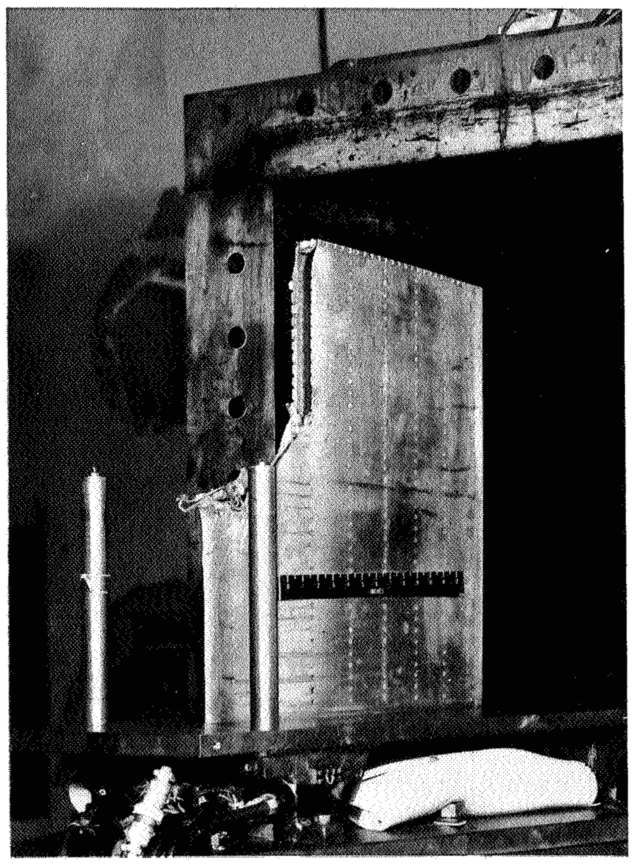


FIGURE 215. View of the first of a series of 20-inch-cord-and-span structures research wings, following test at Mach 2 in Preflight Jet, September 30, 1952.

SIMPLE INFRARED MISSILE HOMING SYSTEM: D38

By 1952, the Air Force still did not have an operational supersonic air-to-air guided missile, and its complexity seemed to extend its development indefinitely. Through various committees and panels, the Air Force asked for ideas for simplifying the missile systems. Gilruth, an active member of the committees, encouraged PARD researchers to think along these lines. A number of simplified control and stability components were proposed and evaluated, but the most radical proposal, made by Gilruth, was a complete guided missile system with only one moving part.

Gilruth formed a special team at Langley to develop the idea and to establish the validity of the concept. Robert A. Gardiner was the project manager, assisted by C. L. Gillis, C. A. Brown, H. D. Garner, G. B. Graves, Jr., A. L. Passera, and H. J. E. Reid, Jr. Wind-tunnel and rocket-model tests were made of components and complete systems, and an active simulator was constructed. The project was designated D38, and a total of 18 firings of rocket models were made at Wallops, including three complete systems fired at aerial targets. The program at Wallops extended from May 1952 to March 1955.

Figure 216 shows one of the missiles on the trainable launcher used in the final flights. The missile was designed around an HPAG rocket motor, with four fins mounted near the rear of the motor serving as stabilizing and lifting surfaces. This was the motor in use in the Navy Sidewinder missile, which also contained several new concepts aimed at simplification. A section slightly larger in diameter than the motor was attached to its head end and contained the target seeker, space for a warhead, the control system, and a telemeter compartment. Controls were set to trim the missile at about a 5-degree angle of attack at supersonic speeds, to provide maneuver capability. All of the nose section ahead of the telemeter compartment was mounted on bearings to allow freedom in roll.

In operation, the nose section would either roll continuously under the action of a deflected aileron or would hunt back and forth under the action of ailerons that were deflected alternately to the left and then to the right. When the flight path of the missile was aligned with the target, a continuous roll canceled the lift and produced an essentially straight but sightly helical flight path. When the missile was off target, the ailerons would force a hunting oscillation about a pursuit flight path, and the missile would maneuver toward the target. The target seeker had a narrow rectangular field 1 degree wide by 5 degrees long with a 1-degree circular dead spot that would trigger the ailerons every time the target image crossed the seeker detection rectangle. A lead sulfide infrared detector was used. A glass window over the detector was protected by a tripod windshield developed in the E2 seeker-nose studies discussed in Chapter 9. This tripod was replaced by an octopod in later flights.

As part of the development phase of this project, a simulator was constructed to study the dynamics of the system. For this purpose, a tricycle was converted into a simulated missile. The target was a motor-driven cart equipped with a light source (ref. 101).

As a result of improper performance of the missile at subsonic speeds in one flight test, the pitch control was modified so that it provided trim only at supersonic speeds. This was done by setting the canard fins to provide pitch and then counteracting their action by deflecting trailing-edge flaps on the same surfaces in the opposite direction. At subsonic speeds, the flaps would cancel the lift of the canards, but they would not do so at supersonic speeds.

The D38 simple homing system was limited to the correction of relatively small angular errors, but was expected to be one step better than unguided rockets.

Flight tests of the complete missile were made at night, first against an essentially stationary target in the form of a high-powered parachute flare, and finally against a ground-launched jato (14AS1000) equipped with an aircraft flare. The flights demonstrated both the pursuit and homing phases of operation of the missile and indicated that this unique principle of guidance and control was fundamentally sound. Considerable improvement, however, was needed to make the system operational as an air-to-air guided missile against aircraft at high altitude (ref. 102).

After all modifications to the missile geometry had been completed, a special missile without the homing system was flown to determine the overall aerodynamic characteristics. Pulse rockets were used to provide disturbances in flight. A two-stage propulsion system provided a maximum Mach number of 1.54 in the tests (ref. 103).

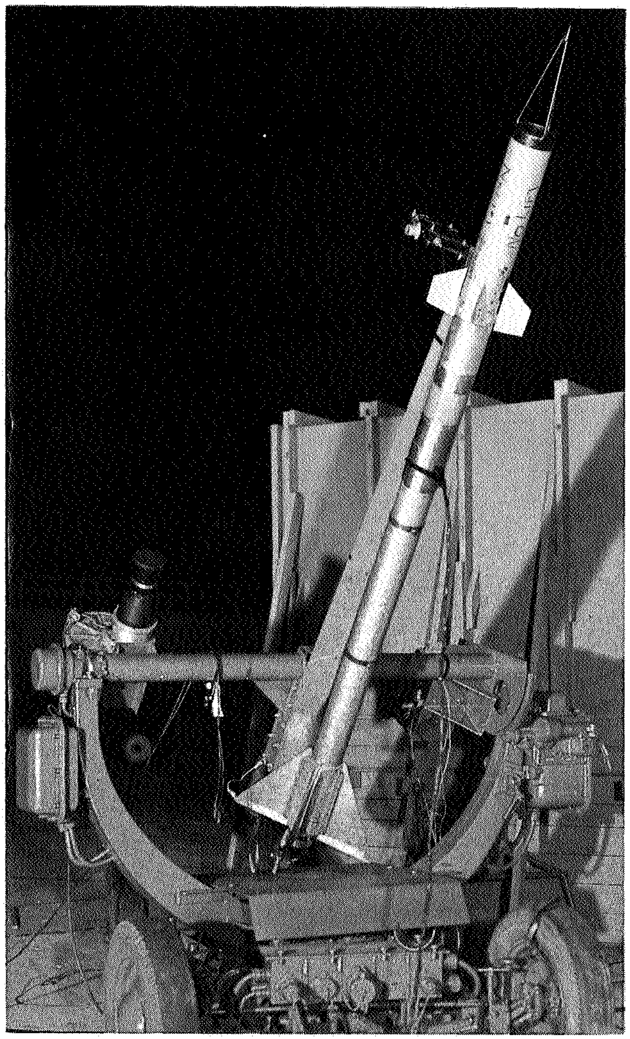


FIGURE 216. Preparation for night launching at Wallops, February 10, 1954. A D38 simple infrared homing missile is shown on the trainable launcher.

GUST LOADS RESEARCH AT TRANSONIC SPEEDS: E39

The subject of gust loads on aircraft had been studied by the Dynamic Loads Division at Langley for many years, theoretically and then experimentally with full-scale airplanes in flight and, later, with models in the Langley Gust Tunnel. The airplane flight investigations were confined to configurations available for study, and were limited by the performance capabilities of the airplanes. The Gust Tunnel was limited to low speeds and allowed determination of only the initial response to a single gust. In view of these limitations, an exploratory investigation was undertaken to determine the feasibility of using rocket-powered models to extend the range of experimental studies. This rocket-model program was designated E39 and was initiated cooperatively by the Dynamic Loads Division and PARD. The initial launching was made on October 3, 1952. Ten models were eventually launched over a 5-year period.

In preparation for the tests, the turbulence spectrum over Wallops was determined for a variety of atmospheric conditions by aerial surveys conducted with an F-51 airplane. From this survey, it was found that clear-air turbulence below an altitude of 2,500 feet occurred normally when the wind was from the west (land breeze) following passage of a cold front. Surveys by the same airplane were made on the days used for launchings, to determine the actual gust intensity.

The first airplane configuration selected for test in the E39 program was a duplicate of the basic F25 wing and body with no horizontal tail, as used earlier in the nacelle-drag program. In figure 217, it is shown at Wallops ready for launching at an elevation angle of 25 degrees. Other tests had shown that this configuration had low damping-in-pitch and large aeroelastic effects. The wing was wing H of the transonic program and had sweepback of 45 degrees, an aspect ratio of 6.0, and a taper ratio of 0.6.

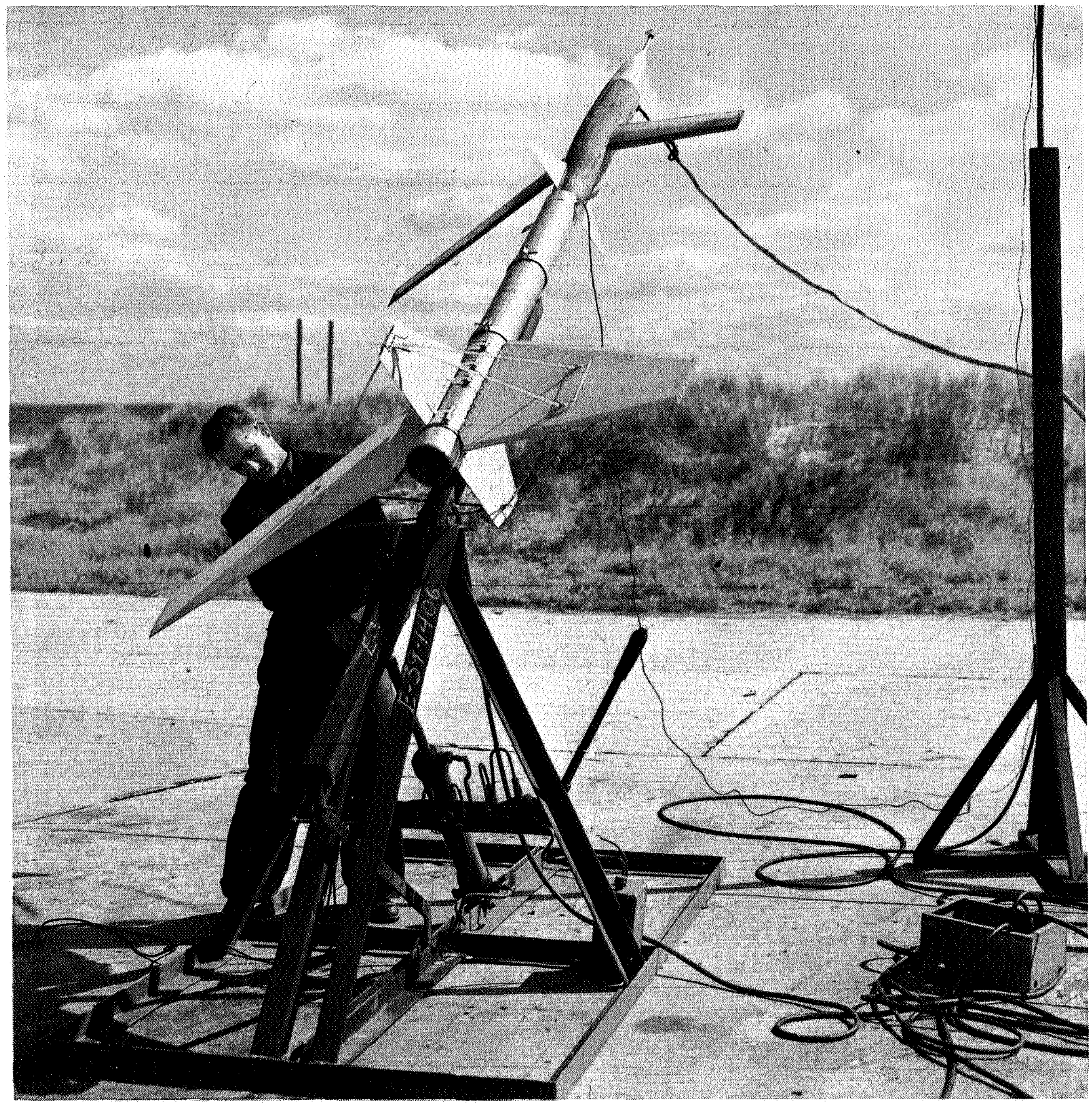


FIGURE 217. Technician Roy Hindle adjusts launcher for E39 gust research model, October 3, 1952.

The airfoil section was 65A009 in the streamwise direction. A two-stage propulsion system was used. First, a lightweight HVAR motor boosted the model to a Mach number of 1.1 at an altitude of 500 feet. This was followed by a 10-second coast period during which the model slowed to Mach 0.8, and then an internal 3.25-inch motor accelerated the model to Mach 1.3 at an altitude of 2,500 feet. After this, the model decelerated to Mach 0.85 at an altitude of 1,000 feet. By this means, it was possible to obtain, in effect, two flights through the transonic range at low altitude with a single model. A second, identical model was launched on the same day to an altitude of 6,000 feet to allow a comparison with model responses in relatively smooth air.

The model in flight through rough air underwent sustained and irregular oscillations with the predominant frequency near that of the normal short-period longitudinal oscillation. The second model at higher altitude showed practically no disturbances. A power-spectral-density analysis of the response of the first model to gusts showed that it acted as a narrow-band-pass filter. Maximum response was at the model's natural frequency. An 85-percent increase in root-mean-square acceleration was measured as the Mach number was increased from 0.85 to 1.0, largely associated with the loss of damping in this range. It was concluded that "This technique is feasible and practical for the study of large-order effects on gust loads" (ref. 104).

The next series of E39 models was designed to show the response of the same configuration modified by the addition, first, of a conventional horizontal tail; and, second, by the addition of a canard tail surface. The canard model was identical to the one discussed earlier in this chapter under stability research and shown in figure 208. The results of these two new E39 tests were similar to those of the tailless model as far as response frequency was concerned, but models with tails did not show the increase in magnitude of accelerations at Mach 1.0 because of their higher damping-in-pitch. An improvement in the technique was made by obtaining indications of atmospheric turbulence through measurements made with a special instrument that recorded fluctuations in total pressure caused by gusts (ref. 105).

Another improvement in data analysis was made possible through the recording of telemetered acceleration data on magnetic tape. A section of the tape, formed as a continuous loop, could then be run through a harmonic analyzer to determine the response at discrete frequencies. Such an analysis showed responses with peaks at the wing-bending and body-bending modes, in addition to the natural frequency in pitch.

The next E39 model flown was a tailless model with 60-degree delta wings that had also exhibited low damping-in-pitch at transonic speeds. A cruciform arrangement of wings (4 panels) was used to double the amount of data and to determine whether it would be possible to test two different wing arrangements on a single model. A four-channel telemeter transmitted measurements of normal and transverse accelerations, total pressure, and fluctuations in total pressure. The results were similar to those obtained earlier with a tailless model in regard to responses at the pitch frequency and also in regard to effect of low damping-in-pitch on acceleration response. The two sets of wings gave similar results and indicated that two different wings could be compared by this method if at least a 5-second record were obtained at a nearly constant Mach number (ref. 106).

The overall flight investigation of the response of rocket models of airplane configurations to gusts at transonic speeds confirmed the findings of prior analyses that such models would respond to conditions of low damping-in-pitch noted at such speeds, with resulting amplification of normal loads. This was in addition to the usual response of structures at natural bending frequencies. The use of power-spectral-density analysis of response to gusts was shown to be a useful tool for quantitative determination of gust loads.

References

1. Brown, C. E.; O'Sullivan, W. J., Jr.; and Zimmerman, C. H.: *A Study of the Problems Relating to High-Speed High-Altitude Flight,* Langley document, June 25, 1953.
2. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Space and Technology in the Exploration of Space, 1915–1960.* NASA, 1961, p. 75.
3. *Ibid.*, p. 113.
4. *Ibid.*, p. 91.
5. Langley PARD, "Hypersonic Research," proposal transmitted to NACA Headquarters June 5, 1953.
6. Thibodaux, J. G., Memorandum for Chief of Research, Mar. 6, 1952, proposing the development of a 60,000-pound/second rocket motor.
7. Krieger, R. L., Engineer-in-Charge, Wallops Island, Memorandum for Chief of Research, Oct. 23, 1952, regarding travel authority to visit Erie Arsenal.
8. Krieger, R. L., Memorandum for Associate Director, May 28, 1953, regarding loan of T–121 launcher from Army Ordnance.
9. Morrison, C. R., Memorandum for IRD Files, June 19, 1950, regarding projected work on radar beacons.
10. Krieger, R. L., Memorandum for Associate Director, July 22, 1953, regarding visit to Operations Office, Air Force, Atlantic Fleet.
11. Krieger, R. L., Memorandum for Director, Nov. 17, 1953, regarding Navy request for approval to build plate test facility.
12. Hall, James R.; and Hopko, Russell N.: *Drag and Static Stability at Low Lift of Rocket-Powered Models of the Convair MX–1626 Airplane at Mach Numbers From 0.7 to 1.5.* NACA RM SL53F09a.
13. Hopko, Russell N.; Piland, Robert O.; and Hall, James R.: *Drag Measurements at Low Lift of a Four-Nacelle Airplane Configuration Having a Longitudinal Distribution of Cross-Sectional Area Conducive to Low Transonic Drag Rise.* NACA RM L53E29.

14. Hall, James Rudyard: *Drag Measurements on Equivalent Bodies of Revolution of Six Configurations of the Convair MX−1964 (Originally MX−1626) Proposed Supersonic Bomber.* NACA RM SL53K04.
15. Emme, *op. cit.*, pp. 174, 187, 199.
16. Hopko, Russell N.; and Kinard, William: *Drag at Model Trim Lift of a 1/15-Scale Convair B−58 Supersonic Bomber.* NACA RM SL56G23.
17. Hopko, Russell N.: *Drag Near Zero Lift of a 1/7-Scale Model of the Convair B−58 External Store as Measured in Free-Flight Between Mach Numbers of 0.8 and 2.45.* NACA RM SL55G22a.
18. Hollinger, James A.: *Canard Hinge Moments and Longitudinal Stability of a 1/7-Scale Model of the Convair B−58 External Store in a Free-Flight Investigation at Mach Numbers from 0.94 to 2.58.* NACA RM SL58F10.
19. Shortal, J. A., Memorandum for Associate Director, Feb. 7, 1950, regarding request for tests of rocket models of MX−770 missile.
20. Bond, Aleck C.; and Swanson, Andrew G.: *Rocket-Model Investigation of the Longitudinal Stability, Drag and Duct Performance Characteristics of the North American MX−770 (X−10) Missile at Mach Numbers From 0.80 to 1.70.* NACA RM SL53D10a.
21. Crabill, Norman L.: *The Effects of Extensible Rocket Racks on Lift, Drag, and Stability of a 1/10-Scale Rocket-Boosted Model of the McDonnell XF3H−1 Airplane For a Mach Number Range of 0.60 to 1.34.* NACA RM SL53F15.
22. Crabill Norman L.; and McFall, John C., Jr.: *Summary of the Lift, Drag, and Stability of 1/10-Scale Rocket-Boosted Models of the McDonnell XF3H−1 Airplane For a Mach Number Range of 0.6 to 1.4 as Affected By the Operation of Extensible Rocket Racks.* NACA RM SL54A18.
23. Crabill, Norman L.: *Lift, Drag, Static Stability, and Buffet Boundaries of a Model of the McDonnell F3H−1N Airplane at Mach Numbers From 0.40 to 1.27.* NACA RM SL56A13.
24. Crabill, Norman L.; and Jackson, Bruce G.: *Some Transonic Aerodynamic Characteristics of a Model Similar to the McDonnell F3H−2N Airplane.* NACA RM SL56E15.
25. Merlet, Charles F.; and Carter, Howard S.: *Total-Pressure-Recovery Characteristics of a Model of the McDonnell XF3H−1 Inlets and Forebody in a Free Jet at a Mach Number of 1.55.* NACA RM SL52C12.
26. Carter, Howard S.; and Merlet, Charles F.: *Flight Determination of the Pressure Recovery and Drag Characteristics of a Twin Side-Inlet Model at Transonic Speeds.* NACA RM L53E05.
27. Strass, H. Kurt; and Marley, Edward T.: *Rocket Model Investigation of Rolling Effectiveness of the McDonnell XF3H−1 Wing Control Configuration at Mach Numbers From 0.6 to 1.5.* NACA RM SL51I28.
28. English, Roland D.: *Rocket-Powered-Model Investigation of the Effects of Aeroelasticity on the Rolling Effectiveness of an 8.06-Percent-Scale McDonnell F3H−1 Airplane Wing at Mach Numbers From 0.5 to 1.4.* NACA RM SL54D12.
29. O'Kelly, Burke R.; Lundstrom, Reginald R.; and Lauten, William T., Jr.: *Free-Flight Tests of 1/11-Scale McDonnell XF3H−1 Airplane Wings to Measure Wing Damping of the First Bending Mode and to Investigate the Possibility of Flutter at Transonic Speeds.* NACA RM SL54C22.
30. O'Kelly, Burke R.; and Lauten, William T., Jr.: *Free-Flight Tests of Three 1/9-Scale Models of the Wing-Ramjet Configuration of the Grumman XSSM−N−6a (Rigel) Missile to Investigate the Possibility of Flutter.* NACA RM SL53D15.
31. Seaberg, Ernest C.; and Geller, Edward S.: *Flight Investigation of the Aerodynamic Derivatives and Performance of Control Systems of Two Full-Scale XASM−N−4 Dove Bombs.* NACA RM SL53E22.
32. Littell, R. E., Memorandum, Oct. 28, 1948, regarding Army Ordnance proposal of a free-flight diffuser test.
33. Hinners, Arthur H., Jr.: *Preliminary Flight Measurements of the Total-Pressure Recovery of a Split-Wing Ramjet Inlet at Mach Numbers From 1.4 to 3.16.* NACA RM SL54C03.
34. Falanga, Ralph A.: *Flight Investigation of Nine Reduced-Scale (1:3.75) Hermes A−2S Rocket-Motor Test Vehicles.* NACA RM SL53H11.
35. von Braun, Wernher; and Ordway, Frederick I., III: *History of Rocketry and Space Travel.* 1966, p. 126.
36. Jackson, H. Herbert: *Longitudinal Aerodynamic Characteristics and Effect of Rocket Jet on Drag of Models of the Hermes A−3A and A−3B Missiles in Free Flight at Mach Numbers From 0.6 to 2.0.* NACA RM SL55F15.
37. Welsh, Clement J.: *Combustion in the Wake as a Means of Body-Drag Reduction as Determined From Free-Flight Tests of 40-Millimeter Shells.* NACA RM SL53D01a.
38. O'Sullivan, William J.; Chauvin, Leo T.; and Rumsey, Charles B.: *Exploratory Investigation of Transpiration Cooling to Alleviate Aerodynamic Heating on an 8° Cone in a Free Jet at a Mach Number of 2.05.* NACA RM L53H06.
39. Chauvin, Leo T.; and Carter, Howard S.: *Exploratory Tests of Transpiration Cooling on a Porous 8° Cone at M = 2.05 Using Nitrogen Gas, Helium Gas, and Water as Coolants.* NACA RM L55C29.
40. Rashis, Bernard: *Exploratory Investigation of Transpiration Cooling of a 40° Double Wedge Using Nitrogen and Helium as Coolants at Stagnation Temperatures of 1,295° to 2,910°F.* NACA RM L57F11.
41. Carter, Howard S.: *Water-Film Cooling of an 80° Total-Angle Cone at a Mach Number of 2 For Airstream Total Temperatures up to 3,000° R.* NASA Memo 12−27−58L.
42. Hinners, Arthur H., Jr.; and Foland, Douglas H.: *Preflight Tests and Flight Performance of a 6.5-Inch-Diameter Ramjet Engine.* NACA RM L53H28.
43. Faget, Maxime A.: *A Proposed Ramjet Control System Operated By Use of Diffuser Pressure Recovery.* NACA RM L52E05b.
44. Dettwyler, H. Rudolph; and Trout, Otto F., Jr.: *Flight and Preflight Evaluation of an Automatic Thrust-Coefficient Control System in a Twin-Engine Ramjet Missile.* NACA RM L53K13.
45. Thibodaux, J. G., Memorandum for Chief of Research, Nov. 1, 1949, regarding conference on the launching of a rocket-boosted Cleveland ramjet.
46. Disher, John H.; Kohl, Robert C.; and Jones, Merle L.: *Free-Flight Performance of a Rocket-Boosted, Air-Launched 16-Inch Diameter Ramjet Engine at Mach Numbers up to 2.20.* NACA RM E52L02.

47. Jones, Merle L.; Rabb, Leonard; and Simpkinson, Scott H.: *Drag Data For 16-Inch-Diameter Ramjet Engine With Double-Cone Inlet in Free Flight at Mach Numbers From 0.7 to 1.8.* NACA RM E54H02.
48. Messing, W. E.; and Aker, Loren W.: *Transonic Free-Flight Drag Results of Full-Scale Models of 16-Inch-Diameter Ramjet Engines.* NACA RM E52B19.
49. Messing, Wesley E.; and Rabb, Leonard: *Transonic Free-Flight Investigation of the Total Drag and of the Component Drags (Cowl Pressure, Additive, Base, Friction, and Internal) Encountered by a 16-Inch-Diameter Ramjet Engine For Mach Numbers From 0.80 to 1.43.* NACA RM E52F02.
50. Disher, John H.; and Rabb, Leonard: *Initial Performance Investigation of Pentaborane Fuel in Free-Flight Ramjet Engine.* NACA RM E54D28.
51. Jones, Merle L.; and Disher, John H.: *Flight Investigation of Pentaborane Fuel in 9.75-Inch-Diameter Ramjet Engine at Low Equivalence Ratio.* NACA RM E54L02.
52. Disher, John H.; and Jones, Merle L.: *Flight Investigation of Pentaborane Fuel in 9.75-Inch-Diameter Ramjet Engine With Downstream Fuel Injection.* NACA RM E55G01.
53. Disher, John H.: *Flight Investigation of Pentaborane Fuel in Rocket-Boosted 9.75-Inch-Diameter Ramjet Engine With Convergent-Divergent Exhaust Nozzle.* NACA RM E57F27.
54. Sears, R. I.; Merlet, C. F.; and Putland, L. W.: *Flight Determination of Drag of Normal-Shock Nose Inlets With Various Cowling Profiles at Mach Numbers From 0.9 to 1.5.* NACA RM L53I25a. Reissued as NACA TR 1281, 1956.
55. Merlet, Charles F.; and Putland, Leonard W.: *Flight Determination of the Drag of Conical-Shock Nose Inlets With Various Cowling Shapes and Axial Positions of the Center Body at Mach Numbers From 0.8 to 2.0.* NACA RM L54G21a.
56. Carter, Howard S.; and Merlet, Charles F.: *Preliminary Investigation of the Total-Pressure-Recovery Characteristics of a Symmetric and an Asymmetric Nose Inlet Over a Wide Range of Angle of Attack at Supersonic Mach Numbers.* NACA RM L53J30.
57. Merlet, Charles F.; and Carter, Howard S.: *Total-Pressure Recovery of a Circular Underslung Inlet With Three Different Nose Shapes at a Mach Number of 1.42.* NACA RM L51K05.
58. Merlet, Charles F.: *Pressure Recovery and Drag Characteristics of a Forward Located Circular Scoop Inlet as Determined From Flight Tests For Mach Numbers From 0.8 to 1.6.* NACA RM L54B23.
59. Sears, Richard I.: "Some Considerations Concerning Inlets and Ducted Bodies at Mach Numbers From 0.8 to 2.0." Paper presented at Conference on Aerodynamics of High-Speed Aircraft, Moffett Field, Calif., July 8–10, 1953. Reissued as NACA RM L53I25b.
60. Putland, Leonard W.: *Flight Determination of Drag and Pressure Recovery of Two Scoop Inlets Located at Maximum-Body-Diameter Station at Mach Numbers From 0.8 to 1.8.* NACA RM L55H22a.
61. Whitcomb, Richard T.: *A Study of the Zero-Lift Drag-Rise Characteristics of Wing-Body Combinations Near the Speed of Sound.* NACA RM L52H08.
62. Hoffman, Sherwood: *An Investigation of the Transonic Area Rule By Flight Tests of a Sweptback Wing on a Cylindrical Body With and Without Body Indentation Between Mach Numbers 0.9 and 1.8.* NACA RM L53J20a.
63. Hall, James Rudyard: *Comparison of Free-Flight Measurements of the Zero-Lift Drag Rise of Six Airplane Configurations and Their Equivalent Bodies of Revolution at Transonic Speeds.* NACA RM L53J21a.
64. Jones, Robert T.: *Theory of Wing-Body Drag at Supersonic Speeds.* NACA RM A53H18a. Reissued as NACA TR 1284, 1956.
65. Hoffman, Sherwood: *A Flight Investigation of the Transonic Area Rule For a 52.5° Sweptback Wing-Body Configuration at Mach Numbers Between 0.8 and 1.6.* NACA RM L54H13a.
66. Sandahl, Carl A.: *Effect on Transonic and Supersonic Drag of a Fuselage Protuberance Designed to Improve the Area Distribution of an Essentially Unswept Wing-Fuselage Combination.* NACA RM L53K10.
67. Hall, James Rudyard: *Effect on Transonic and Supersonic Drag of Fuselage Gloves Designed to Give a Smooth Overall Area Distribution to a Swept-Wing-Body Combination.* NACA RM L54H30.
68. Hall, James Rudyard: *Effect of Wing Size and Amount of Indentation on Applicability of Transonic Area Rule to Swept-Wing Configurations.* NACA RM L55F03.
69. Walters, Richard E.: *Application of Transonic Area Rule to a Sharp-Lipped Ducted Nacelle.* NACA RM L53J09b.
70. Hoffman, Sherwood; Wolff, Austin; and Faget, Maxime A.: *Investigation of the Supersonic Area Rule For a Straight Wing-Body Configuration at Mach Numbers Between 0.8 and 1.5.* NACA RM L55C09.
71. Hoffman, Sherwood; and Wolff, Austin L.: *Effect on Drag of Longitudinal Positioning of Half-Submerged and Pylon-Mounted Douglas Aircraft Stores on a Fuselage With and Without Cavities Between Mach Numbers 0.9 and 1.8.* NACA RM L54E26.
72. Nelson, Robert L.; and Welsh, Clement J.: *Some Examples of the Application of the Transonic and Supersonic Area Rules to the Prediction of Wave Drag.* NACA RM L56D11. Reissued as NASA TN D–466, 1960.
73. Sandahl, Carl A.; and Stoney, William E.: *Effect of Some Modifications and Protuberances on the Zero-Lift Drag of Delta Wings at Transonic and Supersonic Speeds.* NACA RM L53L24a.
74. Welsh, Clement J.; Wallskog, Harvey A.; and Sandahl, Carl A.: *Effects of Some Leading-Edge Modifications, Section and Plan-form Variations, and Vertical Position on Low-Lift Wing Drag at Transonic and Supersonic Speeds.* NACA RM L54K01.
75. Welsh, Clement J.: *Free-Flight Investigation to Obtain Drag-at-Lift and Stability Data for a 60° Delta-Wing-Body Configuration Over a Mach Number Range of 1.3 to 1.6.* NACA RM L55G14.
76. Stoney, William E.: *Collection of Zero-Lift Drag Data on Bodies of Revolution From Free-Flight Investigations.* NACA TN 4201, 1958. Reissued as NASA TR R–100, 1961.
77. Purser, Paul E.: *Comparison of Wind-Tunnel, Rocket, and Flight Data Measurements for Eight Airplane Configurations at Mach Numbers Between 0.7 and 1.6.* NACA RM L54F18.
78. McFall, John C., Jr.: *Longitudinal Stability Characteristics at Transonic Speeds of a Rocket-Propelled Model of an Airplane Configuration Having a 45° Swept Wing of Aspect Ratio 6.0.* NACA RM L53G22a.

79. Vitale, A. James; and McFall, John C., Jr.: *Longitudinal Stability Characteristics at Transonic Speeds of a Canard Configuration Having a 45° Sweptback Wing of Aspect Ratio 6.0 and NACA 65A009 Airfoil Sections.* NACA RM L54I01.
80. Kehlet, Alan B.: *Aerodynamic Characteristics at Transonic and Supersonic Speeds of a Rocket-Propelled Airplane Configuration Having a Diamond-Planform Wing of Aspect Ratio 3.08 and a Low, Swept Horizontal Tail.* NACA RM L54G27a.
81. Kehlet, Alan B.: *Aerodynamic Characteristics at Transonic and Supersonic Speeds of a Rocket-Propelled Airplane Configuration Having a 52.5° Delta Wing and a Low, Swept Horizontal Tail.* NACA RM L54A20.
82. Lauten, William T., Jr.; and Teitelbaum, J. M.: *Some Experiments on the Flutter of Wings With Sweepback in the Transonic Speed Range Utilizing Rocket-Propelled Vehicles.* NACA RM L50C03a.
83. Barmby, J. G.; Cunningham, H. J.; and Garrick, I. E.: *Investigation of the Effect of Sweep on the Flutter of Cantilever Wings.* NACA RM L8H30. Reissued as NACA TN 2121, 1950, and as NACA TR 1014, 1951.
84. Lauten, W. T., Jr.; and Sylvester, Maurice A.: *Flutter Investigation of Two Thin, Low-Aspect-Ratio, Swept, Solid, Metal Wings in the Transonic Range By Use of a Free-Falling Body.* NACA RM L51K28a.
85. Lauten, William T., Jr.; and Nelson, Herbert C.: *Results of Two Free-Fall Experiments on Flutter of Thin Unswept Wings in the Transonic Speed Range.* NACA RM L51C08. Reissued as NACA TN 3902. Jan. 1957.
86. Unangst, John R.; and Jones, George W. Jr.: *Some Effects of Sweep and Aspect Ratio on the Transonic Flutter Characteristics of a Series of Thin Cantilever Wings Having a Taper Ratio of 0.6.* NACA RM L55I13a. Reissued as NASA TN D–1594, Feb. 1963.
87. Lauten, W. T., Jr.; and O'Kelly, Burke R.: *Results of Two Experiments on Flutter of High-Aspect-Ratio Swept Wings in the Transonic Speed Range.* NACA RM L52D24b.
88. Lauten, William T., Jr.; and O'Kelly, Burke R.: *Free-Flight Tests in the Transonic and Low Supersonic Speed Range of Three Low-Aspect-Ratio, Swept, Tapered Wings on Rocket-Propelled Vehicles.* NACA RM L55J21.
89. Strass, H. Kurt; and Marley, Edward T.: *Recent Experiences With Flutter Failure of Sweptback, Tapered Wings Having Outboard, Partial-Span Spoiler Controls.* NACA RM L53H26.
90. Lauten, William T., Jr.; and Mitcham, Grady L.: *Note on Flutter of a 60° Delta Wing Encountered at Low-Supersonic Speeds During the Flight of a Rocket-Propelled Model.* NACA RM L51B28.
91. Judd, Joseph H.; and Lauten, William T. Jr.: *Flutter of a 60° Delta Wing (NACA 65A003 Airfoil) Encountered at Supersonic Speeds During the Flight Test of a Rocket-Propelled Model.* NACA RM L52E06a.
92. Lauten, William T., Jr.; and Judd, Joseph H.: *Supersonic Flutter of a 60° Delta Wing Encountered During the Flight Test of a Rocket-Propelled Model.* NACA RM L54D12a.
93. Wallskog, Harvey A.: *Flutter Experiences With Thin Pointed-Tip Wings During Flight Tests of Rocket-Propelled Models at Mach Numbers From 0.8 to 1.95.* NACA RM L55A14.
94. Martz, C. William: *Rocket-Model Investigation to Determine the Lift and Pitching Effectiveness of Small Pulse Rockets Exhausted From the Fuselage Over the Surface of an Adjacent Wing.* NACA RM L58G29.
95. Heldenfels, Richard R.: *The Effect of Nonuniform Temperature Distributions on the Stresses and Distortions of Stiffened-Shell Structures.* NACA TN 2240, Nov. 1950.
96. Thompson, Floyd L., Memorandum, Feb. 14, 1952, regarding organization of Structures Research Facility Unit.
97. Heldenfels, Richard R.; Rosecrans, Richard; and Griffith, George E.: *Test of an Aerodynamically Heated Multiweb Wing Structure (MW–1) in a Free Jet at Mach Number 2.* NACA RM L53E27.
98. Thompson, Floyd L., Memorandum, Apr. 4, 1952, regarding changes in organization of Structures Research Division.
99. Griffith, George E.: "Transient Temperature Distribution in an Aerodynamically Heated Multiweb Wing." Paper presented at NACA Conference on Aircraft Loads, Flutter, and Structures, Langley Field, Mar. 2–4, 1953. Reissued as NACA RM L53E27a.
100. Heldenfels, Richard R.; and Rosecrans, Richard: *Preliminary Results of Supersonic-Jet Tests of Simplified Wing Structures.* NACA RM L53E26a.
101. Passera, Anthony L.; and Garner, H. Douglas: *Simulator Studies of a Simple Homing System.* NACA RM L55G06.
102. Gardiner, Robert A.; Gillis, Clarence L.; and Graves, G. B., Jr.: *Analysis of a Flight Investigation at Supersonic Speeds of a Simple Homing System.* NACA RM L55J28.
103. Brown, Clarence A., Jr.: *Longitudinal Stability Characteristics of a Simple Infrared Homing Missile Configuration at Mach Numbers of 0.7 to 1.4.* NACA RM L56D10.
104. Vitale, A. James; Press, H.; and Shuffelbarger, C. C.: *An Investigation of the Use of Rocket-Powered Models For Gust-Load Studies With an Application to a Tailless Swept-Wing Model at Transonic Speeds.* NACA RM L53L08. Reissued as NACA TN 3161, June 1954.
105. Vitale, A. James: *Characteristics of Loads in Rough Air at Transonic Speeds of Rocket-Powered Models of a Canard and a Conventional-Tail Configuration.* NACA RM L54L17.
106. Vitale, A. James; and Mitchell, Jesse L.: *Experimental Results From a Test in Rough Air at High Subsonic Speeds of a Tailless Rocket Model Having Cruciform Triangular Wings, and a Note on the Calculation of Mean Square Loads of Aircraft in Continuous Rough Air.* NACA RM L55L28.

CHAPTER 11

CENTURY-SERIES AIRPLANES AND MULTISTAGE ROCKETRY: 1954

NORTH AMERICAN YF–100A SUPERSABRE AIRPLANE

The North American F-100 Supersabre airplane was the first Air Force fighter to exceed the speed of sound in level flight, which it did on its maiden flight, May 25, 1953. A speed record of 755 miles per hour was established by an F-100 on October 29, 1953; and this was, in turn, exceeded by another F-100 on August 20, 1955, when it established a speed record of 822 miles per hour (ref. 1). Although production of the airplane ended in October 1959, it was to be the principal Air Force fighter in close-support operations in the Vietnam war. In addition, it was supplied to NATO countries as well as to Nationalist China (ref. 2).

The F-100 was the first of the century series of fighters to be developed with the aid of rocket models flown at Wallops. It was designed as a supersonic follow-on to the very successful F-86 Sabre jet and for a while was called Sabre 45, after its 45-degree sweep. The desire for rocket-model tests was first disclosed to Gilruth and Shortal by H. A. Storms, aerodynamicist at North American, during a visit there in October 1951. The plan was to fly a series of "break-down" models, much as was the custom in wind tunnels. There would be a complete model, a wingless model, and a tailless model, plus a spare. The main purpose of the program was a drag evaluation.

At this time, the F-100 was not officially under contract, and North American was willing to construct the four models if Langley would supply the instrumentation and boosters and conduct the tests. The NACA would be allowed to publish the results for general distribution. The tests were officially requested by North American in a letter to NACA Headquarters, October 31, 1951. The NACA approved the plan on November 13, 1951, and authorized Langley to carry it out as a general research program. The project became a specific Air Force program when the service officially requested it on February 5, 1952; and the NACA then issued RA A73L89 on March 26, 1952, to cover the work. Later, the Air Force requested an additional rocket-model investigation of wing flutter, which was approved by NACA Headquarters with the release of RA C32L29.

The first model of the drag program was flown on September 25, 1952, but no data were obtained because a malfunction caused the model to break apart 4 seconds after takeoff. The second model, flown on November 7, 1952, as well as three others flown in the first half of 1953, were all successful. The model flown in November 1952 is shown in figure 218. A Deacon booster was used to accelerate the model to Mach 1.3, following which a 3.25-inch motor mounted internally increased the Mach number to about 1.8. Two small pulse rockets were fired during the decelerating period to provide disturbances in pitch. A four-channel telemeter was used to transmit measurements of total and base pressure, and longitudinal and normal accelerations.

FIGURE 218. Rocket model of North American YF–100A airplane with Deacon booster, shown at Wallops, November 7, 1952.

The first models flown were of an interim version of the airplane with regard to horizontal-tail location, and the nose inlet was replaced by a pointed fairing. The drag results of the first complete model agreed well with predictions based on earlier wind-tunnel tests. The trim change at transonic speeds was mild, with no indication of buffeting (ref. 3). The tests of the models without wings and without a horizontal tail provided data on component drag (ref. 4).

The last model flown in this program incorporated changes made in the final design of the airplane. The horizontal tail was reduced in thickness from 7 to 3.5 percent and was placed in a lower position on the fuselage. The vertical tail was also reduced in thickness to 3.5 percent and was given less taper. The wing in both cases was of 7-percent thickness, and the wing and horizontal tail were sweptback 45 degrees. This modified version of the airplane showed less drag than the earlier model, particularly at supersonic speeds (ref. 5). Data from all four successful flights were summarized in a single report for general distribution (ref. 6).

The flutter program with rocket models was initiated after calculations by North American had indicated a possibility of single-degree bending flutter of the wings near Mach 1.0. Three models were flown on D18 vehicles, two with wings of 5-percent thickness, and one with a 3.5-percent-thick wing. By this means, data were secured on both wing and tail flutter. The wing panels were purposely made weaker than the scaled airplane surfaces, to provide a more severe test. Two types of D18 vehicles were used. Two models were equipped with a motor-driven unswept tail unit that was moved sinusoidally with respect to time, to provide flutter information over a range of angles of attack. The third model had a fixed sweptback tail unit, shown in figure 219, and angles of attack were provided by the firing of small pulse rockets. The first model was flown on December 18, 1952, and the last, on August 19, 1953.

In two of the tests, the angles of attack reached were excessive and the models broke apart near a Mach number of 0.9, although the wings did not come off and there was no indication of flutter. In the third test, the angle of attack was kept at a lower value and no failure occurred throughout the flight to

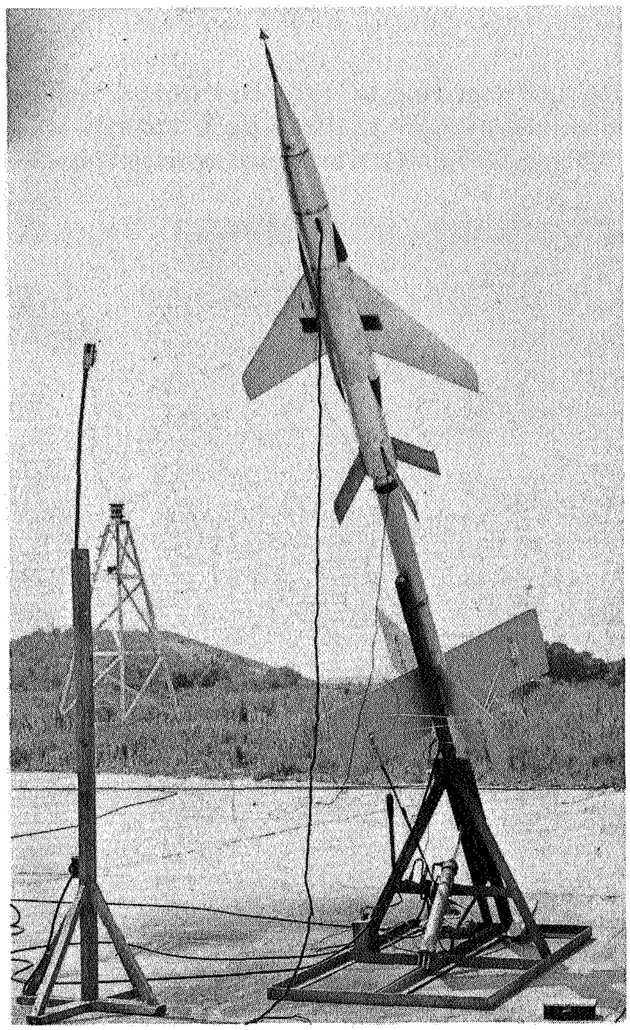


FIGURE 219. Scaled wings of North American YF−100A airplane on D18 flutter vehicle at Wallops, August 19, 1953.

the top Mach number of 1.23. Some oscillations in bending were measured, but no flutter occurred and it was concluded that the airplane would be safe from flutter (ref. 7).

CONVAIR F−102 DELTA DAGGER FIGHTER

The Convair F-102 Delta Dagger fighter, developed for the Air Force, was the supersonic version of the XF-92A subsonic, tailless, delta-wing airplane discussed in Chapter 6. It was the world's first all-weather jet interceptor. The F-102 was somewhat larger than the XF-92A, was powered with a J-57 turbojet engine, and had side scoop inlets located about halfway between the nose of the fuselage and the wing. The 60-degree delta wing had a modified NACA 0004 section. On March 20, 1952, the Air Force requested the NACA to evaluate the drag of the design by rocket-model tests, and RA A73L91 was issued to cover the work. A 1/5-scale model about the size of the E17 general research drag models was selected. The internal Deacon rocket motor that provided major propulsion was assisted by an HPAG booster, as shown in figure 220. The model was constructed by Convair with extensive use of molded fiberglass and resin.

The first model in this program was launched on July 24, 1953. It was equipped with an eight-channel telemeter which transmitted accelerations and pressures needed for the evaluation of drag and inlet performance. A choking cup, originally used in the F26 inlet program, was installed in the exit to ensure sonic flow at the simulated engine exhaust. The important longitudinal acceleration channel had a severe frequency shift during the test, which made the drag measurements questionable, but the values obtained were high enough to indicate that supersonic flight with the full-scale airplane would be difficult. When this airplane, flown initially on October 24, 1953, failed to achieve supersonic flight, a major redesign was initiated.

Consideration was given immediately to applying the area rule to this pre-area-rule design. Convair designers and PARD researchers laid out numerous redesigns of the airplane incorporating fuselage modifications. Extensive use was made of the Wallops Helium Gun to launch equivalent bodies

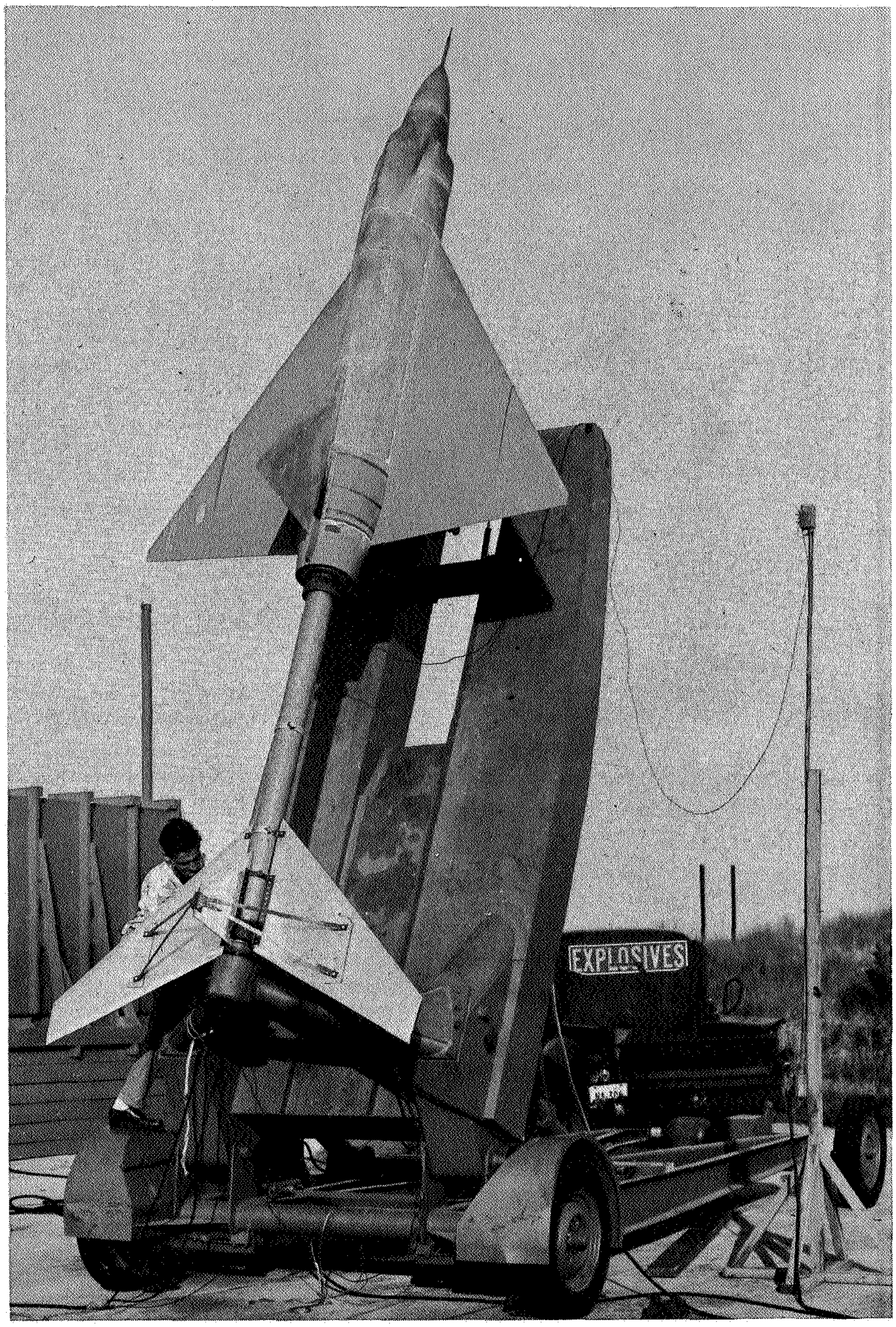


FIGURE 220. Technician Roy Hindle connects firing leads to HPAG booster for model of Convair YF–102 airplane, July 24, 1953.

of revolution to determine the pressure drag of the configurations under consideration. Thirteen such models were tested.

A body equivalent to the first rocket model flown was tested for comparison with the various new designs. It was quickly shown that a significant reduction in drag could be obtained by lengthening the fuselage by 7 feet and indenting the fuselage in the vicinity of the wing to form a wasp-waist shape. With this redesign, the pressure drag coefficient at a Mach number of 1.05 was reduced from 0.0183 to 0.0137 (refs. 8 and 9). This design was applied to the airplane, whose designation was changed to F-102A. The designation of the first version was changed to YF-102.

A 1/5-scale rocket model of the redesigned F-102A airplane was also flown at Wallops. This model, as shown in figure 221, had a double HPAG booster. The flight, made on January 29, 1954, gave good results and provided the high-Reynolds-number data needed to proceed with the design. The rocket model was an accurate representative of the airplane except that the model wing did not have the twist and camber selected for the final version from concurrent research at the Ames laboratory for lower drag under lifting conditions. The rocket-model tests showed a total drag coefficient of about 0.025 at Mach numbers from 1.05 to 1.45. The pressure recovery of the side inlets with their boundary-layer splitter plates was 0.96 at Mach 1.45 (ref. 10).

The redesigned full-scale airplane was flown on December 20, 1954, and exceeded Mach 1 the next day. It thereby became the world's first supersonic all-weather jet interceptor and the first to incorporate area-rule fuselage design. About 1,000 airplanes of this design were constructed. The B version of the airplane, later designated F-106 Delta Dart, was the follow-on to the F-102A and incorporated the higher thrust J-75 engine, which made flights at Mach 2 possible. In fact, one of the F-106A airplanes set a speed record of 1,526 miles per hour on December 15, 1959. The major user of these airplanes was the Air Defense Command of the Air Force (ref. 11).

A second series of rocket models was flown at Wallops to investigate the flutter characteristics of the wing and vertical tail of the YF-102 airplane. The Air Force requested these tests, and the NACA issued RA C32L34 to cover them. Six 1/9-scale models were flown with the wings or vertical tail, constructed by Convair, mounted on basic D18 test vehicles shortened to simulate the tailless configuration. Two propulsion systems were used. One was an HVAR booster in combination with an internal Cordite motor, which covered the speed range to Mach 1.3. The second system had a Deacon booster with an HPAG internal motor shortened to three-fourths its length for tests to Mach 2.0.

The test wings were constructed as a close simulation of the full-scale wings with ribs, spars, and outer metal skin. The elevons were spring-mounted to allow restrained motion. A flight test with each of the propulsion systems was made in the spring of 1954. In neither test was flutter encountered, but in the low-speed test elevon buzz was noted near Mach 1.0, and in the high-speed test the wings failed—but apparently not from flutter (ref. 12). It was reasoned that the failure was associated with loss of strength of the glue bond due to aerodynamic heating. In a repeat test with the entire surface of the wing covered with an insulating compound, the model traversed the speed range to Mach 2 without failure.

To obtain additional information on the margin of safety possessed by the wings, a model was flown with wings simulating those of the airplane, with reduced stiffness. Failure occurred at maximum speed. In another test, the wings cambered as on the airplane did not fail. The final test was of a model simulating the vertical tail of the airplane. No flutter was encountered. These additional tests were not formally reported, but the results were made available to the Air Force and to Convair.

LOCKHEED XF-104 STARFIGHTER AIRPLANE

The Lockheed XF-104 Starfighter airplane was the Air Force's small straight-wing supersonic fighter whose wing design bore a close resemblance to that of the Douglas X-3 research airplane. The wing had a span of only 22 feet, with an aspect ratio of 2.50 and a thickness ratio of 3.4 percent of the chord. The XF-104 had about one-half the empty weight of the other century-series fighters. It was developed into a very successful interceptor and was manufacturered in large quantities not only by Lockheed in this country, but under license in Canada, Germany, and Italy for use by NATO countries and in Japan. It was flown for the first time on February 7, 1954, and for a time was the world's fastest combat aircraft

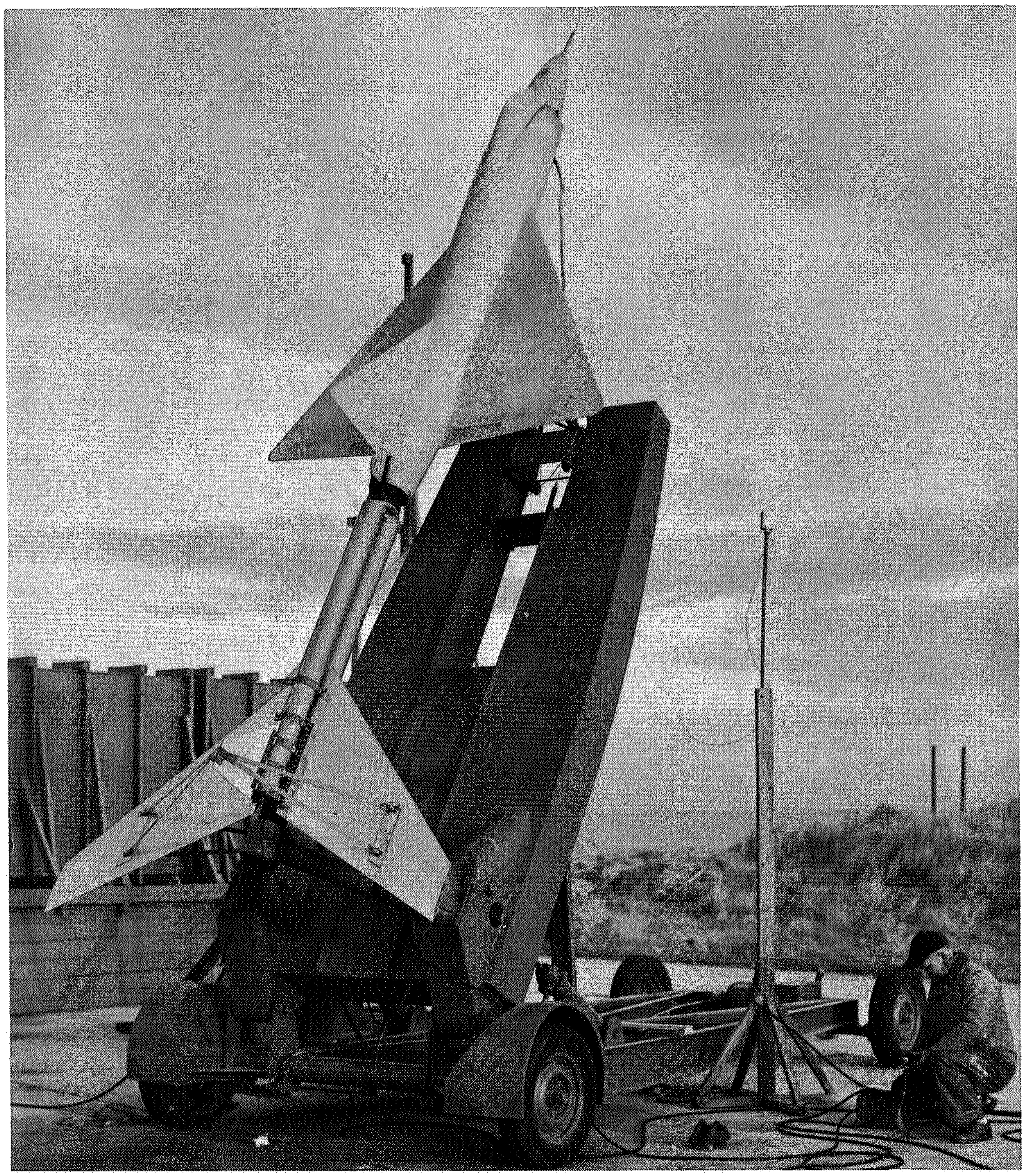


FIGURE 221. Technician Ed Matthews checks circuitry to double HPAG booster for model of Convair F−102A airplane, January 29, 1954.

(ref. 13). In 1958, two world records were set by Starfighters, an altitude record of 91,249 feet on May 7, and a level flight speed of 1,404 miles per hour on May 16. The altitude record was upped to 103,389 feet on December 14, 1959, by an F-104C airplane (ref. 14). The Collier Trophy for 1958 was presented to the Air Force and industry team responsible for the F-104 (ref. 15).

At the request of the Air Force on July 30, 1953, a 1/10-scale model of the XF-104 was flown at Wallops for an overall evaluation of the drag of the design. RA A73L117 was issued by the NACA on August 27, 1953, to cover the program. Figure 222 shows the model with its Deacon booster. In addition

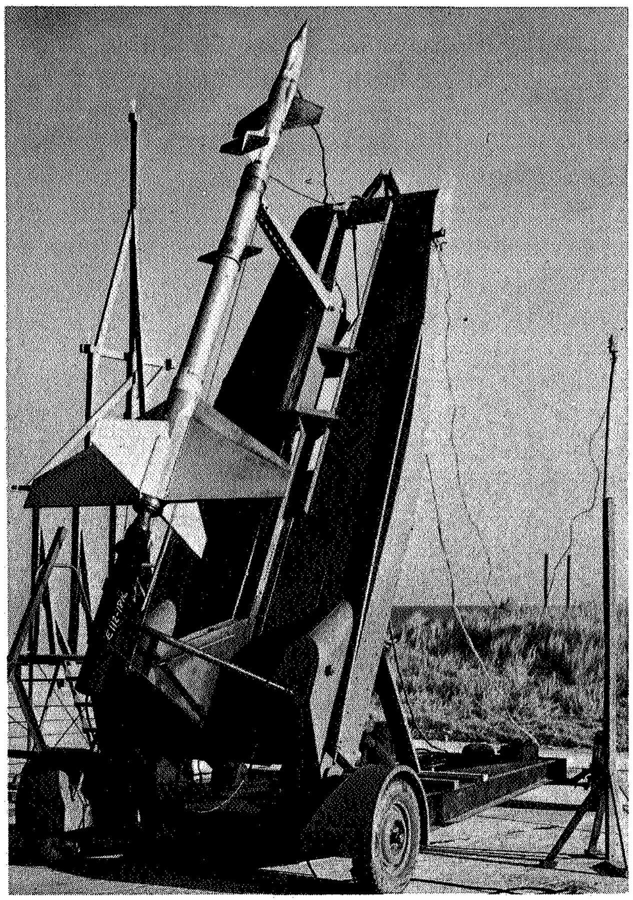


FIGURE 222. Model of Lockheed XF−104 Starfighter, shown with Deacon booster at Wallops, January 4, 1954.

to the Deacon, the model contained a 2.25-inch rocket motor, mainly to provide a visual tracking aid for the small model, although this motor did contribute a slight amount to the maximum Mach number of 1.47 reached in the test. A four-channel telemeter was used, and three pulse rockets provided pitch disturbances. The rocket model differed from the airplane slightly in fuselage shape, and the inlets were faired over on the model. The model was constructed principally as a casting of aluminum or magnesium alloys.

Two identical models were constructed by Lockheed for this program, but only one was flown after it achieved all the objectives of the program. This model was launched on January 4, 1954. Drag and longitudinal stability data were obtained from Mach number 0.8 to 1.47. No unusual characteristics were exhibited. Static and dynamic stability was indicated with only a small trim change near Mach 1.0 (ref. 16).

CHANCE VOUGHT XF8U−1 CRUSADER AIRPLANE

The Chance Vought XF8U-1 Crusader airplane, developed for the Navy, was a sweptwing, supersonic fighter with a single Pratt and Whitney J-57 turbojet engine. One of these aircraft set a speed record for U.S. combat aircraft of 1,015 miles per hour on August 21, 1956. The Navy purchased a large number of these airplanes, which later were designated F-8 and were to remain in production until 1965.

The Crusader had a 42-degree sweptback wing with variable incidence, a low horizontal tail, and a forward underslung scoop inlet. The wing, mounted high on the fuselage, had 5-degree negative dihedral, which compensated in part for the effect on lateral stability produced by the high wing location and the sweepback. The wing thickness ratio varied from 6 percent at the root to 4 percent at the tip.

Two rocket-model programs were requested by the Navy. One was a drag investigation, covered by RA A73L122 issued by the NACA on September 11, 1953; and the other was a wing-flutter investigation covered by RA C32L35 issued by the NACA on the same date. All models were of 0.11 scale. The drag models were complete models, boosted by either single or double Deacon boosters, one of which is shown in figure 223. The booster motors for the D18 flutter vehicles were either HVAR or HPAG motors, and the internal motors were Cordites.

The first four drag models were flown between October 7, 1953, and January 7, 1954, in an expedited program. To save time, no internal instrumentation was used; the drag was determined solely from ground-based radars. Two additional models of a redesigned configuration, flown in 1955, were equipped with six-channel telemeters. All of the flutter models were equipped with four-channel telemeters.

The uninstrumented drag models were flown with a basic nose shape to the fuselage and with modifications consisting of a slimmer canopy, a sharper nose, and thinner inlet lips. The airplane was a pre-area-rule design and had a rather abrupt area distribution at the wing location. The basic model had a minimum drag coefficient of 0.044, but with the refined nose model, the drag was reduced to 0.042 (ref. 17).

The two instrumented drag models reflected a major redesign of the airplane to incorporate changes consistent with the area rule for a Mach number of 1.2. The fuselage was lengthened somewhat and was thickened ahead of the wing, and a slight coke-bottle shape was incorporated near the wing juncture. One model was flown with the nose inlet faired over for easier comparison with theory (ref. 18), and the second model had the complete inlet and duct system (ref. 19). The models with the area-rule modifications showed a substantial reduction in drag, with a total drag coefficient for the model with open inlet being 0.035 at Mach 1.0, and 0.040 between Mach 1.2 and 1.7. The pressure recovery of the inlet was 0.90 at a Mach number of 1.7. All of the drag data were summarized in a report for general distribution (ref. 20).

The flutter program indicated that the full-scale airplane would be safe from wing flutter. Although four models were flown between October 7, 1953, and March 2, 1954, only one was considered representative of the airplane. The wings on the other models were considerably weaker than those of the airplane in the areas just behind the leading edge and just ahead of the trailing edge. As a result, destructive flutter that occurred was discounted as not being representative of the airplane (ref. 21). One of the flutter models is shown in figure 224.

CONVAIR XF2Y–1 SEA DART HYDROSKI FIGHTER

The Conviar XF2Y-1 Sea Dart seaplane was the first water-based aircraft to exceed Mach 1. It was a research seaplane to explore the possibilities of a water-based transonic fighter and was a 60° delta tailless, twin-jet airplane with retractable water skis. Original research into the possibilities of adapting water skis to a high-speed airplane was conducted by John R. Dawson and Kenneth L. Wadlin during 1946 in the NACA Tank at Langley, with a modified model of the Douglas D-558-II research airplane (ref. 22).

On December 8, 1950, Adolph Burstein of Convair, San Diego, California, visited Langley to explore the possibilities of a rocket-model program of the airplane that had the company designation of Y2-2 at that time. Shortly afterward the Navy issued a contract for development of this delta-wing fighter and requested the NACA to participate in a rocket-model program. RA A73L62 was issued by NACA Headquarters on May 7, 1951. Four 1/10-scale models were flown at Wallops, the first on November 12, 1952, and the fourth on March 19, 1954. The first flight of the full-scale airplane was made on April 9, 1953, with two J-34 turbojet engines installed. On August 3, 1954, after two J-46 engines had been substituted, the Sea Dart exceeded the speed of sound to become the first water-based aircraft to do so.

The rocket-model program was conducted to investigate the drag and stability characteristics at transonic speeds. Two models were flown with the inlets sealed and the turbojet engines simulated by small internal solid-rocket motors. The other two models had open inlets to allow evaluation of inlet

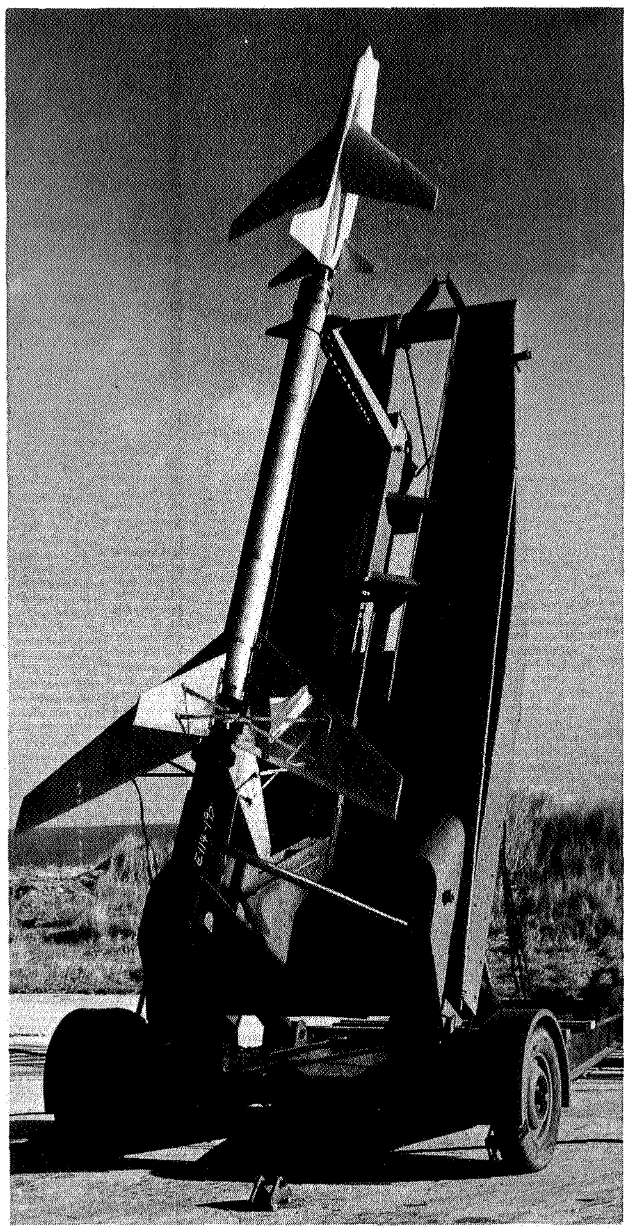


FIGURE 223. Model of Chance Vought XF8U–1 Crusader airplane on launcher at Wallops, January 7, 1954.

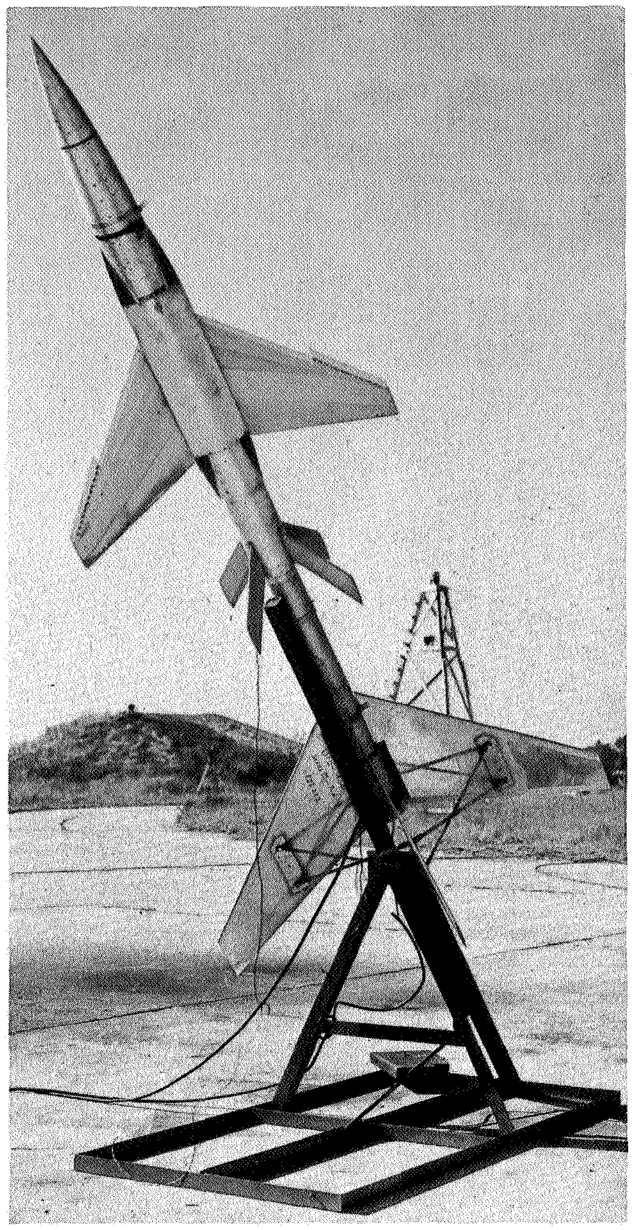


FIGURE 224. Scaled wings of Chance Vought XF8U–1 airplane on D18 flutter vehicle, March 2, 1954.

and duct performance. Single Deacon rocket boosters were used, as shown in figure 225. A special two-prong adapter was used to hold the model by its twin exits. Maximum Mach numbers of about 1.5 were obtained with the 94-pound models. The models were equipped with 14-channel telemeters which transmited information on accelerations, angle of attack, and various pressures, including those on the "beach" area just aft of the twin-jet exits.

The first model flown was found to be dynamically unstable laterally soon after separation from its booster, and only a short flight was obtained. Analysis showed that this behavior resulted from the negative trim angle associated with the 0-degree setting of the elevons (ref. 23).

In the second power-on flight, the elevons were fixed at a 4.2-degree up deflection, and the speed range was traversed without serious lateral instability. The internal rocket was ignited at Mach 1.2 for a power-on simulation. It was found that the jet exhaust increased the suction forces on the beach and base areas to create a nose-down pitching moment (ref. 24).

The two models flown with open inlets and ducts differed only in the inlet design. One model had a splitter plate added to each inlet to form a diverter or separator that would prevent the boundary layer

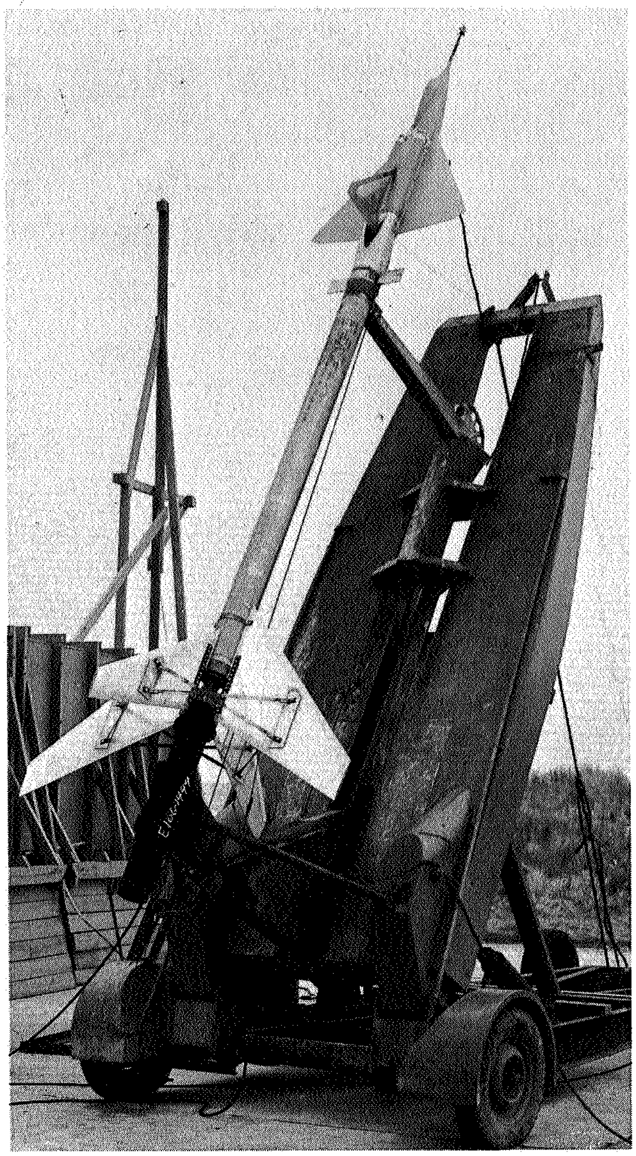


FIGURE 225. Model of Convair XF2Y–1 Sea Dart hydro-ski airplane, shown with Deacon booster at Wallops, March 19, 1954.

air at the fuselage surface from entering the inlet. A large increase in pressure recovery was obtained with the addition of this plate, particularly at the higher Mach numbers. An equivalent body of revolution of the complete model, flown from the Helium Gun, showed about the same drag rise as the rocket models. Although both the wing and vertical tail added area to the body behind the midstation, the total drag coefficient of 0.036 was not excessive. No unusual characteristics were encountered except for the lateral instability problem at negative trim angles, discussed earlier (refs. 25 and 26).

CONVAIR XFY–1 POGO VTO AIRPLANE

The Convair XFY-1 Pogo was designed to take off and land vertically and yet possess all the qualities of a high-speed fighter in level flight. It had a 9-percent-thick 57-degree delta wing and two large vertical tails. It was a tail-sitter; the landing gear was simply four struts, one on the trailing edge of each of the wing and tail panels. Two large coaxial, contrarotating three-blade propellers driven by a turboprop engine provided propulsion. On March 31, 1951, the Bureau of Aeronautics awarded Convair a contract to develop this airplane. Because of the expectation of possible transonic flight in a dive with the XFY-1, BuAer on May 10, 1951, requested the NACA to conduct a rocket-model investigation. The NACA issued RA A73L70 on June 26, 1951, to cover the program. Four models were flown at Wallops prior to the first flight of the airplane on August 1, 1954. Three of these were successful. They were to be the only propeller-driven airplane models flown at Wallops.

A Deacon booster was selected for propulsion of the 0.133-scale rocket models to a Mach number of just under 1.20. Two models were flown with free-wheeling propellers, and one without propellers. One of the complete models is shown in figure 226. A twelve-channel telemeter was used to transmit angle of attack and sideslip, propeller speed, control position and hinge moment, and various accelerations and pressures. Either the elevons on the wing or the rudders on the vertical tails were pulsed in flight. The main purpose of the tests was to determine whether any serious difficulties would be encountered in the transonic range.

With the propellers removed, the model was found to have a serious trim change at Mach 0.9, although it could be controlled by the elevon; and there was evidence of some wing dropping and buffeting. These characteristics were not unexpected for this relatively thick-winged airplane (ref. 27).

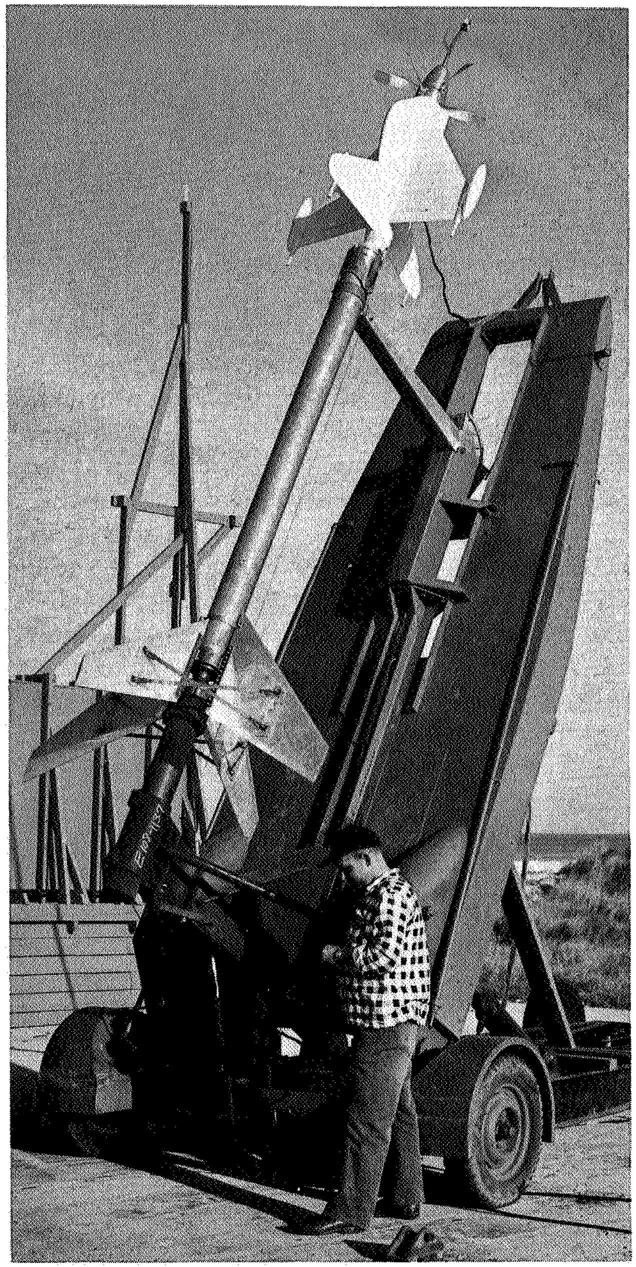


FIGURE 226. Technician Ed Matthews connects firing leads to Deacon booster for model of Convair XFY−1 Pogo VTO airplane, October 26, 1953.

The only effect noted from the addition of the windmilling propellers to the next model was a reduction in stabic stability (ref. 28). At top speed in flight the 2-foot-diameter propellers rotated at close to 10,000 revolutions per minute.

The last model was flown to evaluate lateral stability by analysis of transient motions induced by abrupt movement of the rudder. No unusual characteristics were noted (ref. 29).

CHANCE VOUGHT REGULUS II GUIDED MISSILE

The Chance Vought Regulus II guided missile was developed for the Navy as a supersonic follow-on to the Regulus I subsonic surface-to-surface missile. With its J-79 turbojet engine, it had Mach 2 capabilities and could be launched from the ground, a ship, or a submarine, by means of a solid-rocket booster. It had a 4-percent-thick wing with 46-degree sweepback, a single vertical tail, and no horizontal tail except for a small, fixed canard well forward on the nose of the fuselage. Its wing span was 20 feet and its fuselage was about 56 feet long. The fineness ratio of the nose of the fuselage was 4.5. The air inlet was a large semicircular sweptforward scoop located below the fuselage just ahead of the wing. It had a boundary-layer bleed splitter plate which discharged the boundary-layer air on each side of the fuselage beneath the wing. The first full-scale missile was launched on May 29, 1956.

On December 7, 1953, the Bureau of Aeronautics, Navy, requested the NACA to conduct a rocket-model investigation of 0.12-scale models of the missile to determine aerodynamic characteristics, including inlet and duct performance. On January 20, 1954, the NACA issued RA A21L183 to cover the tests, and five models were launched at Wallops beginning March 24, 1954. The program was completed on November 16, 1955, with all flights successful. One of the 75-pound models was launched with a single Deacon booster to Mach 1.75, while the other four were boosted to Mach 2.2 with double Deacon systems. One of the models with a double Deacon is shown in figure 227.

The first two models were flown without instrumentation, for a simple overall evaluation of the drag (ref. 30). The other three had 10-channel telemeters and were flown to evaluate longitudinal and lateral stability as well as overall aerodynamic characteristics. Disturbances in pitch or yaw were provided by pulse rockets. A combination angle of attack and sideslip indicator was mounted on a short boom ahead of the nose. The longitudinal stability of the basic design was investigated with an auxiliary vertical tail mounted on the bottom of the fuselage to prevent crosscoupling between lateral and longitudinal motions (ref. 31). Stability was found to be good, and no unusual characteristics were noted. The effects of the addition of a small canard fin a short distance back of the nose, as finally adopted for the full-scale missile, were measured in another flight test; and, in the last test, the lateral stability was investigated (ref. 32). The canard fins reduced the stability as expected, and no unexplained characteristics were found. The inlet performed quite well with a pressure recovery of 86 percent at Mach 1.9 for a mass-flow ratio of 1.0.

CONTINUATION OF BELL RASCAL GUIDED MISSILE PROGRAM

The rocket-model program in support of the Air Force's Bell Rascal air-to-ground guided missile, which began in 1948 (as discussed in Chapter 6), was continued with a redesigned version through February 1954. The redesigned Rascal had blunt trailing-edge ailerons to overcome the control reversal noted in the first series of tests, and the fuselage was much fatter. Aileron effectiveness and longitudinal stability were investigated with 1/6-scale models, and special sting-mounted models of smaller scale were flown to evaluate damping-in-roll and aileron power under combined pitch and yaw attitudes. In addition, two models were modified to simulate the Shrike test vehicle.

The two models that simulated the Shrike test vehicle were modified 1/6-scale models on hand for the Rascal program. After modification, the models became 1/3.7-scale models of the smaller Shrike. The horizontal canard surface was reduced in area as a part of the modification, but in the flight test very low static stability at low angles of attack was still indicated (ref. 33).

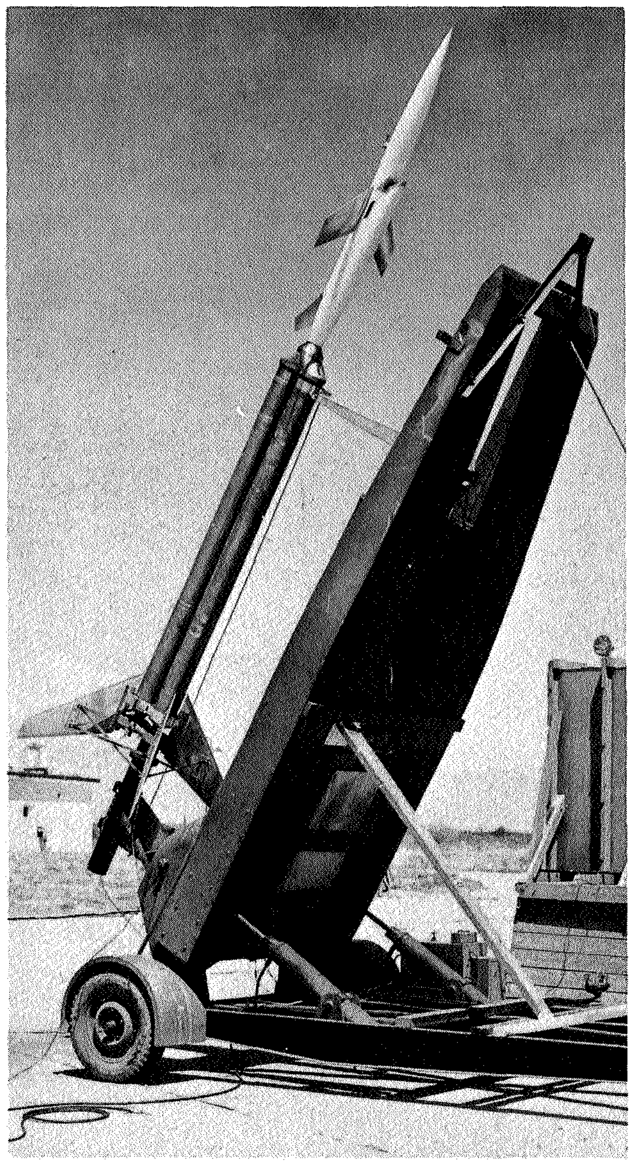


FIGURE 227. Model of Chance Vought Regulus II guided missile with double Deacon booster, April 22, 1954.

The first series of tests of the redesigned Rascal missile with the stubby fuselage was made with three 1/6-scale models to evaluate aileron effectiveness. The ailerons had been changed to full-span controls with blunt trailing edges equal to the thickness at the 75-percent chord station. HVAR boosters and 3.25-inch internal rocket motors provided a maximum Mach number of 1.2 with these 89-pound models, one of which is shown in figure 228. Positive control effectiveness was indicated with these ailerons over the speed range (ref. 34).

The second series of rocket-model tests of the redesigned Rascal was made to investigate longitudinal stability. Four-channel telemeters were installed, and pulse rockets were used to provide disturbances in pitch. One of these models was propelled by a Deacon booster to about Mach 1.4. The tests showed that longitudinal instability between Mach numbers of 0.8 and 0.9 produced changes in longitudinal trim of as much as 8 degrees for neutral control settings. Above Mach 1.0, however, no instability was noted. These results were in general agreement with previous findings of tests in the WADC 10-foot transonic tunnel (ref. 35).

The damping-in-roll of the Rascal was determined by a special test of a 1/24-scale model, sting-mounted in front of an HVAR motor, as shown in figure 229. The technique used was the same as that used in the general research E14 program. The model was constructed in the shops at Langley. The basic damping data obtained were used to evaluate rolling moments produced by the ailerons in the earlier tests (ref. 36).

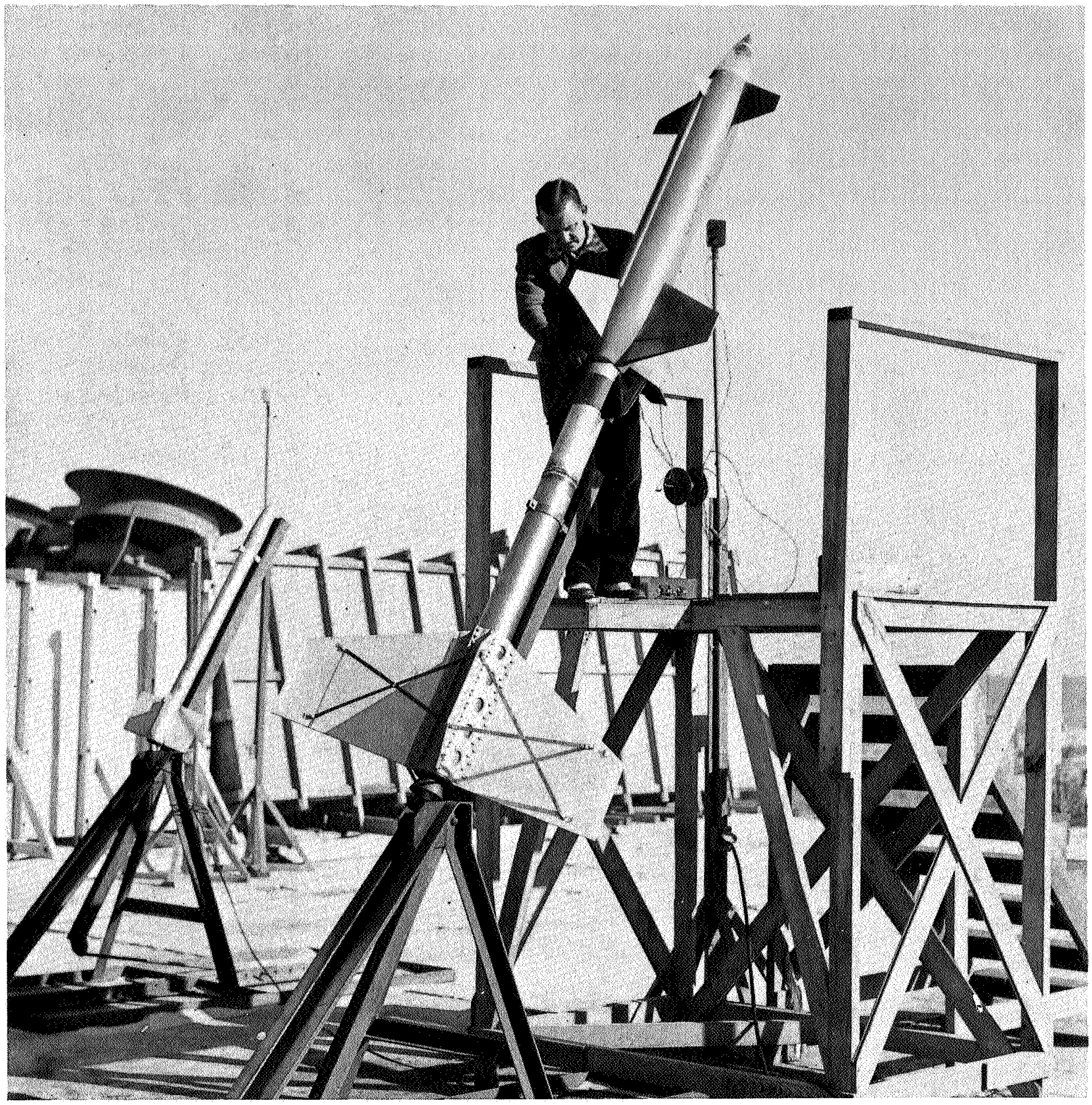


FIGURE 228. Technician Nat Johnson connects firing leads to internal rocket motor of model of Bell Rascal guided missile, shown with HVAR booster, December 1, 1950.

The effectiveness of the ailerons in overcoming the rolling moments induced by combined sideslip angles and angles of attack was investigated by an ingenious adaptation of the E14 technique. Sting-mounted, 1/20-scale models were attached to the front end of a Deacon booster, as shown in figure 230. The sting was so bent that the model was at all times at a 15-degree angle. Ailerons on the model were kept in a deflected state by an electric motor and gearing system. As the model rolled about the bent sting axis, it experienced a continuously varying combination of angles of attack and sideslip.

Analysis of the results was attempted, but no satisfactory results were obtained because torsional vibrations in the mechanism practically obscured the basic data, and rapid deceleration through the speed range allowed too little time for steady-state conditions to be attained (ref. 37).

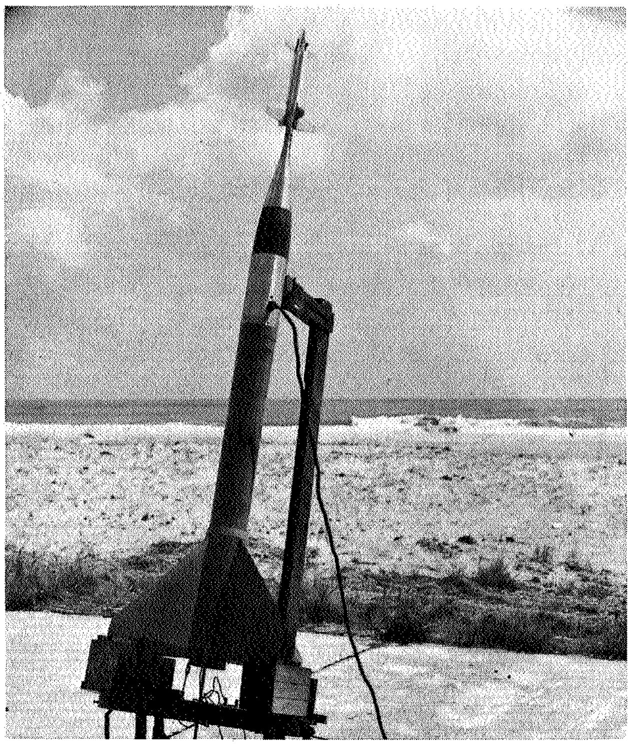


FIGURE 229. Small-scale model of Bell Rascal missile on E14 damping-in-roll test vehicle, September 5, 1952.

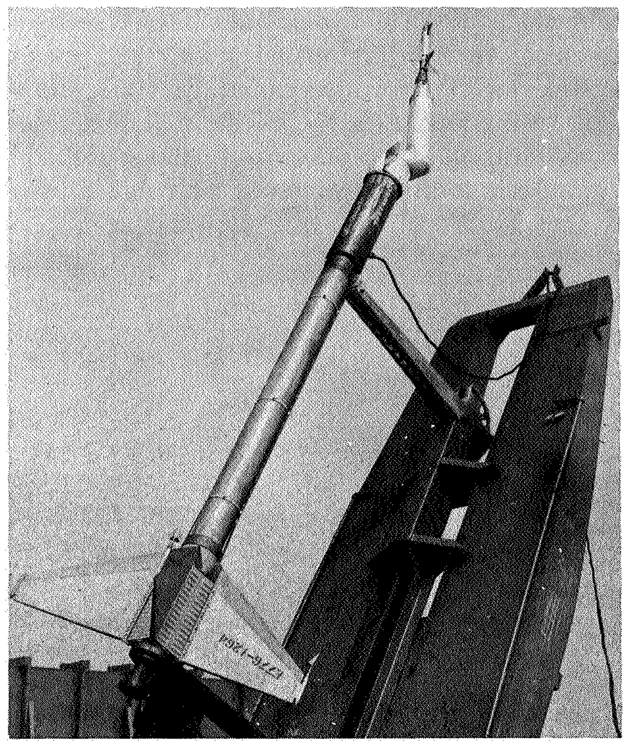


FIGURE 230. Small-scale model of Bell Rascal missile on bent sting of Deacon booster for special roll control study, August 4, 1953.

HUGHES FALCON AIR-TO-AIR GUIDED MISSILE

The Hughes Falcon was the Air Force's first supersonic air-to-air guided missile. Its development began in 1950, and it was to remain the Air Force's major air-to-air missile at least through 1968. A number of versions of the Falcon were developed which differed principally in the seeker in the nose. An extensive wind-tunnel program was conducted in the Langley 9-inch supersonic tunnel; and on May 5, 1951, the Air Force asked the NACA to flight test special full-scale missiles at Wallops.

Seven full-size missiles were launched from the ground at Wallops, six with a double Deacon booster, as shown in figure 231. The seventh missile was launched unsuccessfully with a quadruple Deacon system. One of the missiles contained an internal Thiokol T-42 solid-rocket motor with which a maximum Mach number of 2.5 was attained although the missile diverged in pitch and broke up shortly after booster separation. The remaining five missiles were flown to a maximum Mach number of 1.8 with only the double Deacon. Good data were obtained with four of these.

The ground-launched missiles at Wallops were subjected to greater loads than the air-launched missiles and were made heavier and stronger than the actual missiles. Typically, they weighed 144 pounds compared with 110 pounds for the actual missile. They were equipped with a pulsing mechanism that moved the elevons in a square-wave pattern, either together as elevators or differentially as ailerons. Typically, the missiles had eight-channel telemeters which transmitted continuous readings of normal, lateral, and longitudinal accelerations, angle of attack, control deflection, total and static pressure, and rate of roll.

Of the four missiles flown without failure in the Wallops program, three were the C configuration with horn-balanced elevons, while the fourth was the D configuration whose elevons had a full-span, beveled, overhung, aerodynamic balance. The Falcon missile of either the C or D series was essentially a cylindrical body with a rounded nose, a diameter of 6.4 inches, and a length of 86.5 inches. It had four cruciform 76-degree delta wings of 20-inch span, and four highly tapered, unswept, canard fins in line with the wings. The two missiles of the C series were flown with programmed movements of the elevons as elevators while the series D missile had its elevons programmed to produce roll maneuvers. The first missile was flown on December 19, 1951, and the last on January 11, 1955.

In the first tests, the missile rolled continually in flight about its body axis, and analysis required consideration of simultaneous readings of the pitch and yaw accelerations in evaluating the response of the missile to the longitudinal control. This was possible because of the cruciform arrangement of the

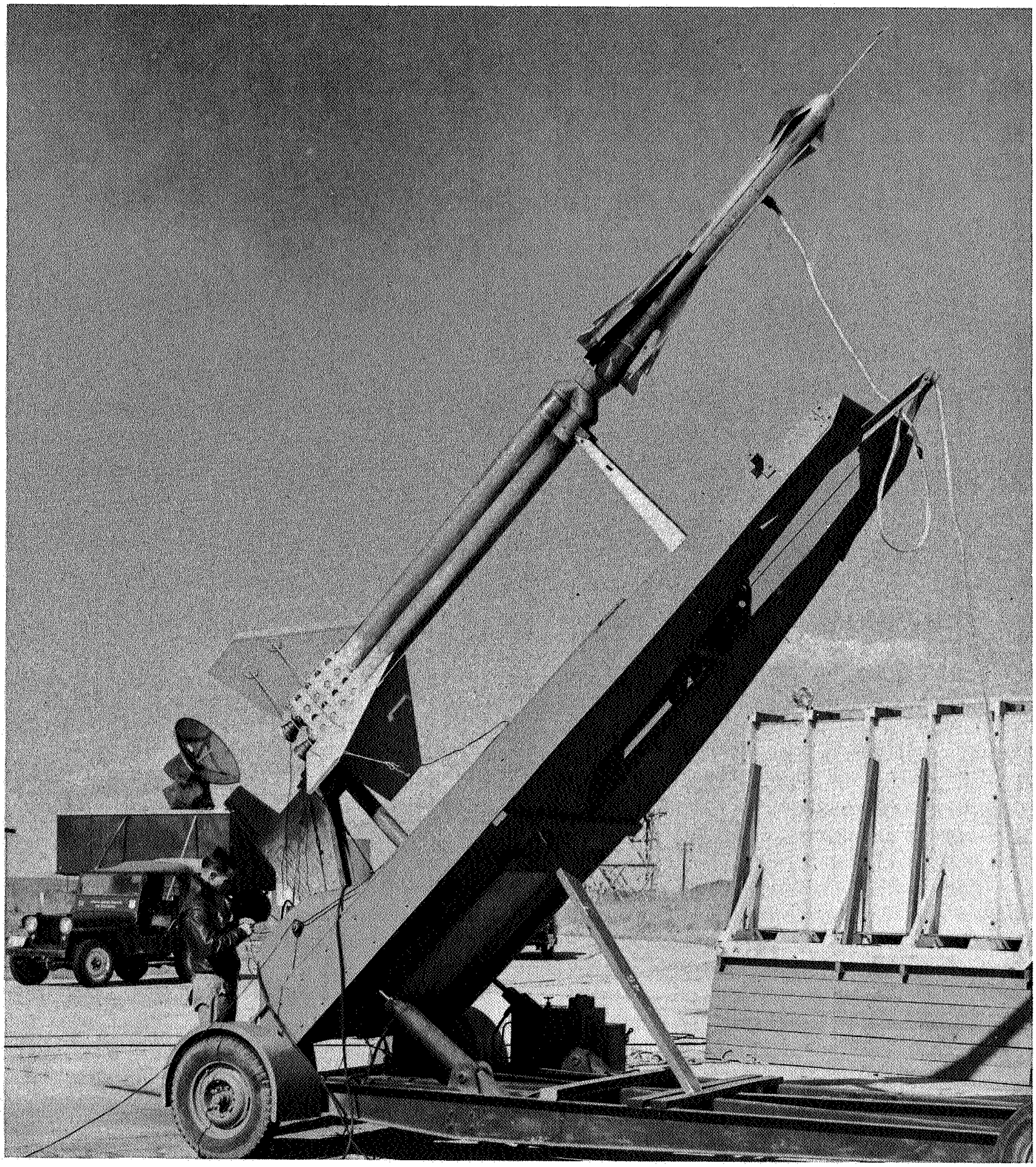


FIGURE 231. Technician Roy Hindle connects firing leads to double Deacon booster for Hughes Falcon guided missile, March 5, 1953.

wings and canard fins. The principal finding of these tests was that the static stability was much lower at a 0-degree angle of attack than at 5 degrees, particularly at supersonic speeds (ref. 38).

The third C series missile was flown with the ailerons deflected to produce a continuous roll rate of 5 radians per second, which was considerably higher than the accidental rate of the first test. The analysis procedure was the same, and the results were in general agreement, indicating that for cruciform missiles, pitching motions may be assumed to take place essentially in a fixed plane in space if the roll rate is no greater than one-third the natural pitch frequency (ref. 39).

The D series missile was flown with the ailerons pulsed in a square-wave pattern to allow evaluation of aileron effectiveness and damping-in-roll over the speed range. An accurate determination of the drag of the complete missile was also made. In the earlier tests, the drag values were not realistic because the test missiles had an angle-of-attack vane mounted on a sting forward of the nose. This vane would reduce the drag of the round-nose bodies (ref. 40).

Although this program took a long time and attempts to obtain data at Mach numbers above 2 were unsuccessful, the initial objectives of the program were eventually attained.

NAVY SIDEWINDER MISSILE

The Sidewinder air-to-air guided missile was developed at the Naval Ordnance Test Station (NOTS) of the Bureau of Ordnance at Inyokern, California, under the direction of W. B. McLean. It was one of the attempts at simplification of missile systems that was really successful. The missile was built around the 5-inch-diameter HPAG rocket motor with a hemispherical nose, containing a heat-seeker for homing on targets. It had four low-aspect-ratio wings at the rear of the body and four canard control surfaces well forward and interdigitated with respect to the wings. The total length was about 9 feet and the wing span, about 2 feet. With a total weight of 160 pounds, it could attain a Mach number of 2.5 when air-launched at high altitudes. Although its range was only 2 miles, it was to become a very effective missile for both the Air Force and the Navy following its impressive demonstration when the Nationalist Chinese downed 10 Communist airplanes with it near Formosa on September 24, 1958.

The major simplification feature of the Sidewinder was its "rolleron" roll-rate limiting system. Roll damping was achieved by independently acting wing-tip ailerons having enclosed airstream-impelled gyro wheels whose spin axis was perpendicular to the plane of the wing. When the missile rolled, gyroscopic forces deflected the ailerons in a direction to oppose the roll, thereby limiting its magnitude. During a visit of Paul R. Hill and Robert A. Gardner of PARD to NOTS early in 1952, the various features of the Sidewinder were described to them, and they expressed an interest in assisting the NOTS team in the missile development by testing instrumented Sidewinders at Wallops. Gardiner was particularly interested in the rolleron concept. Details of a proposed series of tests were discussed during a visit of L. T. Jagiello of NOTS to Langley on May 28, 1952, and NACA Headquarters issued RA A21L150 on July 25, 1952, to cover the tests. It is of interest that the Commanding Officer of NOTS at this time was the former commander of NAOTS, Chincoteague, W. V. R. Vieweg, who was well acquainted with Wallops capabilities.[1]

The main purpose of the NACA tests of the Sidewinder was to obtain aerodynamic characteristics of the full-scale missile at supersonic speeds and to evaluate the effectiveness of the rolleron. The models tested at Wallops, therefore, did not contain the seeker head, the warhead, or the normal pitch and yaw control mechanisms. Four missiles were flown, the first on October 13, 1953. This program was concurrent with the flight development program of the complete missile at NOTS.

In the Wallops tests, a Deacon booster was used as the first stage to accelerate the missile to a Mach number of about 1.5, after which the HPAG motor increased the speed to Mach 2.3. To simulate the actual flight conditions of the externally carried air-to-air missile, the rolleron wheels were accelerated to high speed by an externally applied air jet. The wheel speed was 12,000 revolutions per minute at takeoff and attained a maximum value of 45,000 revolutions per minute 8 seconds after launch.

1. Letter from W. V. R. Vieweg, Commanding Officer, NOTS, to the NACA, June 13, 1952, regarding tests of Sidewinder missile by the NACA. The letter was signed by W. B. McLean.

In the first test, an unstable situation was encountered at a Mach number of 2.07, with a resulting self-sustained oscillation in roll throughout the flight as the missile decelerated to subsonic speeds. The amplitude of this oscillation was about 2 degrees at Mach 2 and 5 degrees at Mach 0.8. A dynamic analysis of the rolleron system explained this instability, and a subsequent test was made with a damping system, developed at Langley, added to the aileron hinge. Addition of the damping system eliminated the instability. The dynamic analysis was generalized for application to other configurations (refs. 41 and 42).

The remaining two missiles were flown to determine dynamic response to pitch disturbances. A 10-channel telemeter was used, and pulse rockets supplied the initial disturbances. As shown in figure 232, a double Deacon booster was used in these tests because of the somewhat higher weight. The first of the flights provided static and dynamic stability data with the rollerons inoperative (ref. 43). The second flight with the rollerons in operation was unsuccessful because of a telemeter failure.

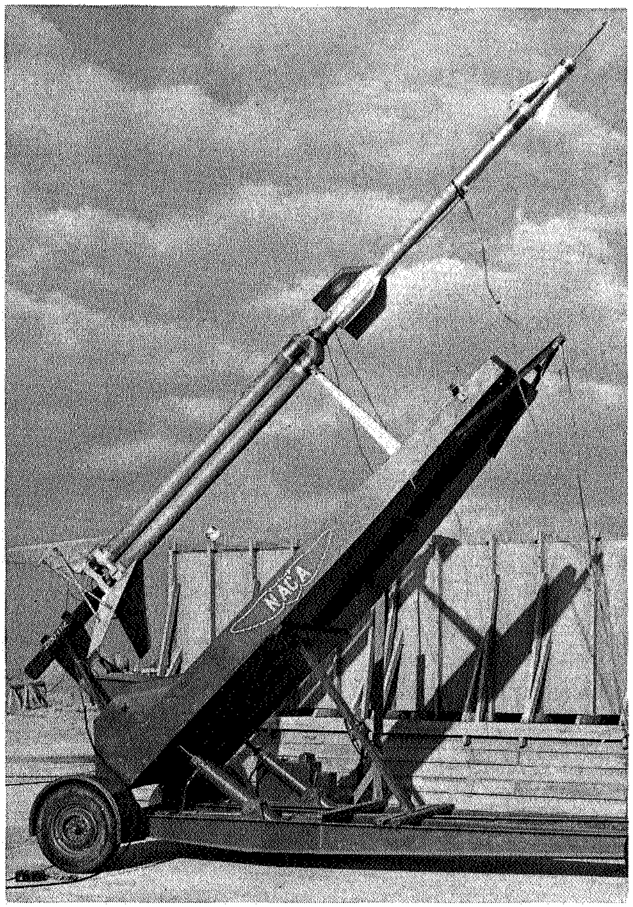


FIGURE 232. Navy Sidewinder missile, shown with double Deacon booster at Wallops for aerodynamic stability test, December 16, 1954.

AGARD MODEL 2

The NACA was involved in the activities of the NATO Advisory Group for Aeronautical Research and Development (AGARD) through membership in the main group and on its many panels. One of the activities of AGARD was correlation of the many supersonic facilities in the member countries. At its meeting in Rome, Italy, in December 1952, AGARD decided to encourage tests of standardized models. The adoption of the PARD RM-10 configuration for comparative tests in the facilities and its designation as AGARD Model 1 have been discussed in Chapter 8. In extension of this activity, a complete airplane model with 60-degree delta wings was designated AGARD Model 2. The delta wing was attached to a fuselage of fineness ratio 8.5, consisting of an ogival nose with a fineness ratio of 3.5, and a cylindrical afterbody plus vertical tail surfaces. The wing was of circular-arc section, with 4-percent thickness.

Two models of this configuration were tested in the Helium Gun at Wallops as a part of the AGARD correlation. The first model reached a Mach number of 1.2, and the second contained a small internal rocket motor that provided additional propulsion for a maximum Mach number of 1.74. The only measurements were of total drag, but summation of the calculated component drags, skin friction, and pressure drag of wing, fuselage, and tail surfaces, agreed well with the measurements (ref. 44).

These tests were supplemented by flight tests of two rocket models of the E7 type, one of which is shown in figure 233 with its Deacon booster. The first model, launched on July 27, 1954, was unsuccessful; but on November 27, 1956, a second model was flown successfully over a Mach number range of 0.92 to 1.74. Six small pulse rockets, located in the nose of the model, were fired at predetermined time intervals to disturb the model in pitch and allow determination of lift, stability, base pressure, and drag over a range of angles of attack. Agreement of these data with data from the Langley 9-inch supersonic tunnel was good (ref. 45).

AGARD was interested in the techniques used at Wallops to obtain transonic and supersonic data. In response to a request from the Model Testing Panel of AGARD, J. A. Shortal presented a paper on the rocket-model and Helium Gun techniques at the Fourth General Assembly of AGARD meeting in the Netherlands in May 1954 (ref. 46).

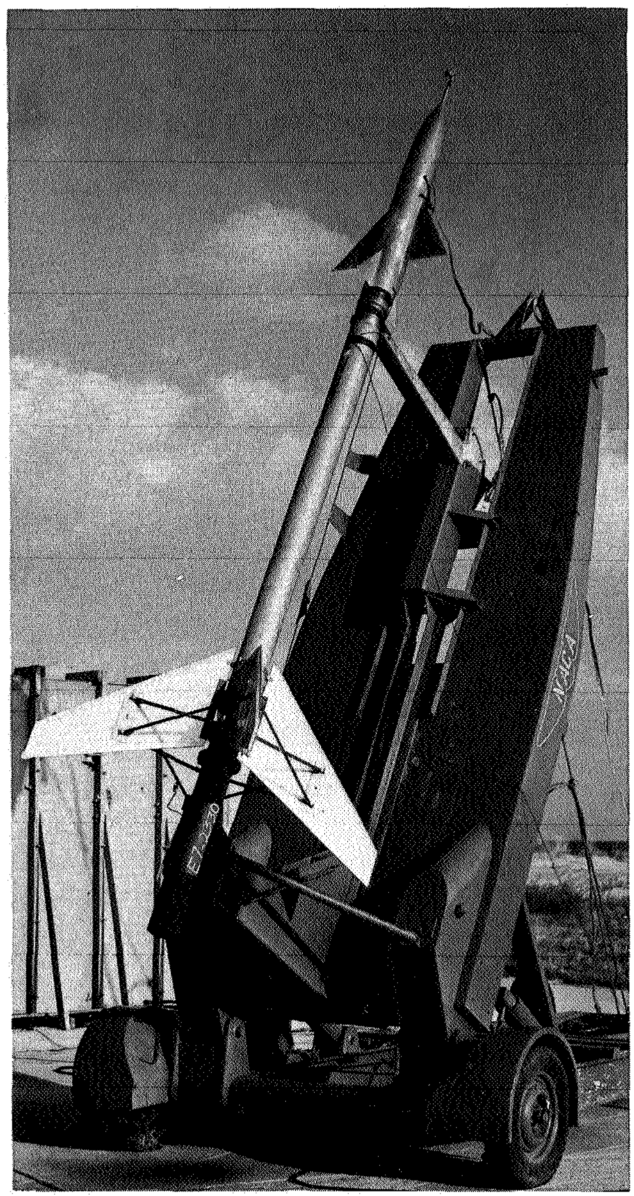


FIGURE 233. Rocket model of AGARD Model 2 with Deacon booster at Wallops, November 27, 1956.

JET EFFECTS ON BODY DRAG: F12

Chapter 8 has discussed some early findings in rocket-model flights regarding the beneficial effects of jets issuing from a base in actually providing a thrust on the base area. Research on such effects was being conducted in supersonic tunnels, but these tests were limited to the use of cold air to simulate the jet.

Early in 1952, a jet-effect program was started in the Wallops Preflight Jet, with use of a small internal solid-rocket motor to provide the jet. Figure 234 shows one of the models in the 27-inch Mach 1.6 nozzle. The nacelle containing the rocket motor was supported on a half-span tapered wing, as shown. Three boattailed shapes of the nacelle (0 degrees, 5 degrees, and 10 degrees) were tested with nozzle angles of 0 degrees, 11 degrees, and 22 degrees. The combustion chamber of the solid propellant was tapered to provide regressive burning and thereby supply a variation in jet-pressure ratio in a single test. Pressure distribution on the base and afterbody section was measured in the tests.

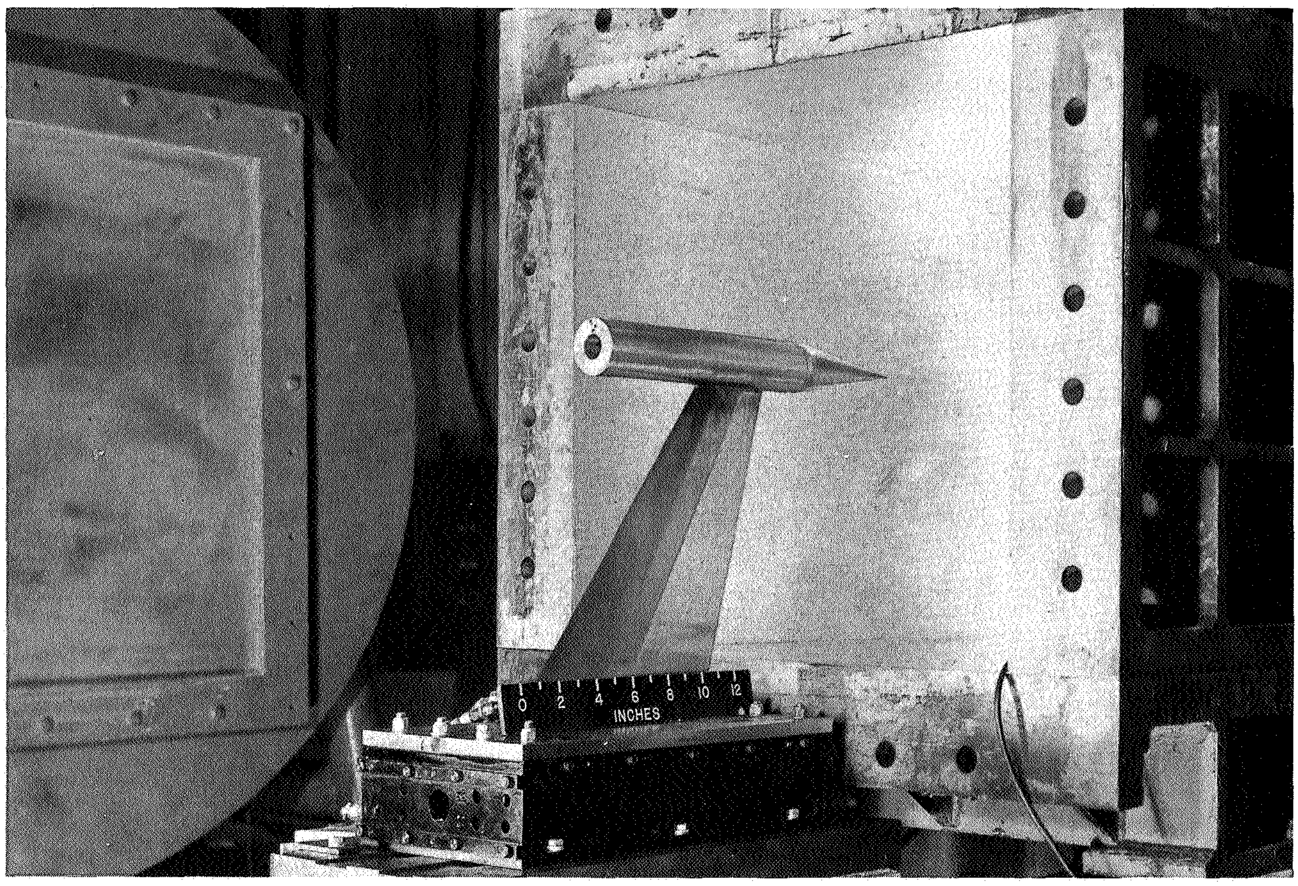


FIGURE 234. Nacelle mounted on wing tip in 27-inch nozzle of Preflight Jet for study of jet effects on nacelle drag, January 1952.

The tests showed that, at low jet pressures, the base pressure was more negative than it had been with no jet flow, but as the jet pressure was increased, the base pressure became more positive until, at high pressures, a positive thrust was created on the base. These results agreed with earlier tests in indicating that power-on effects must be considered in designing optimum afterbody shape (ref. 47).

A flight test was made with the 10-degree boattailed body scaled up by a factor of 3.5 with an internal Cordite motor. An HVAR booster provided the first stage of propulsion, as shown in figure 235. This test was made to extend the jet-effects data to the transonic speed range. The decrease in drag anticipated from the Preflight Jet tests was not realized because the jet-pressure ratio was never more than 0.86 in flight, which was near the value of maximum unfavorable effects in the Preflight Jet (ref. 48).

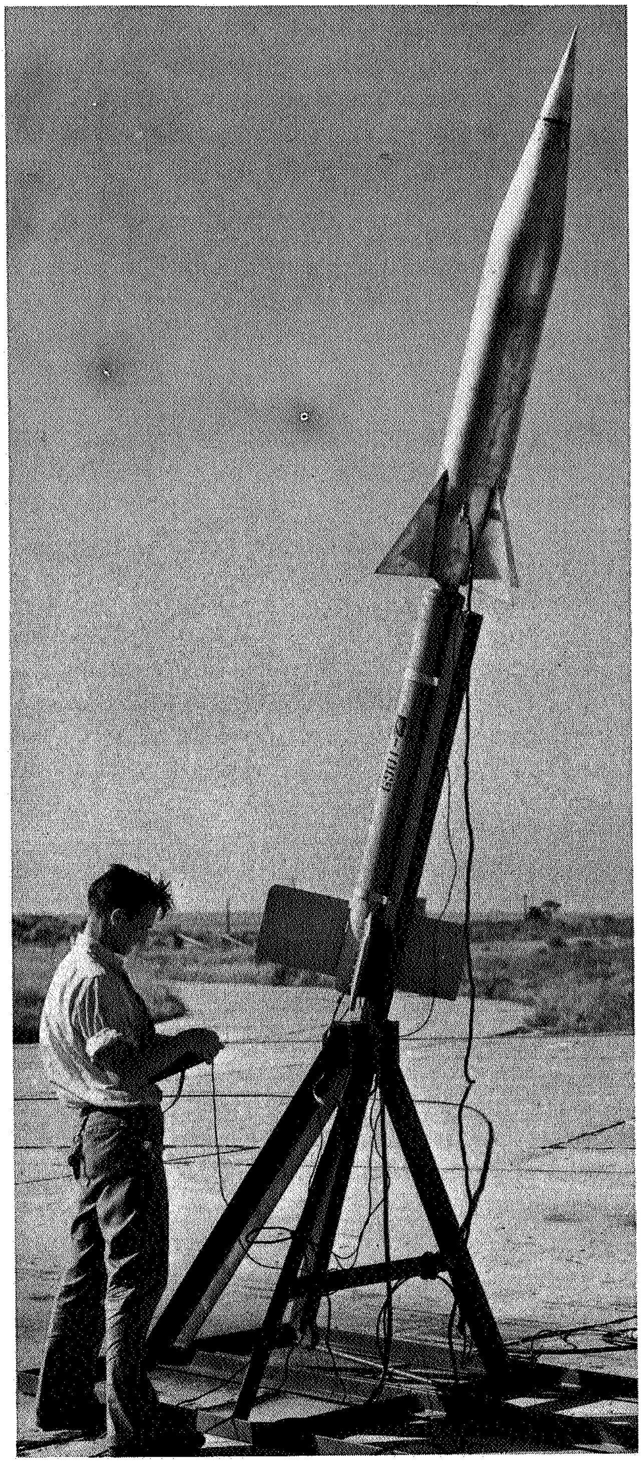


FIGURE 235. Technician Roy Hindle connects firing leads to HVAR booster for F12 jet-effects flight model, June 3, 1952.

CONTINUATION OF E5 ROLLING EFFECTIVENESS PROGRAM

Through 1954, the simple E5 technique was used in the general research rocket-model program, to evaluate the rolling effectiveness of various lateral-control devices in the transonic and supersonic speed range. The emphasis in this period continued to be on the problems of controls for airplanes.

The large losses of flap-type controls at transonic speeds and the high effectiveness obtained with either wing-tip lateral controls or all-movable horizontal tails for longitudinal control led researchers to examine the use of differentially deflected horizontal tails for lateral control. Wind-tunnel studies had been made at subsonic speeds, but the first tests at transonic speeds were made with two E5 models. The tail of the model was tapered and had 45-degree sweepback. The wing had a 55-degree modified delta planform, and both a stiff and a flexible wing were tested. A maximum Mach number of 1.5 was obtained with the standard E5 two-stage propulsion system. The flight data showed a nearly constant rolling effectiveness over the speed range; and, with the stiff wing, the results agreed well with a modified lifting-line theory. With the flexible wing, the rolling effectiveness was increased 60 percent (ref. 49).

Confirmation of the results for the stiff wing were obtained in a separate investigation in the E15 general research series, with use of the same horizontal-tail shape, but with a 45-degree sweptback wing (ref. 50). The differentially deflected horizontal tail for lateral control was applied to the X-15 research airplane; later, it was to be used on the Convair F-111A fighter-bomber.

The flight tests in the E5 lateral control program were originally made with the test wings arranged as three-panel stabilizing surfaces at the rear of the body. Later, this arrangement was replaced by a more normal two-panel wing in a mid-fuselage location, and four stabilizing fins were used. The fins were mounted on free-to-roll bearings to avoid interference with the basic wing and aileron test.

When it was found that, with some wings, an inboard location for the aileron was desirable, the influence of the tail on the overall response required investigation. A series of flight tests with a 45-degree sweptback wing having inboard and outboard half-span ailerons was conducted with the standard free-to-roll tail assembly, first locked in position and then unrestrained. The standard E5 two-stage propulsion system was used to cover a Mach number range up to 1.5. The tests showed a strong influence of downwash from the inboard deflected ailerons in inducing a rolling moment on the horizontal tail in opposition to the direct moment of the ailerons. The opposing moment from the tail was about a constant amount over the speed range, but it was large enough to completely nullify the aileron effect at Mach numbers above 1.3. With the ailerons in the outboard location, no appreciable interference from the tail was noted. All of the losses were explained by theory (ref. 51).

The effects of downwash were investigated further with a series of ten E5 models having 55-degree modified delta wings. This time, the free-to-roll tails were operative in all tests. The downwash effects were determined for a conventional horizontal tail and a single vertical tail located about midway between the wings and the free-to-roll tail, as shown in figure 236. The horizontal tail was tested in a high position, as shown, as well as in a low position. Ailerons one-third the span in length were tested in both inboard and midspan locations. Ailerons and spoilers two-thirds the wing span in length were also tested in inboard locations. The horizontal tail had little effect on the roll response of the midspan aileron, but reduced the effectiveness of all of the inboard controls. Raising the horizontal tail had little effect on the results. Available theory predicted the trends of the data but not the magnitude (ref. 52).

Some lateral control tests were made with 1/11-scale models of the wing of the Bell X-5 research airplane, to investigate aeroelastic losses. The 20-degree and 46.5-degree sweptback positions of this variable-sweep airplane were investigated. The tests showed that the airplane would be subject to severe aeroelastic losses for either sweep angle, and—at the test altitude of the rocket models—control reversal was obtained at speeds above Mach 0.9 (ref. 53).

The E5 rocket-model technique was used to investigate the effectiveness of external streamwise stiffening ribs or fences in reducing aeroelastic losses on a sweptback wing. The amount of stiffening possible by this method was small. Consequently, the improvement in control was quite small (ref. 54).

The use of wing-tip tanks was a common means for extending the range of fighter airplanes. Tests with E5 models were used to investigate the influence placement of such tanks on a thin, tapered, unswept wing had upon the effectiveness of plain and half-delta tip ailerons. Addition of the tanks reduced the rolling effectiveness of the plain ailerons somewhat and slightly increased the effectiveness of the tip controls (ref. 55).

The addition of roughness to the leading-edge area of an unswept wing to cause transition to turbulent flow had no effect on the transonic rolling effectiveness of plain ailerons (ref. 56).

In a series of 10 models, the general lateral control program with wings of various planforms was extended to wings of an aspect ratio of 8.0 and sweepback of 45 degrees. A thickness ratio of 12 percent was necessary for adequate strength. Results were compared with wings of lower aspect ratio and lesser thickness to establish that rolling effectiveness decreased as aspect ratio or thickness was increased. In

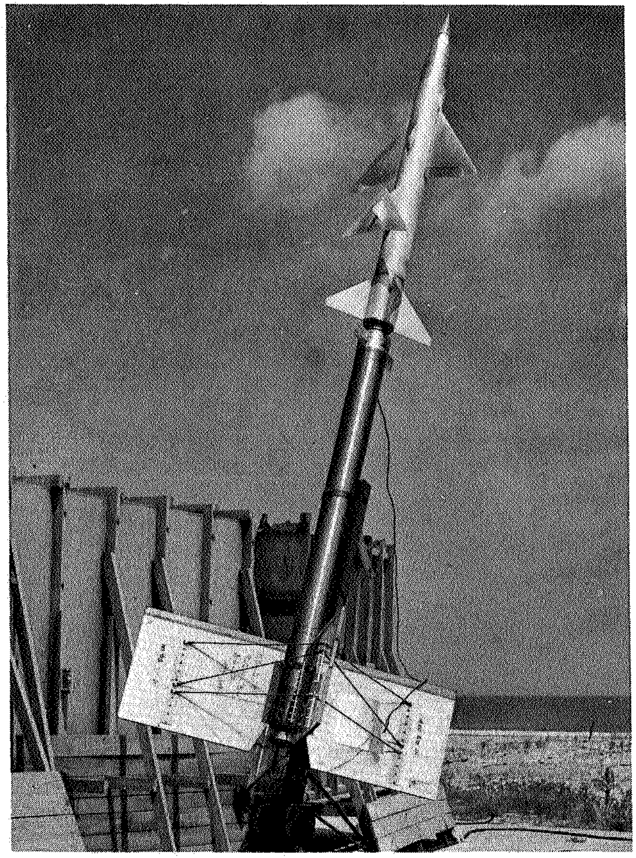


FIGURE 236. View of E5 rolling-effectiveness model with horizontal tail. Model is shown ready for test to determine downwash effects, June 20, 1955.

particular, the aileron on the wings of aspect ratio 8 and 12-percent thickness gave very poor effectiveness, with a reversal in control occurring in the transonic region (ref. 57).

To provide more data on the effects of aileron chord and span on rolling effectiveness, a series of E5 models having wing C planform were flown with full-chord deflected ailerons varying in span from 8 to 86 percent of the wing span. The results furnished end points for a general analysis (ref. 58).

A comprehensive collection and summary of E5 lateral control program data was made for 109 different wing and aileron combinations tested at Wallops during the first 10 years. All of the data were corrected for flexibility to give pure aerodynamic effectiveness (ref. 59).

AEROELASTICITY RESEARCH PROGRAM: E31

The influence of elastic deformations on aerodynamic loads had been appreciated for many years, and their effects had been considered in many of the rocket-model programs. A special program, designated E31, was initiated in 1951 to explore effects of aeroelasticity on the lift characteristics of sweptback wings. Wing H of the transonic program was selected because it would be of interest for transonic bombers and because it could have large aeroelastic effects. This wing had sweepback of 45 degrees, an aspect ratio of 6, a taper ratio of 0.6, and an NACA 65A009 airfoil section. The fuselage and vertical tails were the same as those used before in the F25 program.

Three models were flown at Wallops with wings of different stiffnesses, provided by variations in the metal used as surface inlays in the construction of the models. One of the models is shown in figure 237. A 65-inch HVAR motor was used as a booster, and an internal 3.25-inch motor provided the additional propulsion to reach a maximum Mach number of 1.5. A four-channel telemeter transmitted measurements of normal and longitudinal accelerations, total pressure, and angle of attack. Eight pulse rockets were used to disturb each model in pitch.

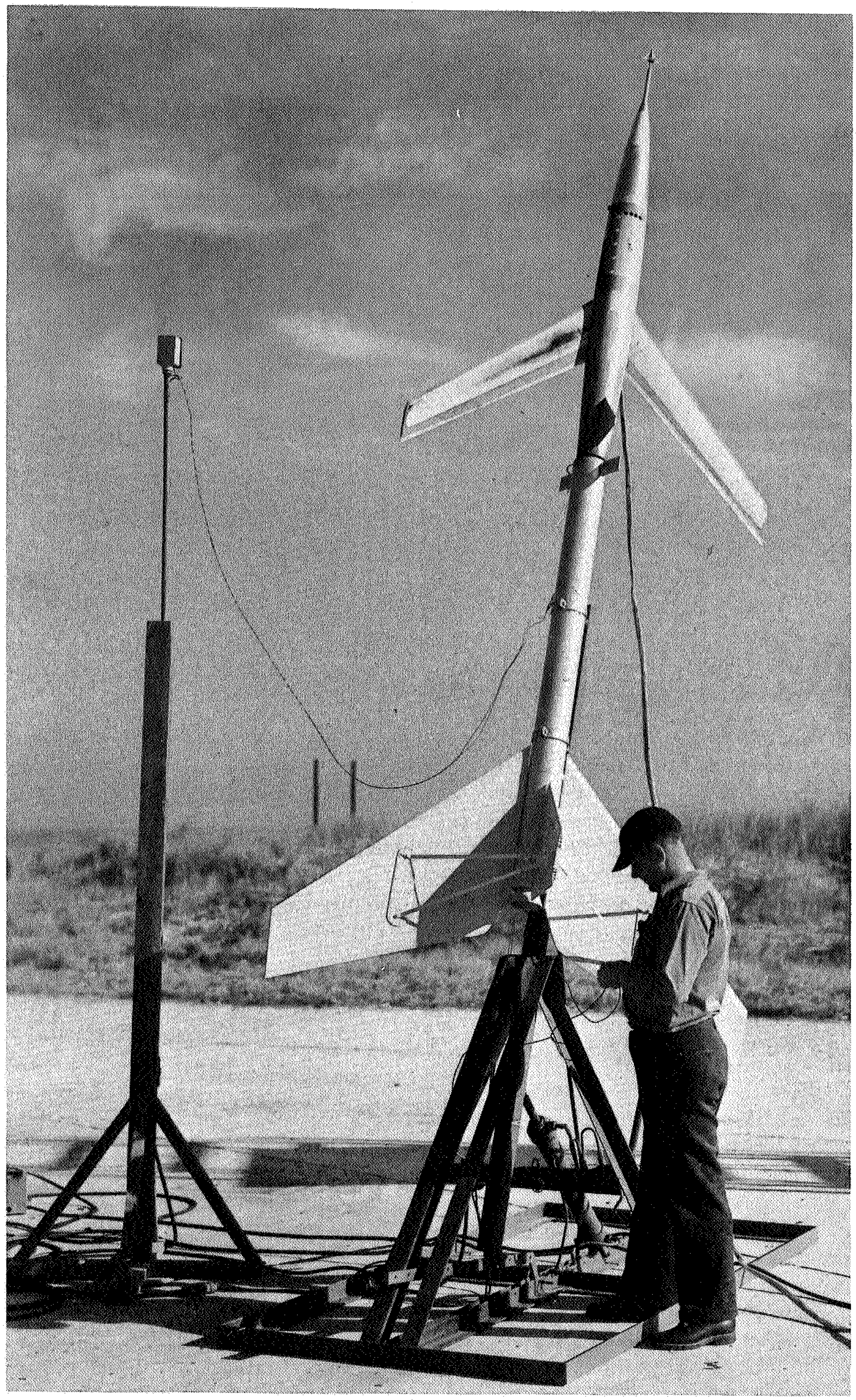


FIGURE 237. Technician Ed Matthews connects firing leads to 65–HVAR booster for E31 aeroelasticity model, November 14, 1952.

The characteristics of the wing structures were determined by loading the wings at different chordwise and spanwise points and measuring the deformation, from which the structural influence coefficients were determined. Strip theory was used to calculate the effects of these deformations on the lift distribution. The results of the flight tests of the three different wings were extrapolated to a rigid wing condition to establish the degree of loss in lift-curve slope for each wing. Comparisons of these losses with strip theory showed excellent agreement (ref. 60). In fact, the agreement was so good that no further testing was considered necessary, and the E31 program was terminated.

INITIATION OF HYPERSONIC HEAT-TRANSFER PROGRAM: F40

The extensive planning behind the hypersonic rocket-model research program—in terms of new rocket motors, instrumentation, and range support—has been discussed in Chapter 10. By the close of 1954, the first phase of this program had been completed, and data on heat transfer at Mach 10 were available for the first time. The Mach 10 vehicle was the outgrowth of a series of rocket vehicles designed to reach hypersonic speeds.

Two separate groups at PARD were directly involved in the hypersonic research program. The original RM-10 heat-transfer group, headed by C. B. Rumsey, was a part of the Performance section of the Propulsion Aerodynamics branch. A. C. Bond headed the Performance section, and M. A. Faget was head of the Performance Aerodynamics branch. This was the main group assigned responsibility for heat transfer research, and they had initiated a hypersonic heat-transfer program, designated F40. The group concentrated on models built around the Deacon or T40 motors as the last stage, with the Nike as the first stage.

The second group at PARD which involved itself with hypersonic research was in the General Aerodynamic branch, headed by P. E. Purser, and specifically in the Aircraft Components section, headed by C. A. Sandahl. This section had major responsibility in the fields of drag (wings and bodies) and lateral control. Robert O. Piland, R. N. Hopko, and W. E. Stoney, Jr., were in the drag-research group. Although Purser and Faget were equally involved in the preparation of the hypersonic research program, it was expected that the heat transfer research would be carried out in Faget's branch. Purser's group, nevertheless, initiated studies of other propulsion systems to reach hypersonic speeds. As it turned out, the first hypersonic model was Hopko's HPAG model, and the first Mach 10 model, which employed a Thiokol T55 motor as the last stage, was Piland's project.

Hopko's project was an extension of the RM-10 research and, as such, carried the designation E10. Piland wanted to call his project E40 as a parallel to the F40 program. Division Chief J. A. Shortal welcomed the competition between these two branches; but to mollify management he insisted upon assigning a different designation, E41, to the project of Piland. Officially, E41 was supposed to cover stability research at hypersonic speeds, and some information was obtained on the stability of bodies in these tests. Nevertheless, the major measurements of interest in both programs were of heat transfer. The first technical report on the hypersonic heat transfer measurements contained results from both groups. Several years later, in a major reorganization of PARD, the two groups were to be brought together in a single Heat Transfer section with Piland as the head.

The vehicle developed by Hopko had a triple Deacon for the first stage and an HPAG motor for the second stage. (See figure 174, Chapter 10.) The first triple Deacon-HPAG combination was flown on August 20, 1953, and the first heat-transfer measurements with this vehicle were made on a parabolic nose on November 20, 1953. The nose was a 2/3-replica of the RM-10 shape and was made of 0.031-inch inconel. The temperature of the skin was measured at a single station by means of a platinum wire 0.0005 inches in diameter cemented to the inner surface of the skin. A four-channel telemeter in the nose section was wrapped with asbestos for insulation from the high temperatures reached by the skin in flight. The skin temperature pickup failed at the maximum Mach number of 5.0. Heat transfer rates, as indicated by Stanton numbers, were found to be in fair agreement with the theory of Van Driest for a cone with turbulent flow (ref. 61).

The Nike-Deacon vehicle developed by Rumsey was first flown on November 19, 1953. A 10-degree conical nose, containing the telemeter, was attached to the front of the Deacon. The 10-degree cone was selected to provide data directly applicable to the Atlas missile. The skin was made from 0.029-inch inconel and had a single temperature pickup attached to the inner surface. This vehicle reached a Mach number of 5.6, but early failure of the temperature pickup limited the data to Mach 4. Again, fair agreement was obtained between measured Stanton numbers and the theory of Van Driest.

Two other multiple Deacon booster vehicles were flight tested at Wallops for possible high-speed application. The first was a quadruple Deacon, a cluster of four Deacons in parallel. Although it was developed for use as a booster in the PARD guided missile research program, it was watched closely by the men involved in hypersonic research. This vehicle was first flown on January 14, 1953. It was used later in the Falcon missile program and in a high-speed wing-drag research program.

The second new Deacon system was a so-called peel-away arrangement developed by the Performance section, in which three Deacon motors were strapped around a single central Deacon, as shown in figure 238. An HPAG rocket motor, mounted in tandem ahead of this central Deacon, powered the last stage. A Mach number of about 6.0 was expected. In operation, the outer three Deacons were ignited first; and, after burnout, the empty cases peeled away from the central motor as one peels a banana. The other two rockets were then ignited in turn. This system was flown successfully on April 29, 1954. The design of the system was initiated early in 1953 for possible use in the hypersonic program, but it was never so used, being superseded by the Nike booster. It did, however, find application in a later jet-effects program.

The peel-away feature of this design was rather ingenious. The three outer motors were hinged at the rear of the central motor by a device that prevented separation until the empty cases had rotated back more than 90 degrees. Knowledge gained with this vehicle was to be useful later to the Air Force in the design of other strap-on launch vehicle systems, such as the Thrust-Augmented Thor and the Titan III.

When the top Mach number obtained with the Nike-Deacon was found to be only 5.6 instead of 7.0 as calculated, PARD lost little time in adding a second Nike to the vehicle to form a three-stage Nike-Nike-Deacon system. Such a vehicle, with a 10-degree cone attached to the nose of the Deacon for heat transfer measurements, was launched April 29, 1954. This system is shown in figure 239. A maximum Mach number of 6.9 was reached, but the skin-temperature instrument failed at Mach 3.9, so no new heat-transfer data were obtained. The drag of the slender Deacon motor case with its conical nose and four stabilizing fins was evaluated for this and the earlier model to provide drag data between Mach 2 and 7 (ref. 62).

Word of the success of the hypersonic program at Wallops reached Washington, and NACA Headquarters arranged for a firsthand inspection and a briefing on the progress for two NACA

FIGURE 238. Triple "peel-away" Deacon booster on basic Deacon-HPAG hypersonic test vehicle, April 29, 1954.

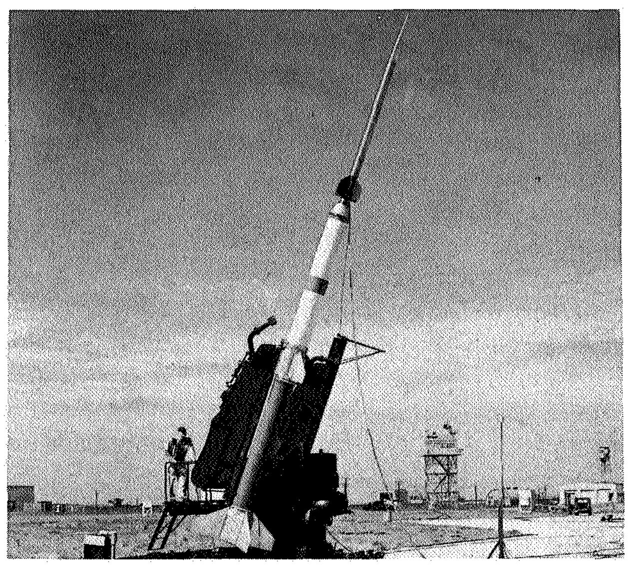


FIGURE 239. View of F40 heat-transfer model with Nike-Nike-Deacon launch vehicle on Terrier launcher at Wallops, April 29, 1954.

committees. The NACA Executive Committee, composed of NACA members, met at Wallops on June 17, 1954. In figure 240, they are shown outside the Model Assembly Shop. The Subcommittee on High-Speed Aerodynamics met at Wallops on August 31, 1954. They are shown in figure 241.

The original hypersonic program envisioned obtaining Mach 10 with a three-stage Nike-Nike-T-40 rocket motor combination. When the Nike-Nike-Deacon, flown by Rumsey, reached only Mach 6.9, Piland realized that a much smaller last stage would have to be used as a fourth stage if Mach 10 were to be reached with the basic Nike system. He selected the Thiokol T-55 motor, which weighed only 46 pounds, for such a last stage. This motor had been developed by Thiokol as a part of the Falcon missile program, and was generally similar to the T40 motor except for size. It had a diameter of 5.8 inches and a length of about 3 feet, and provided a thrust of 4,800 pounds for 1.3 seconds. Piland calculated that with this motor on top of a Nike-Nike-T40 vehicle to form a four-stage system, a Mach number in excess of 9 could be obtained. The vehicle as flown on October 14, 1954, is shown in figure 242. A Mach number of 10.4 was reached.

The launcher used in this first launching of a four-stage system was a simple I-beam device that had been used by the Army to launch the large solid-propellant motor developed for the Hermes A-2 missile. Wallops obtained the launcher from the Army after the Hermes was canceled.

As may be seen in figure 242, the first two stages made from Nike motors had fin-stabilization systems. The third stage also had fins for stability, but these were concealed at launch by wood fairings. The upper T55 stage was stabilized by a unique 10-degree flare stabilization system. The flared body was calculated to possess greater stability at hypersonic speeds than conventional fins, and its greater drag was of little consequence because of the high altitude of operation. The final stage or test model was about 6 feet long and, in addition to the flare, consisted of an inconel central section 6 inches in diameter and a Von Karman nose section of fineness ratio 5, made of stainless steel. The telemeter antenna consisted of two slender sweptback fins made from molybdenum with a siliconized coating, and located just behind the nose section. An inner radiation shield spaced 0.2 inch inside the outer skin protected the telemeter from extreme aerodynamic heating. Temperature was measured by a thermocouple inserted through a hole in the skin, welded in place, and faired smooth, and by a resistance wire cemented to the inner surface.

The first stage was connected to the second stage by a conventional plug-type adapter, and separated by itself after burnout. The second stage was connected to the third by a similar adapter but, in addition, had a lock to prevent premature separation. This lock was removed by pressure from the second stage after its ignition. The fourth stage was connected to the third by a special blowout diaphragm which was ruptured and released at ignition of the fourth-stage T55 motor. This system worked like a charm the first time it was tried. The maximum Mach number of 10.4, reached at an altitude of 86,000 feet was followed by a coast to an altitude of 219 miles and a range of about 400 miles, establishing new records in each for Wallops launchings (ref. 63).

The temperature data obtained from the Mach 10 flight was analyzed for heat transfer and was converted to Stanton numbers for comparison with theory. As before, the Stanton numbers agreed well with Van Driest's theory for turbulent flow until apparently the flow became laminar at high altitudes. The measured values were then of the same order as the laminar theory of Van Driest. Transition from turbulent to laminar flow occurred at a Reynolds number of 6.8 million, based on local conditions (ref. 64).

The day of the launching of this four-stage model (October 14, 1954), was indeed a busy one. Arrangements had been made with the Navy to provide assistance with launchings on this date. Three different, long-range, hypersonic models were prepared for launching in order to take advantage of the range clearance and surveillance provided. The three were the four-stage vehicle just described, a Nike-Nike-T40 heat-transfer vehicle, and a Nike-Nike-HPAG model instrumented for stability measurements. In figure 243, all may be seen in preparation. The four-stage vehicle and the Nike-Nike-HPAG model are on the two launchers. The third model is on its dolly in the background awaiting its turn. Two Navy search planes from Patuxent were provided to search the sea near the expected impact points, which extended 400 miles downrange in the Atlantic ocean between Jacksonville, Florida, and Bermuda. Because of the long range, use was made of the special radio communication facilities at Andrews Air Force Base, Maryland, plus a telephone relay from Andrews to Wallops.

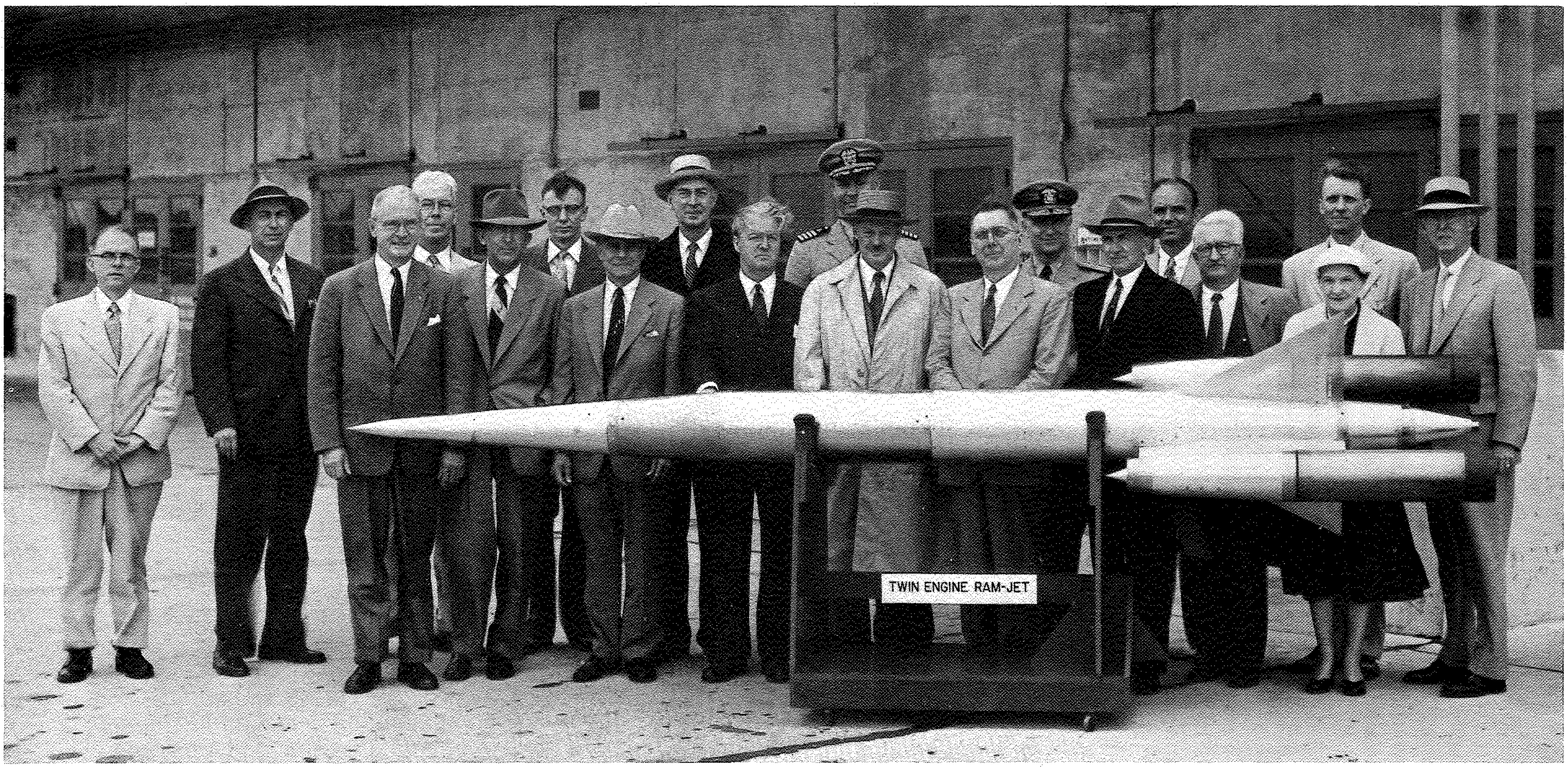


FIGURE 240. The NACA Executive Committee, photographed in front of Model Assembly Shop prior to meeting at Wallops on June 17, 1954. Left to right: A. M. Rothrock, NACA Hq.; R. R. Gilruth, Asst. Director, Langley; R. S. Damon, TWA; H. J. E. Reid, Director, Langley; R. M. Hazen, General Motors, Allison Div.; A. V. Astin, Bureau of Standards; J. H. Doolittle, Shell Oil Co.; L. Carmichael, Smithsonian Institution; J. P. Adams, CAB; Captain H. T. Johnson, U.S. Navy; J. C. Hunsaker, MIT, Chairman; H. L. Dryden, Director, NACA; Rear Admiral L. Harrison, Navy BuAer; P. R. Bassett, Sperry Gyroscope Co.; J. A. Shortal, Chief, PARD; J. W. Crowley, Assoc. Director, NACA; F. L. Thompson, Assoc. Director, Langley; Catherine Wheeler, NACA Hq.; and J. F. Victory, Executive Secretary, NACA.

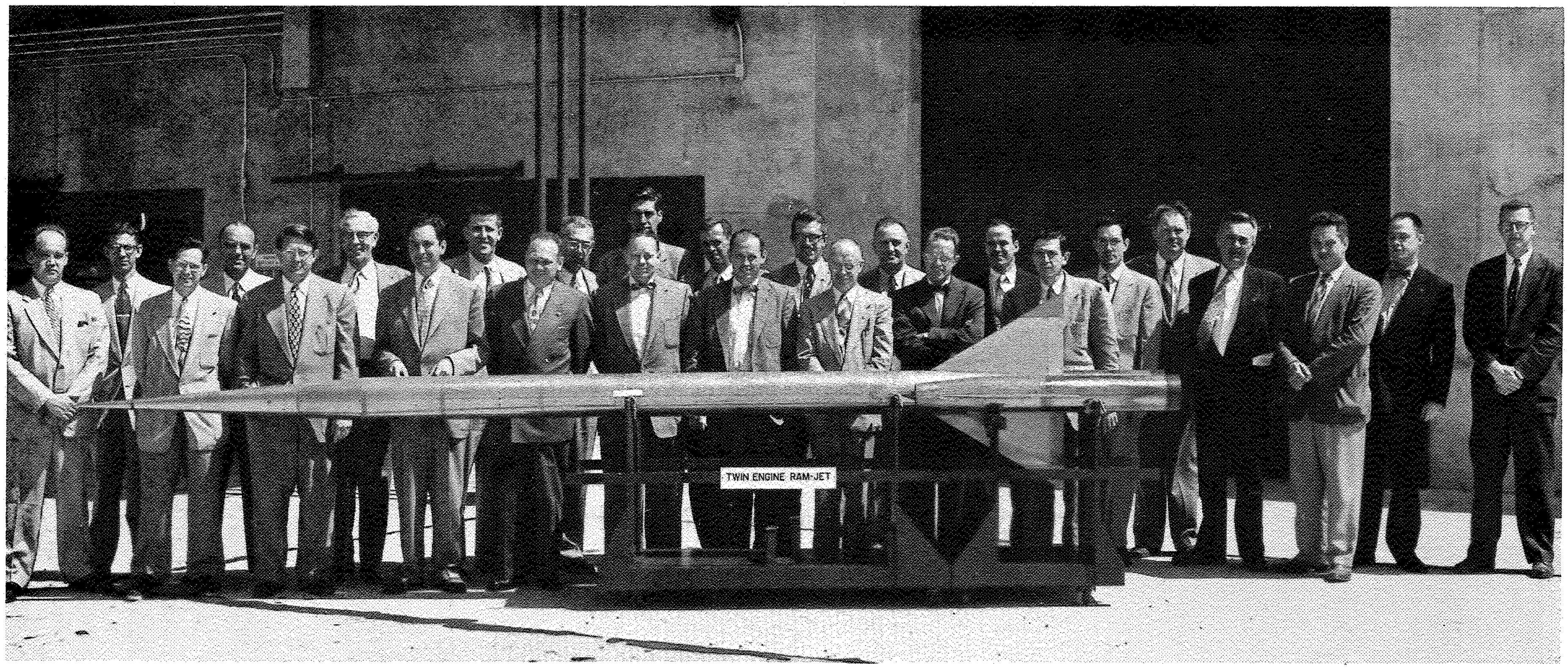


FIGURE 241. The NACA Subcommittee on High-Speed Aerodynamics, photographed at Wallops Model Assembly Shop prior to meeting on August 31, 1954. Left to right: R. L. Krieger, Engineer-in-Charge, Wallops; J. C. Palmer, Head of Research, Wallops; M. B. Ames, NACA Hq.; J. A. Shortal, Chief, PARD; A. Silverstein, Assoc. Director, Lewis; F. A. Louden, Navy BuAer: P. A. Colman, Lockheed Aircraft Corp.; H. J. Longfelder, Boeing Airplane Co.; K. E. Van Every, Douglas Aircraft Co.; J. G. Lee, United Aircraft Corp.; J. R. Clark, Chance Vought Corp.; C. L. Poor, Army BRL; H. E. Puckett, Hughes Aircraft Co.; L. P. Greene, North American Aviation, Inc.; G. Graff, McDonnell Aircraft Corp.; H. L. Anderson, WADC; H. H. Kurzweg, NOL; G. S. Trimble, Jr., Glenn L. Martin Co.; A. J. Evans, NACA Hq.; A. H. Flax, Cornell Aero. Lab.; C. Wood, NACA Hq.; H. J. Allen, Ames; J. Stack, Asst. Director, Langley; W. C. Williams, Edwards HSFS; D. W. Lueck, ARDC; and E. O. Pearson,NACA Hq.

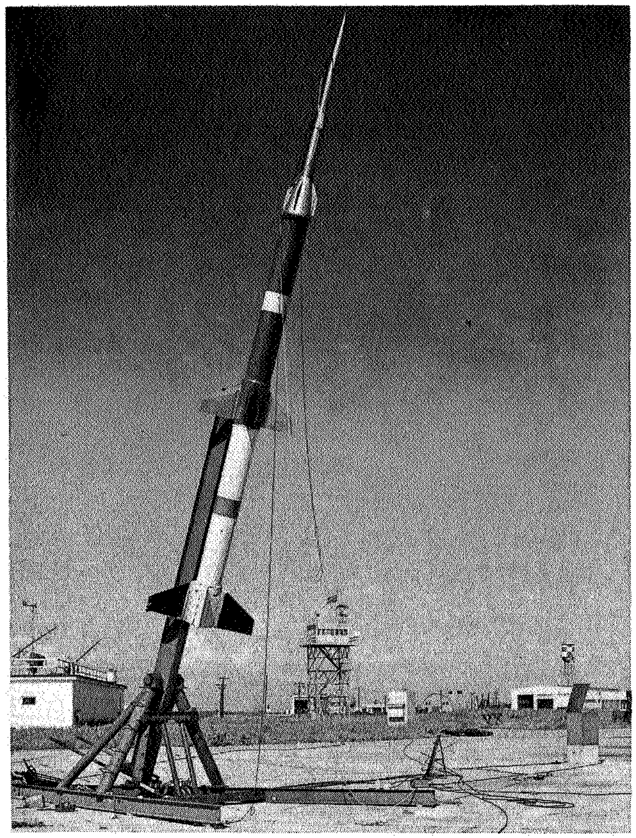


FIGURE 242. Four-stage Nike-Nike-T40-T55 hypersonic heat-transfer vehicle, shown on launcher at Wallops, October 14, 1954.

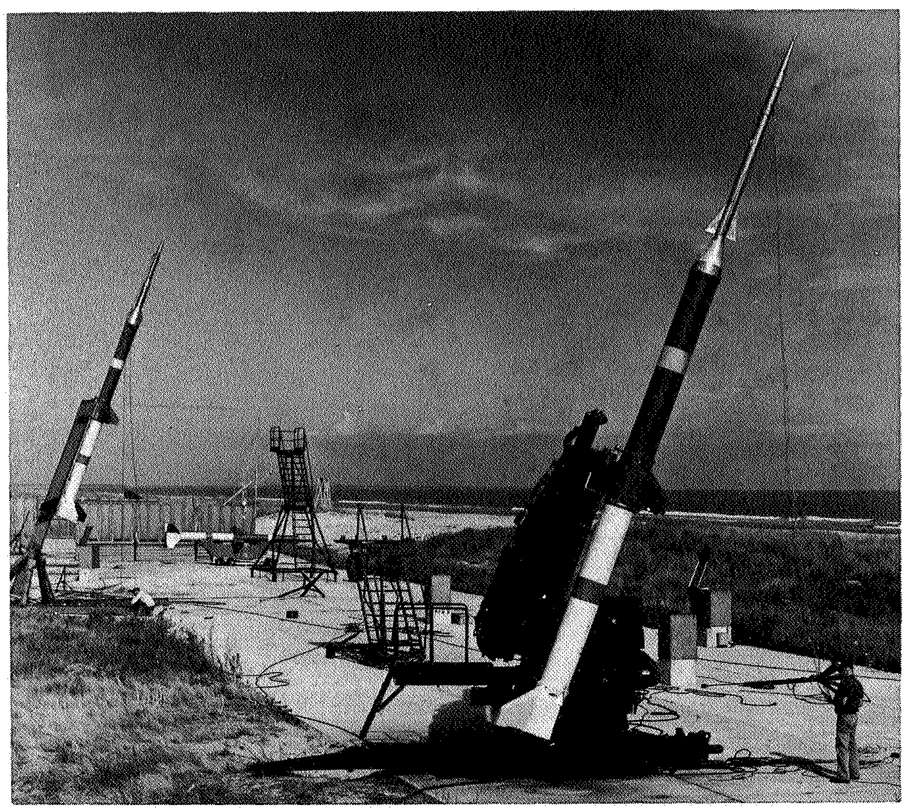


FIGURE 243. View of Wallops launch area on October 14, 1954, showing two hypersonic multistage vehicles on launchers and a third awaiting its turn to be mounted.

The sea area was found to be surprisingly clear of ships and the three models were launched as follows: Nike-Nike-HPAG at 3:24 p.m.; four-stage model at 4:20 p.m.; and Nike-Nike-T40 model at 5:12 p.m. All of the rocket motors fired as planned, and the objectives of all of the flights appeared to have been achieved.

It was not until later that an explanation of the lack of shipping was found. A hurricane, proceeding up the Atlantic coast, had apparently driven shipping into port. The hurricane, named Hazel, arrived at Wallops the next afternoon and inflicted considerable damage to powerlines and buildings. The weather at Wallops was beautiful and it was not until after the launchings that a hurricane prediction was received. About 10:00 p.m. on the day of the firings, a call came from Langley warning of the approaching storm and stating that an airplane was on its way to bring Langley personnel at the island back home. It seemed unnecessary at the time because there was no wind and the sky was clear, but the wisdom was apparent the following afternoon when Hazel struck the Virginia Capes with 120-knot winds.

LEWIS HEAT-TRANSFER PROGRAM FOR AIR-LAUNCHED MODELS

By the middle of 1952, the air-launched ramjet program of the Lewis Laboratory was being phased out and the personnel involved in the program were available for a new project. The NACA, at its meeting on February 14, 1952, had recommended development of new approaches to the problem of hypersonic testing, and Abe Silverstein, Chief of Research at Lewis, felt that the air-launched technique used for ramjet research could be applied to hypersonic flight research. The job of working out the details was assigned to John H. Disher, who had been in charge of the ramjet program.

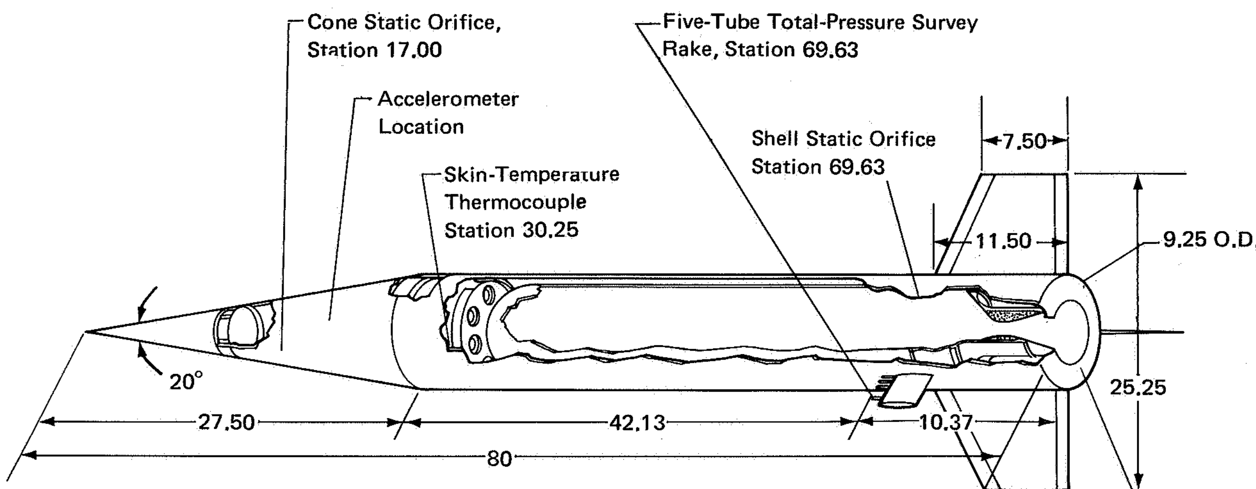
The plan was to use the same launching technique followed in the rocket-boosted ramjet tests. In that procedure, the rocket motor was ignited after the released vehicle had cleared the airplane by a safe distance, normally reached about 5 seconds after release. Disher had been in contact with Thibodaux at Langley in connection with the earlier rocket applications and was aware of the high-performance T40 motor now available. Calculations indicated that a single-stage model designed with the T40 as its propulsion unit could reach Mach 5 if air-launched at a 35,000-foot altitude. The system looked very promising, and plans were made to implement the proposal. The only stumbling block in the path was a reluctance of NACA Headquarters to approve what appeared to be a duplication of PARD rocket-model activity. In fact, they withheld approval of an RA, pending discussion with Langley.

On January 30, 1953, Disher, W. V. Gough, Jr., Warren J. North, and Leonard Rabb of Lewis visited Langley to discuss with PARD the duplication problem (ref. 65). PARD personnel concurred in the feasibility of the proposal and in the estimate that Mach 5 would be obtainable with the T40 motor at high altitude. Gilruth and Shortal agreed that Wallops would provide the necessary support during each test. The problem of duplication of PARD effort was resolved after Disher explained that, "If, as a result of the first flight, the technique appears promising, subsequent flights could be used for checking tunnel data at high Reynolds numbers and over a wide range of Mach numbers on such items as thrust from overexpanded nozzles and the off-design performance of inlets." On this basis, Gilruth offered no objection to the program.

After the Lewis personnel returned home, Silverstein disapproved Disher's inlet and exit test proposal and stated that the main use of the new vehicles should be for the measurement of drag of bodies at a high Mach number. This information was relayed to Gilruth, but he still raised no objections. As it turned out, the main use made of the system was for heat-transfer research. While this might seem to be a direct duplication of PARD research, the two different groups actually complemented each other, and the research was no more a duplication than was heat-transfer research conducted in the different wind tunnels of the NACA.

The first air launch in the hypersonic program was made at Wallops on March 17, 1953, and a Mach number of 5.2 was reached. The complete vehicle is shown schematically in figure 244. The T40 motor was mounted inside a cylindrical body of 9.25-inch diameter, with four stabilizing fins and a

20-degree conical nose to make an overall length of 80 inches. The weight at release was 202 pounds. A 10-channel telemeter transmitted measurements of skin temperature, accelerations, and pressures, including those from a boundary-layer probe. The model was prepared at Cleveland, Ohio, was flown to an altitude of 35,000 feet over Wallops on a North American F-82 airplane, and then was launched out to sea on command from the Wallops controller. During its long prelaunch exposure to low temperatures, the complete model was kept warm by an electric blanket. Wallops tracked the model by SCR-584 radar, recorded the telemeter data, and provided information on winds aloft by launching a weather balloon.



Gross Weight, lb	202
Empty Weight, lb	99
Launching Altitude, ft	35,000
Design Mach Number at 30,000 ft.	5.0
Rocket Engine	jato 6-KS-3000 T40
Center of Gravity at Gross Weight	Station 48
Center of Gravity at Burnout	Station 43.5
Total Base Area, ft^2	0.467
Annular Base Area, ft^2	0.331

FIGURE 244. Schematic view of air-launched cone-cylinder test vehicle, including general specifications and location of instrumentation pickups. (Dimensions are in inches.)

The test was quite successful and indicated the feasibility of the technique for hypersonic flight research. The telemeter operated continually through the acceleration period and a short time afterward, failing at 16.4 seconds after launch, apparently from excessive heat. Data on total and component drag, skin friction, and heat transfer were obtained from a Mach number of 1.5 to one of 5.2 (ref. 66).

STATUS OF WALLOPS AT THE END OF 1954

By the end of 1954, a major expansion of research facilities at Wallops had been completed, and rocket-model testing was fast becoming a routine affair. Transonic wind tunnels were in operation at Langley, and much of the research in this speed range had been taken over by these facilities. Emphasis at Wallops had now shifted to the hypersonic range (Mach 5 and higher) with the successful launching of three- and four-stage launch vehicles. The mastery of the technique of multistaging solid-rocket motors in tandem was a noteworthy achievement and was to influence the design of military ballistic missiles in the years ahead. Instrumentation at Wallops had been improved as required for the higher speeds, but a remaining need for longer range tracking radars was not to be filled until several years later.

By 1954, several new solid-rocket motors had been added to Wallops' inventory, along with the required launching equipment. In particular, the Nike booster motor had been adopted as a large first-stage motor, and two high-performance, cast, polysulfide rocket motors, the Thiokol T40 and T55, were instrumental in increasing the speed capability of rocket models.

During the 1950-1954 period, rocket models of practically all the supersonic missiles and airplanes under development by the military services were tested at Wallops. Models of 10 new airplanes and 9 new missiles were investigated by this technique. Models included the Convair F-102, XF2Y-1, XFY-1, and B-58 airplanes; the North American F-100 airplane and Navaho missile; the Chance Vought XF8U-1 airplane and Regulus II missile; the Hughes Falcon missile; the Northrop Snark missile; and the Navy Sidewinder. In several instances, major redesign of an airplane was initiated following preliminary findings of the rocket-model tests, and resulted in large gains in performance of the final airplane. It was now almost a standing order that the military services make use of Wallops facilities in the development of all supersonic airplanes and missiles.

During this period, rocket-model research at Wallops established the requirements for design of an airplane with safe and smooth flight characteristics through the transonic region. The major factor was found to be the wing thickness ratio: 3- to 4-percent thickness for straight or delta wings, and 5- to 7-percent for sweptback wings. With these thickness ratios, the undesirable phenomena of large trim changes, wing dropping, buffeting, and loss of control near Mach 1 were practically eliminated.

Whitcomb's area rule was discovered at Langley during this period, and by the end of 1954, through extensive transonic-tunnel and rocket-model research, the applicability and limitations of the rule for all types of aircraft had been determined. Through application of this rule, most supersonic airplanes now had the familiar coke-bottle or wasp-waist fuselage design for higher performance.

During the same period, ramjet propulsion systems burning liquid, gaseous, or solid fuels were successfully developed, and altitude and speed records for ramjets were set by the PARD F23 twin-engine vehicle. The requirements for efficient air-inlet design for all types of engines were also determined.

The Preflight Jet, with its true-temperature supersonic jets and large air-storage capability, demonstrated its versatility and, by the end of 1954, had been found suitable for many new uses. One of these was in the development of two new unique vertically rising aircraft, the Jet Board and the Whirligig, which demonstrated that a man can stand on a board equipped with a thrust device and can control his in-flight motions through inherent body movements. A second new use of the Preflight Jet was for research with scaled models of actual wing structures.

With the initiation of the hypersonic flight program at Wallops, the long-standing 25-mile limitation of the range was removed. Cooperation of the Navy in all long-range operations was now obtained, and the way was opened for unlimited extensions of operations at ever-increasing speeds and ranges, eventually leading to space flight.

References

1. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Science and Technology in the Exploration of Space, 1915–1960.* NASA, 1961, p. 158.
2. *Air Force and Space Digest,* Sept. 1967.
3. Blanchard, Willard S., Jr.: *Drag and Longitudinal Trim at Low Lift of the North American YF–100A Airplane at Mach Numbers From 0.76 to 1.77 as Determined From the Flight Test of a 0.11-Scale Rocket Model.* NACA RM SL53E11a.
4. Blanchard, Willard S., Jr.: *A Summary of the Drag and Longitudinal Trim at Low Lift of the North American YF–100A Airplane at Mach Numbers From 0.75 to 1.77 as Determined by Flight Tests of 0.11-Scale Rocket Models.* NACA RM SL54B01.
5. Blanchard, Willard S., Jr.: *Drag and Longitudinal Trim Characteristics of a Low-Tail Version of the North American YF–100A Airplane as Determined From the Flight Test at Low Lift of a 0.11-Scale Rocket-Powered Model at Mach Numbers Between 0.75 and 1.78.* NACA RM SL54D05.
6. Blanchard, Willard S., Jr.: *A Summary of the Low-Lift Drag and Longitudinal Trim Characteristics of Two Versions of an Interceptor-Type Airplane as Determined From Flight Tests of Rocket-Powered Models at Mach Numbers Between 0.75 and 1.78.* NACA RM L54E31.
7. O'Kelly, Burke R.: *Free-Flight Tests of 0.11-Scale North American F–100 Airplane Wings to Investigate the Possibility of Flutter in Transonic Speed Range at Varying Angles of Attack.* NACA RM SL54G29.
8. Wallskog, Harvey A.: *Free-Flight Zero-Lift Drag Results From a 1/5-Scale Model and Several Small-Scale Equivalent Bodies of Revolution of the Convair F–102 Configuration at Mach Numbers up to 1.34.* NACA RM SL54D09b.

9. Stoney, William E., Jr.: *Transonic Zero-Lift Drag Tests of Four Equivalent-Body-of-Revolution Models Representing Variations of the Convair F−102 Airplane.* NACA RM SL55J31a.
10. Wallskog, Harvey A.: *Summary of Free-Flight Zero-Lift Drag Results From Tests of 1/5-Scale Models of the Convair YF−102 and F−102A Airplanes and Several Related Small Equivalent Bodies at Mach Numbers From 0.70 to 1.46.* NACA RM SL54J25.
11. Dawson, Judith E.; and Scholin, Allan R.: "A Gallery of USAF Weapons." *Air Force and Space Digest,* Sept. 1967, p. 232.
12. O'Kelly, Burke R.: *Free-Flight Tests of 1/9-Scale Convair YF−102 Airplane Wings at Transonic and Supersonic Speeds to Investigate the Possibility of Flutter.* NACA RM SL54L22.
13. *Jane's All the World's Aircraft,* 1958−1959, p. 331.
14. Emme, *op. cit.,* pp. 158, 160.
15. Emme, *op. cit.,* p. 174.
16. Kehlet, Alan B.: *Flight Results From a 1/10-Scale Rocket Model of the Lockheed XF−104 Airplane at Transonic Speeds.* NACA RM SL54E14.
17. Blanchard, Willard S., Jr.: *Minimum Drag of 0.11-Scale Rocket-Powered Models of the Chance Vought XF8U−1 Airplane, With and Without Nose Modifications at Mach Numbers Between 0.85 and 1.30.* NACA RM SL54F17.
18. Hastings, Earl C., Jr.: *Flight Determination of Minimum Drag of 0.11-Scale Rocket-Boosted Model of the Chance Vought XF8U−1 Airplane With Modified Fuselage Area Distribution and Faired Inlet at Mach Numbers From 0.82 to 1.68.* NACA RM SL55I27.
19. Hastings, Earl C., Jr.: *Minimum Drag of the Chance Vought XF8U−1 Airplane as Determined From the Flight Test of a 0.11-Scale Rocket-Boosted Model at Mach Numbers Between 0.73 and 1.71.* NACA RM SL56C19.
20. Hastings, Earl C., Jr.: *Minimum Drag of Four Versions of a Swept-Wing Fighter Airplane Obtained From Flight Tests of Rocket-Boosted Models at Mach Numbers From 0.81 and 1.71.* NACA RM L56E25a.
21. O'Kelly, Burke R.: *Free-Flight Tests of 0.11-Scale Chance Vought XF8U−1 Airplane Wings to Investigate the Possibility of Flutter in the Transonic and Low Supersonic Speed Ranges.* NACA RM SL54J21.
22. Dawson, John R.; and Wadlin, Kenneth L.: *Preliminary Tank Tests of NACA Hydroskis for High-Speed Airplanes.* NACA RM L7I04.
23. Bland, William M., Jr.; and Nelson, Robert L.: *Results of a Power-On Flight of a 1/10-Scale Rocket-Propelled Model of the Convair XF2Y−1 Airplane at a Mach Number of 1.55.* NACA RM SL53I30a.
24. Bland, William M., Jr.: *Results of Free-Flight Test of 1/10-Scale Model of the Convair XF2Y−1 Airplane Between Mach Numbers of 0.7 and 1.45, Including Power-On Flight at Mach Number 1.2.* NACA RM SL54B05.
25. Welsh, Clement J.; Bland, William M., Jr.; and Walters, Richard E.: *Rocket-Model Investigation of the Longitudinal Stability and Drag Characteristics of a 1/10-Scale Model of the Convair XF2Y−1 Airplane Having Open Ducts and the Elevons Deflected Upward 3.5°.* NACA RM SL54A05.
26. Bland, William M., Jr.: *Stability and Drag Characteristics of 1/10-Scale Model of the Convair XF2Y−1 Airplane With Open Inlets Containing Boundary-Layer Splitter Plates as Obtained in Free Flight at Mach Numbers Between 0.7 and 1.5.* NACA RM SL55D14.
27. Hastings, Earl C., Jr.; and Mitcham, Grady L.: *Flight Determination of the Longitudinal Stability Characteristics of a 0.133-Scale Rocket-Powered Model of the Consolidated Vultee XFY−1 Airplane Without Propellers at Mach Numbers From 0.73 to 1.19.* NACA RM SL54B03a.
28. Hastings, Earl C., Jr.; and Mitcham, Grady L.: *Longitudinal Stability Characteristics of the Consolidated Vultee XFY−1 Airplane With Windmilling Propellers as Obtained From Flight of 0.133-Scale Rocket-Propelled Model at Mach Numbers From 0.70 to 1.13.* NACA RM SL54F11.
29. Hollinger, James A.; and Mitcham, Grady L.: *Flight Test of the Lateral Stability of a 0.133-Scale Model of the Convair XFY−1 Airplane With Windmilling Propellers at Mach Numbers From 0.70 to 1.12.* NACA RM SL55J31.
30. Church, James D.: *Zero-Lift Drag of the Chance Vought Regulus Missile at Mach Numbers Between 0.8 and 2.2 as Determined From the Flight Tests of Two 0.12-Scale Models.* NACA RM SL54H02.
31. Wineman, Andrew R.: *Some Flight Data for the Chance Vought Regulus II Missile.* NACA RM SL56D02.
32. Wineman, Andrew R.: *Summary of Flight Data Obtained From 0.12-Scale Rocket-Powered Models of the Chance Vought Regulus II Missile.* NACA RM SL58H11.
33. Michal, David H.: *Free-Flight Investigation of the Static and Dynamic Longitudinal Stability Characteristics of 1/3.7-Scale Rocket-Powered Models of the Bell MX−776A.* NACA RM SL50B23.
34. Stevens, Joseph E.: *Preliminary Results of a Flight Investigation of 1/6-Scale Rocket-Powered Models of the Bell MX−776 to Determine Aileron Rolling Effectiveness and Total Drag.* NACA RM SL51D27.
35. Stevens, Joseph E.; and Parks, James H.: *Free-Flight Investigation of the Stability Characteristics of 1/6-Scale Rocket-Propelled Models of the Bell MX−776.* NACA RM SL54D24.
36. Bland, William M., Jr.; and Purser, Paul E.: *Rocket-Model Measurements of Zero-Lift Damping in Roll of the Bell MX−776 Missile at Mach Numbers From 0.6 to 1.56.* NACA RM SL54A13.
37. Stevens, Joseph E.: *Qualitative Results From a Flight Investigation to Determine Aileron Effectiveness of Two Rocket-Propelled 1/20-scale Models of the MX−776 Missile.* NACA RM SL55J11.
38. Baber, Hal T.; and Moul, Martin T.: *Longitudinal Stability and Control Characteristics as Determined by the Rocket-Model Technique for an Inline, Cruciform, Canard Missile Configuration With a Low-Aspect-Ratio Wing Having Trailing-Edge Flap Controls for a Mach Number Range of 0.7 to 1.8.* NACA RM L54B12.
39. Lundstrom, Reginald R.; and Baber, Hal T., Jr.: *Some Effects of Roll Rate on the Longitudinal Stability Characteristics of a Cruciform Missile Configuration as Determined From Flight Test for a Mach Number Range of 1.1 to 1.8.* NACA RM L55L16.
40. Lundstrom, Reginald R.: *Free-Flight Investigation of the Full-Scale Hughes Falcon Missile D Configuration to Determine Aileron Effectiveness and Damping in Roll.* NACA RM SL54K19.

41. Brown, Clarence A., Jr.; and Nason, Martin L.: *Flight Investigation to Evaluate the Roll-Rate Stabilization System of the Naval Ordnance Test Station Sidewinder Missile at Mach Numbers From 0.9 to 2.3.* NACA RM SL54D26.
42. Nason, Martin L.; Brown, Clarence A., Jr.; and Rock, Rupert S.: *An Evaluation of a Rolleron-Roll-Rate Stabilization System for a Canard Missile Configuration at Mach Numbers From 0.9 to 2.3.* NACA RM L55C22.
43. Brown, Clarence A., Jr.: *Flight Investigation at Low Angles of Attack to Determine Longitudinal Stability and Control Characteristics of Sidewinder Missile at Mach Numbers From 1.2 to 2.1.* NACA RM SL55K16.
44. Piland, Robert O.: *The Zero-Lift Drag of a 60° Delta-Wing-Body Combination (AGARD Model 2) Obtained From Free-Flight Tests Between Mach Numbers of 0.8 and 1.7.* NACA TN 3081, Apr. 1954.
45. Mitchell, Jesse L., Memorandum, Feb. 7, 1957, concerning rocket model investigation of the AGARD Model 2 by the NACA Langley Laboratory.
46. Shortal, Joseph A.: "Techniques of Model Testing in Free Flight." Paper presented at Fourth General Assembly of AGARD, NATO, The Hague, Netherlands, May 3, 1954.
47. de Moraes, Carlos A.; and Nowitsky, Albin M.: *Experimental Effects of Propulsive Jets and Afterbody Configurations on the Zero-Lift Drag of Bodies of Revolution at a Mach Number of 1.59.* NACA RM L54C16.
48. de Moraes, Carlos A.: *Transonic Flight Test of a Rocket-Powered Model to Determine Propulsive Jet Influence on the Configuration Drag.* NACA RM L54D27.
49. English, Roland D.: *Free-Flight Investigation, Including Some Effects of Wing Aeroelasticity, of the Rolling Effectiveness of an All-Movable Horizontal Tail With Differential Incidence at Mach Numbers From 0.6 to 1.5.* NACA RM L54K30.
50. Mitchell, Jesse L.; and Vitale, A. James: *Free-Flight Investigation of the Control Effectiveness of a Differentially Deflected Horizontal Tail at Mach Numbers From 0.8 to 1.6.* NACA RM L56B20.
51. English, Roland D.: *Free-Flight Investigation to Determine Some Effects of Tail Damping and Wing-Tail Interference on the Rolling Effectiveness of Inboard and Outboard Ailerons on an Untapered Sweptback Wing.* NACA RM L54L17a.
52. English, Roland D.: *Free-Flight Investigation to Determine Some Effects of Tail Damping and Wing-Tail Interference on the Rolling-Effectiveness of Ailerons and a Spoiler on a Modified-Delta Wing at Mach Numbers From 0.6 to 1.5.* NACA RM L57C13.
53. English, Roland D.: *Some Effects of Aeroelasticity and Sweepback on the Rolling Effectiveness and Drag of a 1/11-Scale Model of the Bell X−5 Airplane Wing at Mach Numbers From 0.6 to 1.5.* NACA RM L53I18b.
54. Stephens, Emily W.: *The Effect of External Stiffening Ribs on the Rolling Power of Ailerons on a Swept Wing.* NACA RM L56D19.
55. English, Roland D.: *Some Effects of External Wing Tip Stores on the Rolling Effectiveness and Drag of Plain and Half-Delta Tip Ailerons on a 4-Percent-Thick, Tapered, Unswept Wing.* NACA RM L54F29a.
56. English, Roland D.: *Some Effects of Leading-Edge Roughness on the Aileron Effectiveness and Drag of a Thin Rectangular Wing Employing a Full-Span Plain Aileron at Mach Numbers From 0.6 to 1.5.* NACA RM L53I25.
57. Strass, H. Kurt: *Summary of Some Rocket-Model Investigations of Effects of Wing Aspect Ratio and Thickness on Aileron Rolling Effectiveness Including Some Effects of Spanwise Aileron Location for Sweptback Wings.* NACA RM L53L11.
58. Strass, H. Kurt; and Tucker, Warren A.: *Some Effects of Aileron Span, Aileron Chord, and Wing Twist on Rolling Effectiveness as Determined by Rocket-Powered Model Tests and Theoretical Estimates.* NACA RM L54G13.
59. Strass, H. Kurt; Stephens, Emily W.; Fields, E. M.; and Schult, Eugene D.: *Collection and Summary of Flap-Type-Aileron Rolling-Effectiveness Data at Zero Lift as Determined by Rocket-Powered Model Tests at Mach Numbers Between 0.6 and 1.6.* NACA RM L55F14.
60. Walters, Richard E.: *Comparison of Experimental With Calculated Results for the Lifting Effectiveness of a Flexible 45° Sweptback Wing of Aspect Ratio 6.0 at Mach Numbers From 0.8 to 1.3.* NACA RM L54B16.
61. Rumsey, Charles B.; Piland, Robert O.; and Hopko, Russell N.: *Aerodynamic Heating Data Obtained From Free-Flight Tests Between Mach Numbers of 1 and 5.* NACA RM L55A14a. Reissued as NASA TN D−216, Jan. 1960.
62. Rumsey, Charles B.: *Free-Flight Measurements of Aerodynamic Heat Transfer to Mach Number 3.9 and of Drag to Mach Number 6.9 of a Fin-Stabilized Cone-Cylinder Configuration.* NACA RM L55G28a.
63. Piland, Robert O.: *Performance Measurements From a Rocket-Powered Exploratory Research Missile Flown to a Mach Number of 10.4.* NACA RM L54L29a.
64. Bland, William M., Jr.; and Collie, Katherine A.: *Free-Flight Aerodynamic-Heating Data to Mach Number 10.4 for a Modified von Karman Nose Shape.* NACA RM L56D25.
65. Minutes, meeting between Lewis and Langley personnel to discuss high Mach number research vehicles, Langley Field, Virginia, Jan. 30, 1953. Minutes prepared by John H. Disher.
66. Messing, Wesley E.; Rabb, Leonard; and Disher, John H.: *Preliminary Drag and Heat-Transfer Data Obtained From Air-Launched Cone-Cylinder Test Vehicle Over Mach Number Range From 1.5 to 5.18.* NACA RM E53I04.

CHAPTER 12

INITIATION OF HIGH-TEMPERATURE RESEARCH: 1955

CHANGES IN ORGANIZATION AND REVIEW OF FACILITY NEEDS

The death of Ernest Johnson, Chief of Administrative and Technical Services at Langley, April 19, 1954, was followed by a rather extensive reorganization of Langley that also affected Wallops. Under the reorganization, effective August 20, 1954, Langley Administrative Services were placed under W. Kemble Johnson with Wallop's Administrative Unit reporting to Johnson; and Technical Services were placed under Percy J. Crain. Wallops' Technical Services Unit continued to report to the Mechanical Service Division, now headed by William B. Mayo. In addition to separating Administrative and Technical Services at Langley, the reorganization resulted in transfer of the Instrument Research Division to Research, reporting to Hartley A. Soulé, Assistant Director. This shift of IRD to Research was partly due to a desire on the part of management for IRD to conduct original research instead of being mainly a service group.

By 1955, Gilruth was eager to extend Langley research on materials and structures into the high-temperature range corresponding to hypersonic flight. The NACA Committee on Aircraft Construction, on which Gilruth was the Langley member, held its regular meeting on April 12, 1955, at Wallops (See figure 245) to examine Wallops' facilities suitable for research over which this committee had cognizance. The 600° F temperature in the Wallops Preflight Jet was of immediate interest, but it corresponded to a range approximating only Mach 2. For Mach 6 simulation, 4,000° F was required; and for tests of ballistic missile nose cones, much higher temperatures were needed.

On June 6, 1955, Paul E. Purser, Head of the General Aerodynamics Branch of PARD, was temporarily transferred to the Office of the Associate Director to work directly with Gilruth in planning new high-temperature facilities for Langley. He was assisted in this task by R. R. Heldenfels, Head, Elevated Temperature Section, Structures Research Division. A presentation was made to the NACA Subcommittee on Aircraft Structures on September 11, 1955, outlining high-temperature problems and describing existing NACA facilities and needs and plans for the immediate future to extend research capability to Mach 20 (ref. 1). On November 28, 1955, Purser was reassigned to PARD and announcement was made of a reorganization of PARD in which Purser was named head of a new High-Temperature Branch, the General Aerodynamics Branch was dissolved, and other internal changes were made.

The organization of PARD, incorporating the changes, was as follows:

Chief:	Joseph A. Shortal
Assistant Chief:	Paul R. Hill
Assistant to Chief:	William J. O'Sullivan, Jr.
Research Operations and Techniques Branch	
Head:	Robert L. Krieger
Aircraft Configurations Branch	
Head:	Clarence L. Gillis
Assistant Head:	Jesse L. Mitchell
High-Temperature Branch	
Head:	Paul E. Purser
Rocket Section Acting Head:	Joseph G. Thibodaux
Materials Section Head:	Joseph G. Thibodaux
Structural Dynamic Section Head:	Aleck C. Bond
Performance Aerodynamics Branch	
Head:	Maxime A. Faget
Heat Transfer Section Head:	Robert O. Piland
Performance Section Acting Head:	Maxime A. Faget[1]
Preflight Jet Section Head:	Carl A. Sandahl[2]
Stability and Control Branch	
Head:	David G. Stone
Automatic Control Section Head:	Howard J. Curfman[3]
Aerodynamic Section Head:	William N. Gardner[4]

1. On Oct. 10, 1956, Sherwood Hoffman replaced Faget as head of this section.
2. Carl A. Sandahl replaced Douglas H. Foland, who was transferred to the Structures Research Division.
3. Howard J. Curfman replaced Robert A. Gardiner, who had resigned.
4. William N. Gardner had been made head of this section on July 1, 1955.

FIGURE 245. The NACA Committee on Aircraft Construction, photographed behind RM−10 missile at Wallops prior to meeting on April 12. 1955. Left to right: R. J. Woods, Bell Aircraft Corp.; G. C. Covington, McDonnell Aircraft Corp.; M. Goland, Southwest Research Institute; W. von Braun, Redstone Arsenal; J. A. Shortal, Chief, PARD; A. A. Vollmecke, CAA; G. Snyder, Boeing Airplane Co.; V. E. Teig, Commander, USN BuAer; J. F. McBrearty, Lockheed Aircraft Corp.; G. D. Ray Bell Aircraft Corp.; D. R. Kirk, Convair; R. R. Gilruth, Asst. Director, Langley; R. L. Schleicher, North American Aviation, Inc.; E. H. Schwartz, WADC; F. W. Phillips, NACA Hq.; L. Schapiro, Douglas Aircraft Co.; and J. F. Parsons, Ames.

This reorganization placed all heat-transfer flight research in a single section and created an entirely new area of research, that related to high temperature.

The high-temperature reseach was directly related to the facilities program planned by Gilruth, Purser, and Heldenfels. Under this program, the Structures Research Division was to develop high-temperature arc-powered air jets while PARD concentrated on chemical and ceramic-heated air jets. The chemical jets required little development and were placed into service almost immediately. These jets used the products of combustion of either a small liquid-rocket engine, located at Langley, or of a 12-inch ramjet burning ethylene fuel, located at Wallops as a part of the Preflight Jet facility. This high-temperature jet was called the Ethylene Jet and will be discussed in detail in a later chapter. The ceramic-heated jets and the arc jets were located at Langley and will not be discussed further. It should be said, nevertheless, that all of these jets contributed much to the understanding of the high-temperature problem facing the missile industry. Initial emphasis centered on the aerodynamic burning of metals and a search for new materials capable of surviving the extreme heat input.

Creation of the High Temperature Branch at PARD required the aeronautical engineers of that division to shift into a new field of research that put them into competition with the Structures Division. This was done intentionally by Gilruth to emphasize the urgency of the need. The competition was keenest in the new Structural Dynamics Section, which was assigned the problem of devising efficient structural panels for hypersonic aircraft.

In the Structures Research Division, Heldenfels was made Chief effective August 27, 1956, following the resignation of John E. Duberg. Heldenfels retained his position as head of the Aero-Thermal Branch as well (ref. 2).

ADDITIONS TO EQUIPMENT

The old radiosonde was replaced during 1955 by the newer, longer range, Rawinsonde (GMD−1), which transmitted on a frequency of 1680 mc. In figure 246, the tracking antenna is shown on its permanent mount atop the north camera station (Station 2), where it was installed on January 6, 1955. As shown in figure 247, a fiberglass cover, installed on February 14, 1955, provided protection from the elements. With this equipment, the weather balloons now could be tracked directly, which relieved the SCR-584 radar of that task.

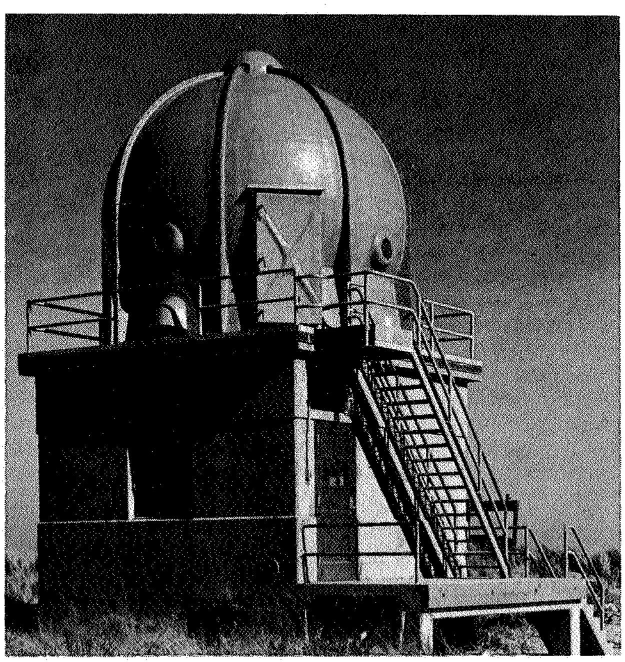


FIGURE 246. Rawinsonde antenna mounted atop Camera Station 2. View at Wallops, January 6, 1955.

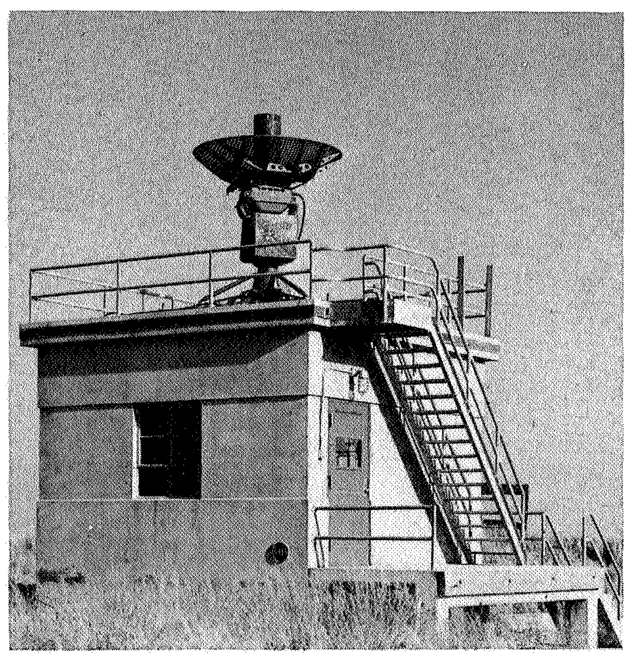


FIGURE 247. Fiberglass enclosure over Rawinsonde antenna at Camera Station 2. Wallops, February 14, 1955.

The high-speed research models with multistage vehicles required meteorological data to an altitude of 100,000 feet or higher, and several methods were tried to reach this altitude. One method was to launch three standard balloons in tandem, separated by 30-foot lines, each balloon being filled with one-half the normal amount of helium. In a successful trial of this system on September 12, 1955, an altitude of 100,000 feet was reached. A simpler solution was to use a balloon of much larger diameter. One of these balloons was tried on November 9, 1955, and was adopted for regular use when needed.

Chapter 11 has discussed the successful use of the Helium Gun at Wallops in 1953 to launch the AGARD Model 2, which had wings and contained internal propulsion. Keen interest in the possibility of more extensive tests of this type with larger models led Purser to propose construction of a 16-inch-diameter Helium Gun, to be constructed from the liner of a 16-inch naval gun. The proposal was made on July 29, 1954, and approved by NACA Headquarters on August 26, 1954, as Project 1563. Considerable effort was expended in planning for this project during 1955 and 1956, but the 16-inch Helium Gun was never constructed, and the project was canceled on May 27, 1957. The 16-inch liner obtained from the Navy for this project was later used as the cylinder for the Free-Piston Compressor constructed at Langley by PARD. One point of interest in connection with the project was a ruling obtained from the CAA regarding the need for a navigation light on top of this 70-foot-long steel tube. A ruling was obtained on September 6, 1955, that no additional light was needed because the height of the tube would be less than that of the 115-foot water tower.

Even though, by this time, the ferry was in regular operation between the Mainland Dock and the island, there was need for a smaller, faster boat for emergency or nonscheduled transportation. In July 1955, a 21-foot Barbour outboard runabout was purchased for $1,301. The boat had a relatively high speed and was used frequently except in bad weather, because the only protection it could offer was a canvas cover over the pilot's compartment. On February 14, 1958, a 22-foot fiberglass plastic boat, powered by an inboard diesel engine, was obtained on loan from the Navy. This boat was the type assigned to aircraft carriers for ship-to-shore transportation. While Wallops personnel liked the safety feature of the diesel engine, the boat was too slow to fill the need and was returned to the Navy.

AERODYNAMIC IGNITION OF METALS

The phenomenon of aerodynamic heating had been the subject of research by aerodynamicists for many years, and calculations had indicated that temperatures beyond the melting point of metals could be reached at hypersonic speeds; but little was known of the behavior of particular materials under such conditions. In the design of aircraft and missiles, the loss of strength at elevated temperatures had been taken into account. Even at hypersonic speeds, this procedure was satisfactory provided the equilibrium temperature (i.e., that temperature at which the heat radiated outward equaled the aerodynamic heat input) was not excessive. For some transient heating conditions, however, such as those experienced by a reentry missile nose cone, temperatures of the skin were calculated to exceed the melting point. In fact, consideration was being given to the use of the skin as a heat sink, plus the use of the heat of fusion or melting to absorb the aerodynamic heating. Since most construction materials, including metals, are combustible at high temperature, it was necessary under these conditions to consider the problem from a chemical as well as thermodynamic viewpoint.

Although, by October 1954, rocket models at Wallops had flown to speeds in excess of Mach 10, no direct observations of burning in these flights had been made. That burning from aerodynamic heating was possible under proper conditions was well known from observation of flaming meteors across the night sky. In some of the rocket-model flights, failure of some components was thought to have been the result of melting or burning under conditions in which such high temperatures were not expected from purely aerodynamic considerations. Paul R. Hill, Assistant Chief, PARD, theorized that heat created by oxidation in such a condition could raise the temperature to the ignition point. Lacking high-temperature wind-tunnel facilities, he demonstrated in the Mach 2, 600° F, Preflight Jet at Wallops on March 18, 1955, that oxidation could, indeed, lead to spontaneous ignition and burning of steel in the solid state, starting at temperatures below the melting point.

In the initial tests in the Preflight Jet, 3/8-inch rods with hemispherical noses were preheated and then inserted quickly into the airstream of the 8-inch B jet. At first, the rods were heated with a blowtorch, but it was replaced with a special coke furnace, shown in figure 248, to achieve higher initial temperatures. Metal temperatures were determined either by optical means or by a thermocouple.

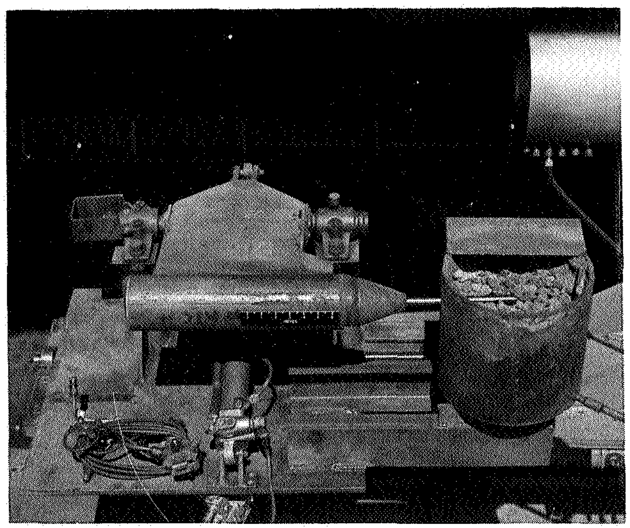


FIGURE 248. View of metal rod being heated in coke furnace by rotation of support arm, prior to insertion in 600° F B jet, March 1955.

It was found that iron or steel rods, regardless of the carbon content, when heated to 2,400° F, rose almost immediately to the melting point of 2,600° F and burned fiercely when inserted into the 600° F jet. Hill described the event in a paper he presented at the NACA conference on high-speed aircraft, held at Langley in November 1955 (ref. 3):

> Combustion appeared to take place over the entire nose and over the first inch of the cylinder, which usually necked down. From this point back, molten metal in a very fluid state streamed over the surface and terminated 4 to 5 inches back of the nose. Apparently this stream of metal evaporated and joined the conflagration. The entire rod was bathed in a luminous and ever-growing sheath of flame.

In following tests, much was learned about the oxidation process for different metals, particularly the importance of the type and thickness of oxide coating formed on the surface. It was found that steels with a substantial chromium content, such as stainless steel, did not undergo spontaneous ignition, even when preheated near their melting point. The same was true of copper or Monel. Apparently their oxides formed a protective coating.

The behavior of magnesium was studied at Langley in tests of a pointed cone in a subsonic airstream heated to 1,600° F. In this case, ignition was delayed until melting of the tip occured. Apparently, the molten metal removed the oxide that had prevented ignition prior to that time.

In order to study the details of the mechanism of ignition, Hill initiated a series of laboratory tests at the PARD rocket test area at Langley. In these tests, 1/16-inch wires were electrically heated inside a pressurized cylinder containing air, nitrogen, or oxygen. Confirmation of the Wallops results was obtained, and a method of calculating spontaneous ignition temperatures for steel was developed. The method related the heat generated by oxidation to the heat loss from the specimen. When a temperature was reached at which the heat of oxidation increased faster than the heat losses, spontaneous ignition followed. Hill developed an engineering formula for calculating the heat of oxidation. The formula contained experimentally established coefficients that recognized the dependence of oxidation rate on the temperature and the reciprocal of the oxide thickness.

The wire tests also showed that aluminum and inconel had the same characteristics as copper and stainless steel, in that there was no spontaneous ignition; neither did ignition occur at melting. Titanium, on the other hand, not only had a spontaneous ignition temperature but burned in nitrogen alone as well as in oxygen or air.

MCDONNELL F–101A VOODOO AIRPLANE

The McDonnell F-101A Voodoo airplane was an Air Force sweptback jet fighter powered with two Pratt and Whitney J-57 engines that exhausted beneath the horizontal tail. Air was supplied to the engines by inlets at the wing root. It was the production version of the McDonnell XF-88 airplane developed earlier for the Air Force. The XF-88 was canceled in August 1950 but was ordered into production with some revisions a year later under the F-101A designation. The first F-101A flew on September 28, 1954, and exceeded Mach 1 in that flight (ref. 4). At least through 1970, it was to be employed in tactical fighter, interceptor, and reconnaissance roles, with top speeds approaching Mach 2.

A rocket-model program was requested by the Air Force WADC on March 13, 1953 and was approved by NACA Headquarters with issuance of RA A73L109 on April 28, 1953. The program consisted of three 0.125-scale models for drag and stability studies and three simplified 0.100-scale wing models for a lateral control investigation. The first model was flown on September 23, 1954, and the last on March 10, 1955. The program was too late to influence the design of the airplane, and fortunately no undesirable characteristics were encountered in the rocket-model tests.

The three complete models were flown with a Nike booster to speeds of about Mach 2. Figure 249 shows the first of the series on the Terrier launcher at Wallops. The models were constructed by McDonnell, and the rocket motors were furnished by the Air Force. In the first model, the horizontal tail was pulsed to allow study of longitudinal stability and control. The second model was instrumented for lateral stability measurements obtained from analysis of disturbances in yaw created by the firing of six pulse rockets. The third model was equipped with an internal solid-rocket motor designed to simulate power-on flight with the full-scale jet engines. The models were very ruggedly constructed and weighed about 400 pounds. All flights were successful.

The longitudinal stability and control characteristics were found to be in good agreement with previous estimates. The total drag coefficient rose from a value of 0.020 at high subsonic speeds to about 0.070 in the supersonic range (ref. 5). The lateral stability, determined from the flight response

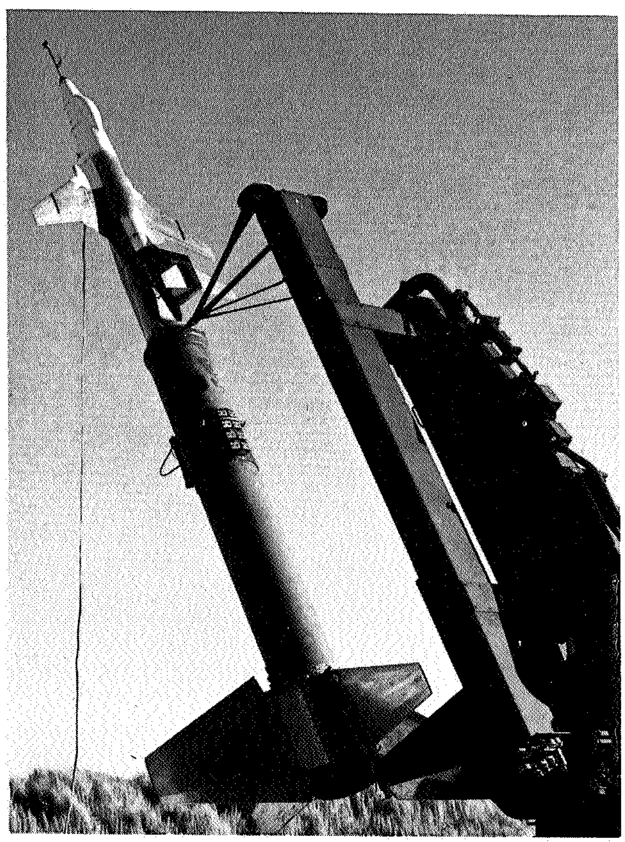


FIGURE 249. McDonnell F–101A Voodoo airplane model and Nike booster ready for launch at Wallops, September 23, 1954.

by a vector analysis procedure, indicated low total damping, but otherwise indicated satisfactory results (ref. 6). The model that simulated power-on flight indicated that the exhaust from the twin jets changed the pressure over the fuselage in such a manner as to produce a slight nose-down trim change and to provide a slight additional thrust (ref. 7).

The three lateral control models had wings scaled in stiffness to simulate the airplane. The models were boosted to Mach 1.2, and the technique used was that of the E5 general research program. The tests indicated that while only a slight loss in control would be encountered at high altitude, losses of up to 84 percent would be expected for sea level flight at Mach 1.2 (ref. 8).

All of the test results were combined in a summary report prepared by Grady L. Mitcham, the overall project manager at PARD, for general distribution (ref. 9).

GRUMMAN F11F–1 TIGER AIRPLANE

The Grumman F11F-1 Tiger airplane was a modification to the F9F Cougar series, incorporating an area-rule indentation in the fuselage for lower transonic drag. It carried the designation F9F-9 at first. It had a sweptback wing and twin side inlets with a splitter plate leading to a single Pratt and Whitney J-57 jet engine in the fuselage.

A rocket-model program to determine the total transonic drag was requested by BuAer on July 1, 1953, and approved by NACA Headquarters on August 12, 1953, with issuance of RA A73L115. The original plan was for two models to be flown without onboard instrumentation, to expedite the program. Drag was to be determined by ground-based instrumentation. When the first model, launched on December 17, 1953, failed to separate from its booster, and the second model, on February 9, 1954, maneuvered after separation so wildly that the radar did not track it, a third model was added to the program, this one equipped with a four-channel telemeter.

Figure 250 shows the third model with its Deacon booster at Wallops. It was flown on August 11, 1954 and was the only rocket model to yield the desired data. The telemeter provided measurements of total pressure, longitudinal acceleration, and two pressures near the base from which base pressure and mass flow of the inlet system could be determined. The duct exit contained a "choking cup," as was used in the F26 general research inlet models, to maintain a mass flow rate of about 0.80 through the duct.

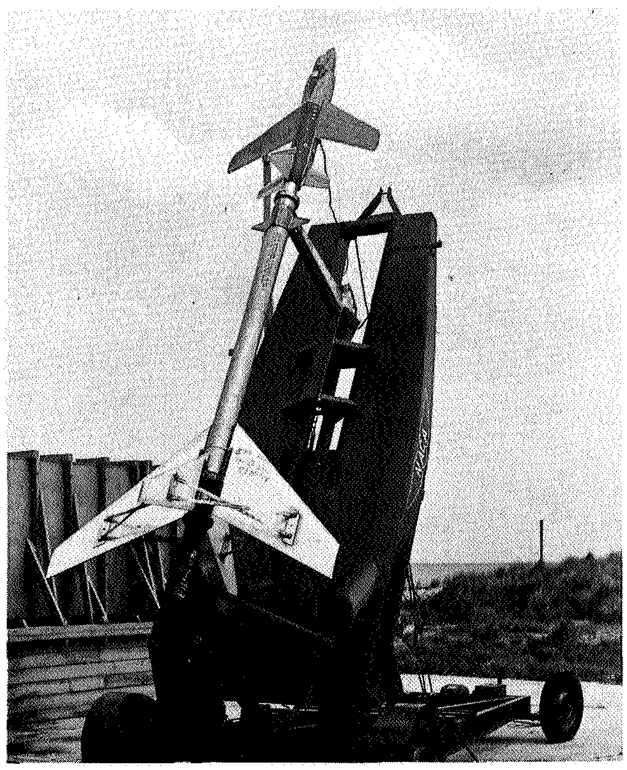


FIGURE 250. Grumman F11F–1 Tiger airplane model, shown with Deacon booster, August 11, 1954.

The total drag coefficient varied from a subsonic value of 0.016 to 0.053 at Mach 1.28, the highest speed reached. Three equivalent bodies of revolution were tested in the Helium Gun at Wallops, but they added nothing to the research data because they represented earlier versions of the airplane (ref. 10).

The full-scale airplane had a more successful flight history than the rocket model. The prototype flew on July 30, 1954, less than 15 months after receipt of the Letter of Intent from BuAer. One attained a speed of 1,220 miles per hour, and one held a short-lived altitude record of 76,932 feet, set on April 18, 1958. The design was selected by the Japanese Defense Agency for production in Japan (ref. 11).

BOEING SUPERSONIC BOMBER: AIR FORCE PROJECT MX–1712

It has been mentioned in Chapter 10 that even though the proposal of the Boeing Aircraft Company for a supersonic bomber lost out in the Air Force competition in 1951 to Convair's B-58 Hustler, the Air Force requested the NACA to conduct a brief rocket-model program with models of Boeing's proposed design.

Two such models were flown, one on January 27, 1954, and the other on June 28, 1954. The first test was a failure due to structural disintegration of the model immediately after separation from its booster. The second test was successful. In figure 251, the second model is shown atop its double underslung Deacon booster, which was similar to the booster used in the Hustler program.

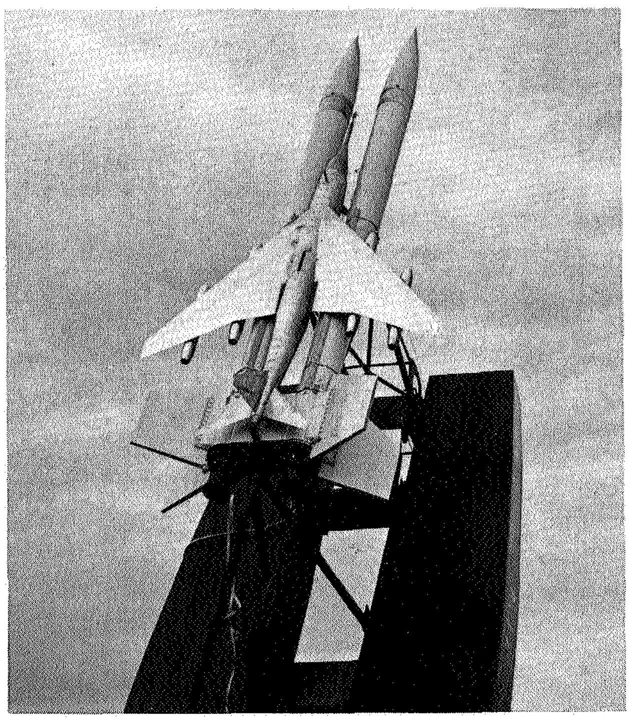


FIGURE 251. Model of Boeing MX–1712 supersonic bomber design, as flown at Wallops with an underslung double Deacon booster, June 28, 1954.

The model had a modified sweptback wing with four nacelles supported beneath the wing by short struts. The nacelles had conical-shock inlets designed for Mach 2. The fineness ratio of the fuselage was about 15, and a conventional tail arrangement was used. An 11-channel telemeter was used in the model to transmit continuous measurements of accelerations, angle of attack, horizontal-tail incidence, static and total pressure, and pressures in one of the nacelles. The horizontal tail was pulsed between two stops during the flight, to provide longitudinal data over a range of lift conditions. A maximum Mach number of 1.75 was reached in the test.

The test provided an excellent set of drag data over a lift range that included maximum lift-drag ratios. Minimum drag coefficients were about 0.012 at subsonic speeds and 0.035 in the supersonic range. All data were in reasonable agreement with previous wind-tunnel tests. The data were of value to the Air Force for consideration of different supersonic designs, and were made generally available to the industry (ref. 12).

MARTIN BULLPUP AIR-TO-GROUND GUIDED MISSILE

The Glenn L. Martin Company won the Navy BuAer competition for a radio-guided air-to-ground missile in early 1954. The Martin design, named "Bullpup," was patterned after the PARD D3 general research missile configuration discussed in Chapter 9.

On March 2, 1954, representatives from Martin and BuAer visited NACA Headquarters to solicit assistance in the development of the Bullpup. One of the BuAer representatives, Marvin Pitkin, and one of the NACA Headquarters representatives, Roy J. Niewald, both former PARD employees, had been directly involved in the D3 missile research program. The Bullpup was a basically simple missile, and since the available D3 aerodynamic data could be adapted readily, a long development program was not required. In fact, one of the factors influencing the Navy in awarding Martin the contract was Martin's agreement to furnish 60 missiles within 18 months. The plan was to bypass the usual wind-tunnel and flight development program and go directly to a flight verification program (ref. 13).

Later in the month, Martin representatives visited Langley and Ames Laboratories and confirmed the plan for a minimum of wind-tunnel testing. Early in April, they visited Langley again to discuss the possibility of conducting the flight tests of 60 air-launched missiles at Wallops. They planned to test this number in one year. The first 5 missiles were to be instrumented to obtain aerodynaic data by telemeter; the next 40 would be under control of the pilot; and the last 15 would contain warheads for proof tests. The flight operations proposed were similar to the Lewis air-launched program, with Martin furnishing the groundbased telemeter receiving equipment as well as the missile onboard instrumentation.

Kreiger recommended that, if the program remained as simple as that outlined by Martin, approval should be given by the NACA. He stated further, "Since BuAer has requested that NACA assist the winner of this contract and since Martin has made extensive use of PARD data in the design, this Laboratory is definitely interested in the outcome of these tests" (ref. 14).

The Bullpup design had the 60-degree delta cruciform canard fins and wings of the D3 missile, but the fuselage was fatter to accommodate an internal rocket motor. The missile was about 11 feet long and 1 foot in diameter. Roll rate was limited by rollerons like those used on the Sidewinder missile. Stabilization was entirely aerodynamic, with guidance effected by radio command from the pilot of the launch airplane to the all-movable canard fins in both planes. The missile was powered by a solid-propellant 2.2DS10000 rocket motor and carried a 250-pound warhead. It was to be launched at altitudes from 8,000 to 15,000 feet and would be guided all the way to the target by the pilot, through four microswitches on top of the control stick of the airplane. The pilot would be visually aided in this guidance by flares on the missile. It was to be launched, at rocket ignition, from beneath the wing of the airplane and would travel to the target at speeds between Mach 1 and 2.

On August 25, 1954, BuAer officially requested the assistance of the NACA in a free-flight aerodynamic investigation of the Bullpup missile, involving air-launching of five program-controlled missiles. Follow-on proof tests were to be conducted elsewhere. The five missiles to be launched at Wallops were to be without warheads and were to contain a telemeter to monitor aerodynamic performance of the missile following movements of the pitch and yaw fins by onboard mechanisms. The function of Wallops in these tests was to vector the launch airplane into firing position, give the firing command, track the missile by SCR-584 radar, and provide atmospheric data from Rawinsonde. Photographic coverage would also be provided by Wallops personnel. Martin was to provide two telemeter receivers to be located in the north and south camera stations at Wallops.

On January 24, 1955, a van arrived at Wallops with the telemeter receivers for the two stations, and the following day a conference was held between Martin and NACA personnel regarding the test plans. By this time, PARD engineer Clarence A. Brown, Jr., had been assigned to the project, designated D116 by PARD. Some changes had been made in the missile and in the test plans. The rollerons in the missile had been eliminated and, instead, the ailerons were to be locked at a small deflection to produce a rate of roll of about 1.5 revolutions per second. In addition, the internal mechanism to program the controls in flight had been eliminated, and control was to be exercised by the pilot from the launch airplane, in either random or uniform programmed pulses. In this manner, the pilot could become familiar with the guidance of the missile at the same time aerodynamic data were being obtained (ref. 15).

On March 14, 1955, a successful captive flight was made over Wallops with the missile mounted on a Douglas F3D-1 airplane. The first attempt at an air launch was made on April 4, 1955, during which (as has been described earlier in Chapter 8) the rocket fired before the locking pin holding the missile to the airplane had been withdrawn. The rocket thrust spun the airplane around, and at one time it was actually traveling backwards. Although the locking pin was intended to be withdrawn mechanically, it was supposed to be weak enough to act as a shear pin under the high thrust of the rocket motor. Through an error however, the pin was made too strong. The crew parachuted to safety, but the airplane crashed into the ocean. Immediately, for safety's sake, a ground-launch at Wallops was planned, using the airborne launch rig attached to a Wallops launcher and a dummy missile. This missile, shown in figure 252, was launched satisfactorily after changes in the launch circuitry had been made.

The second air-launch attempt was made on June 6, 1955. This time, the tracking flares on the missile ignited but the rocket motor did not. The missile was jettisoned by the pilot in the ocean south of Wallops about a mile offshore. It was concluded that the rocket ignited at splash because the pilot noted red smoke at that time and a report was received at the Chincoteague Naval Air Station that an airplane had crashed into the ocean.

The next attempt, on June 5, 1955, was successful. Between this date and August 24, 1955, five additional missiles were launched with two more failures—one, another misfire of the rocket motor, and the other, a failure of the command system to pulse the controls as desired. Nevertheless, five missiles were successfully air-launched in accordance with the original plan, and all within a 5-month period. In one test, a float light was dropped 6,000 yards offshore for a target, and the pilot was able to guide the missile close to it at impact. This completed the first phase of the program, and all of the Martin equipment was removed from Wallops. The NACA was not involved in the next phase of the program, which called for flight trials of the missile at Patuxent Naval Air Station, with the initial launch on October 7, 1955.

One additional ground launch was made at Wallops, later in the program, on October 10, 1956, to check out a new military launcher to be installed on all airplanes scheduled to carry Bullpup missiles. As before, a dummy missile was used with only ground-based instrumentation. This launch was sucessful.

The overall program at Wallops was considered to be quite satisfactory and contributed to successful development of the Bullpup missile, which was to remain an operational missile of the Navy and the Air Force for many years. The basic design, as represented by the missiles flown at Wallops, was placed in production with minor changes. The Martin Company was to produce some 37,800 such missiles over the years ahead, with Maxson Electronics, the follow-on contractor, producing several thousand more. One major change in 1959 was to replace the solid-rocket motor with a Reaction Motors liquid-rocket engine.[5]

NAVAL ORDANCE LABORATORY SMOKE ROCKET

During 1955, the Naval Ordance Laboratory (NOL) was involved in determining characteristics of the blast wave from a nuclear explosion, through studies of its effect on a grid pattern of smoke trails produced by special rockets prior to the explosion. On July 29, 1955, the Commander, NOL, requested the assistance of the NACA in development of the smoke-producing rockets through tests at Wallops Island. A smoke-producing chemical, FS (a solution of sulphur trioxide in chlorosulfonic acid), was to be ejected from special tanks on the nose of Deacon rockets. NACA Headquarters approved the request of NOL on August 9, 1955.

5. Letter from L. Schaidt, Martin Bullpup Manager, to J. A. Shortal, Oct. 27, 1969, enclosing historical information on the Bullpup missile.

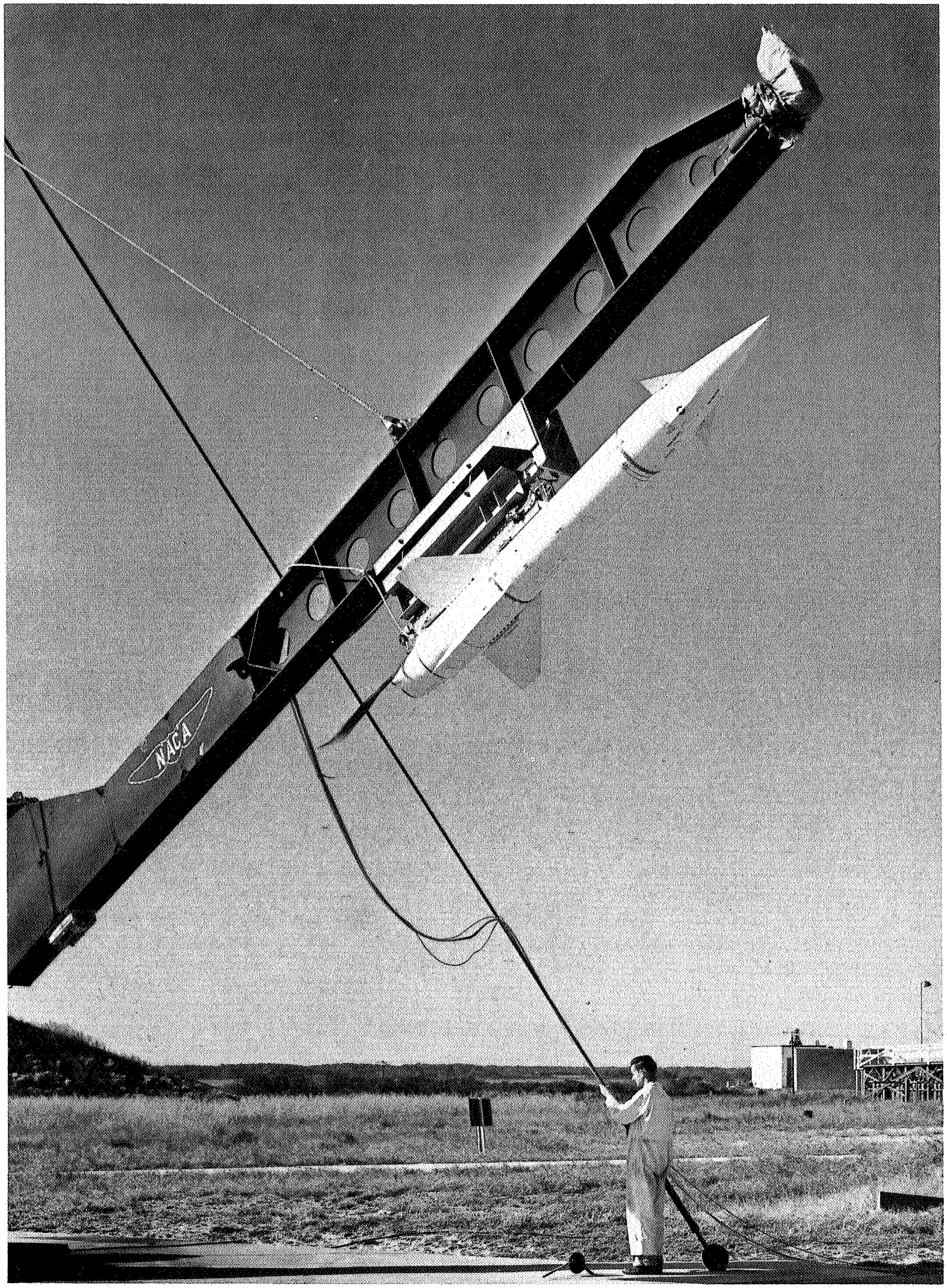


FIGURE 252. Technician Roy Hindle secures firing leads of Martin Bullpup missile prior to ground launch at Wallops, May 6, 1955.

The Deacon system followed the technique developed in 1953 by Wade Lanford, PARD engineer, with a 3.25-inch rocket vehicle. Lanford had been assigned the task of developing a system for creating a smoke trail in high-speed flight, to be used as an aid in tracking models after booster separation in cases in which the model did not contain an internal rocket motor. Difficulty was being experienced by the radar operators in identifying the model, which was the smaller of the two targets. In some cases, to make matters worse, the model, at separation, would diverge sharply from the path of the booster. Lanford tried several different smoke-producing chemicals and found FS, a standard smoke chemical used by the Army, to be the best.

The liquid FS was carried in a tank at the nose of the rocket which was fitted with a total-pressure tube (to provide the ejection pressure) and an outlet tube. The tank was not completely filled so that acceleration forces would aid the ejection. At loading on the elevated launcher and during the positive acceleration period after launching, the FS liquid was forced to the rear of the tank and could not leave the tank because the exit was located near the front end. The air entering the total-pressure tube, whose outlet was at the bottom of the tank, merely bubbled up through the liquid. After rocket burnout, however, the negative acceleration forced the liquid forward, and it was then forcibly ejected. The system was successfully applied to many PARD research models after this time. It was a made-to-order system for the NOL need.

On August 30, 1955, a group from NOL, headed by Peter Hanlon, visited Wallops and discussed the contemplated tests with Krieger, Palmer, and Lanford. It was agreed that NOL would furnish the complete test vehicles, the launcher, and a special camera with its crew. It was desired to create a fairly persistent smoke trail to high altitudes and photograph it from a distance of about 13 miles. Wallops arranged for the use of the Coast Guard Station on Parramore Island, south of Wallops, for the camera and crew. Wallops was also to provide assembly and firing personnel, radar tracking, atmospheric data, and normal documentary photographs at launching. Two or three vehicles were considered to be sufficient, and an early October launching was planned (ref. 16).

The vehicles were ready by early October, as planned, and after a few days' delay because of poor visibility, two were launched on October 11, 1955. The first of these is shown in figure 253, prior to launch. Both tests were quite successful. Smoke trails in each case persisted for 60 seconds to an altitude of 25,000 feet. The diameter of the trail was about 10 feet. One change was made in the second vehicle after the first launching. The rather large external launching lugs were cut down to reduce the drag. The change would allow the vehicle to reach the 25,000-foot altitude at a lower launch angle, or to reach a higher altitude when launched at a higher elevation angle (ref. 17).

A number of the Deacon vehicles later were used by NOL to create the desired smoke trail grid near a nuclear explosion.

A letter of appreciation was received from John T. Hayward, Admiral U.S. Navy, Commander, NOL, as follows:

> As a result of the sound advice and valuable assistance rendered by personnel of the Langley Aeronautical Laboratory and the use of the NACA Test Facility at Wallops Island, Virginia, a special application rocket was successfully developed and tested.
> The Naval Ordnance Laboratory wishes to express its great appreciation to the NACA and to the employees concerned, particularly Messrs. Robert Krieger, J. C. Palmer, W. J. O'Sullivan, and W. E. Lanford for extending this kind service and for a job well done.

The smoke ejection system was to find application later under NASA with a Nike booster rocket motor in a high-altitude wind research program at Wallops and at Cape Canaveral, Florida.

UNIVERSITY OF MICHIGAN NIKE-DEACON SOUNDING ROCKET

The Nike-Deacon sounding rocket for upper atmosphere research was the first of its kind to be flown at Wallops. Two flights, both successful, were made in the development during 1955—the first on April 8, and the second on June 24. The vehicle was an adaptation of the F40 hypersonic heat-transfer model flown on November 19, 1953. The conversion was carried out by the University of Michigan, under the

FIGURE 253. Technician pours PS smoke chemical into nose cone of Deacon-powered smoke rocket used by Naval Ordnance Laboratory for initial test at Wallops, October 11, 1955.

direction of L. M. Jones, with the assistance of Langley and Wallops personnel. The work was performed under a contract with the Air Force Cambridge Research Center (AFCRC).

The early participation of the NACA in upper atmosphere research, including some consultative services in connection with the Rockoon program, has been discussed in Chapter 9. The NACA kept abreast of such research by all agencies of the United States through the membership of W. J. O'Sullivan, Jr., on the Upper Atmosphere Rocket Research Panel (UARRP). Through the efforts of this panel, research had been conducted with captured German V-2 missiles, Aerobee and Viking sounding rockets, and Rockoons—Deacon rockets launched vertically from high altitude balloons.

Funding for most of the upper atmosphere research was provided by the Armed Forces. The success of J. A. Van Allen with Deacon rockets and the Rockoon system led an Air Force representative to ask if the NACA had a ground-launched rocket system that would do the job at a lower cost than that of the systems in use. The question was raised by the Air Force representative from AFCRC at the UARRP meeting of April 29, 1953 (ref. 18). O'Sullivan invited the panel to meet the next time at Wallops and see firsthand the rockets in use there.

The invitation was accepted, but as the time of the next meeting approached, some of the members became apprehensive about the type of accommodations available at Wallops for the meeting and had it changed to Harvard University, Cambridge, Massachusetts. At this meeting, on October 7, 1953, the Air Force again pressured the panel to find less expensive systems. Although Homer E. Newell of NRL, as well as Van Allen, had used the inexpensive Deacon rocket, other members were averse to abandoning the V-2, Viking, and Aerobee.

A budget cut of 40 percent finally forced the issue, (ref. 19). L. M. Jones, representative of the University of Michigan's Department of Aeronautical Engineering, accepted the challenge to develop a low-cost rocket vehicle. He was familar with the Aerobee, and at the October meeting had reported on tests he had made with an inflatable sphere ejected from an Aerobee. In addition, he had familiarized himself with Van Allen's Rockoon and had visited Langley to discuss Deacon rocket motors. His interest in measuring upper atmosphere density over different points on the earth with his small payload (sphere) influenced him to try to find a cheaper and more versatile system than the Aerobee.

The first system considered by Jones was a combination of the Aerobee booster with a Deacon or perhaps the higher performance T40 rocket motor. On February 9, 1954, he asked O'Sullivan's opinion of such a system.[6] O'Sullivan recommended the Nike-Deacon combination that had already been flown at Wallops, and invited Jones to visit Langley to discuss it. Pending the visit of Jones, O'Sullivan had trajectory calculations made which showed that a Nike-Deacon system could carry a 50-pound payload to an altitude of approximately 400,000 feet, with a vertical launching. Since this figure exceeded the altitude of 250,000 feet required by Jones, he quickly accepted the system while on his visit to PARD with coworker W. H. Hansen on April 7, 1954 (ref. 20).

AFCRC authorized Jones to "pursue the possibility of using a Nike-Deacon rocket combination as step #1 in the development of the 'Falling Sphere' experiment" and asked the cooperation of PARD in "providing Mr. Jones with information concerning the Nike-Deacon rocket system and assisting to any extent within your jurisdiction the efforts of Mr. Jones in preparation for and implementation of an actual flight of such a Nike-Deacon rocket."[7]

Upon receiving a favorable recommendation from Langley, NACA Headquarters authorized the requested assistance, and plans were made to launch two vehicles at Wallops. Except for the nose cone, the vehicles were to be identical to the F40 heat-transfer model. NACA drawings were used for the construction of the components. The nose cone was somewhat larger than that used in the F40 model, to accommodate the test sphere approximately 7 inches in diameter. The cone angle was increased from 10 to 11 degrees. One of the complete sounding rockets ready for launch is shown in figure 254. Although each test was chiefly a test of the Nike-Deacon vehicle, the falling sphere experiment was also tested at the same time. By this time, Jones had replaced the inflatable sphere with a small, instrumented, rigid sphere for greater accuracy.

In the tests, the nose cone was separated from the nose of the Deacon rocket, and the small sphere was then ejected from the nose cone by small springs. The flight path was determined with the aid of a DPN-19 radar beacon which was carried inside the nose cone and which allowed the SCR-584 radar to track throughout the trajectory. In the tests, the Nike booster rocket burned for about 3 seconds, after which it separated from the second stage because of higher drag. Next came a coast period of 13 to 17 seconds before Deacon ignition. After Deacon burnout, the second stage coasted to about 180,000 feet, at which altitude the nose cone was separated and the sphere ejected (ref. 21). Atmospheric density in the experiment was determined from direct measurements of drag of the falling sphere, made by means of an internal, sensitive, omnidirectional accelerometer. In the first test, the vehicle was launched without the accelerometer because of prelaunch difficulties with it, but, in the second launch, good accelerometer data were provided.

This was the first time a beacon had been used at Wallops as a radar tracking aid, and the instrumentation people were pleased with its performance and its potential for later use in Wallops firings.

6. Letter from L. M. Jones to W. J. O'Sullivan, Jr., Feb. 9, 1954.
7. Letter from Milton Greenberg, Acting Director, AFCRC Geophysics Research Institute, to W. J. O'Sullivan, Jr., May 28, 1954.

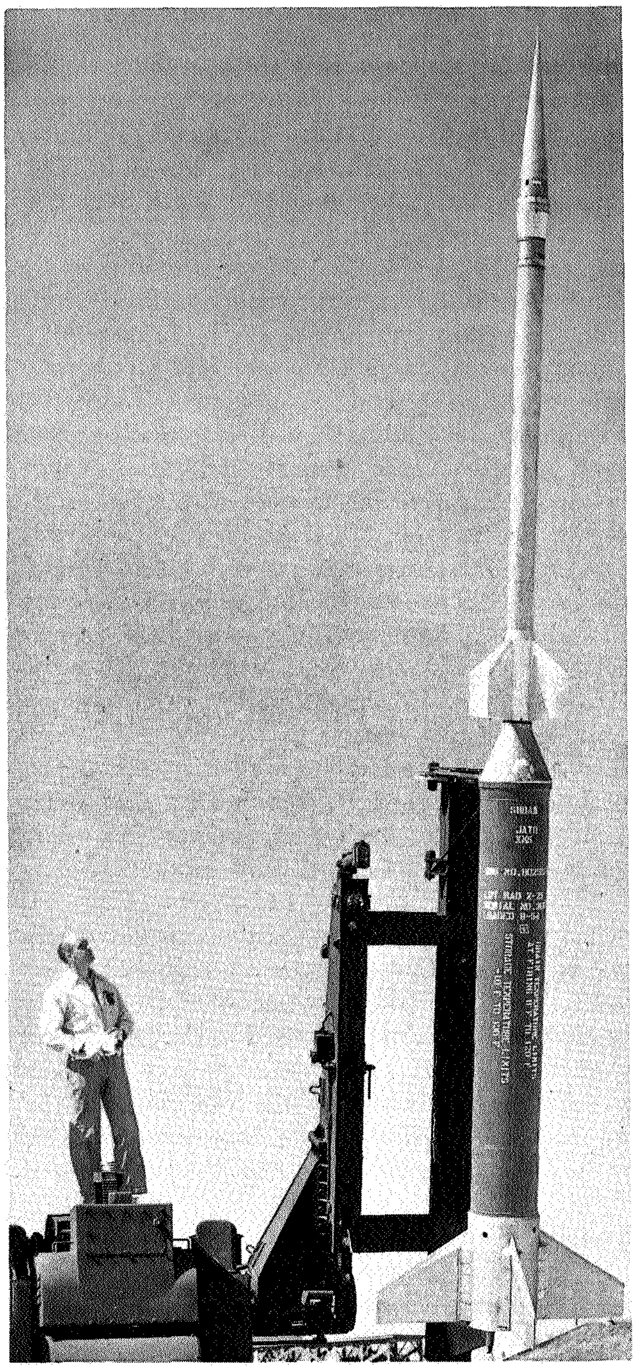


FIGURE 254. University of Michigan engineer W. H. Hansen looks over first Nike-Deacon sounding rocket prior to launch at Wallops, April 8, 1955.

The project marked the beginning of an association between Jones and Hansen of the University of Michigan and NACA employees that was to continue through development of several sounding rockets in the years ahead.

In both of the Nike-Deacon flights, made with 75-degree launch angles, an altitude of about 350,000 feet was reached. Evaluation of the flight results indicated that from a vertical launch an altitude of 385,000 feet would be reached with a 50-pound payload, and that 487,000 feet would be reached with a 10-pound payload.

This joint project required close cooperation between the University of Michigan and NACA personnel. No outside contractor was involved except for the construction of components from NACA drawings. Assembly, launch, and tracking were performed by Wallops personnel. Prelaunch calculations of such items as coast time, skin temperatures, and stability were performed by PARD and Michigan and were compared. The Michigan crew participated directly in the operation at Wallops for training purposes, for they were to be called upon to perform similar operations later from shipboard with the similar Nike-Cajun system to be developed later.

The Nike-Deacon was given the name Dan by Jones and Hansen, for "Deacon and Nike," but the name did not survive. The Nike-Deacon identification found greater acceptance.

Because of the long range of the Nike-Deacon, launchings were scheduled on the same days as those of PARD long-range hypersonic models, to take advantage of the availability of range surveillance aircraft and clearance to impact in Navy operating areas. Four-stage PARD models were launched during the clearance period of the two Nike-Deacon firings.

The UARRP panel showed considerable interest in the Nike-Deacon system for possible application to other experiments during the forthcoming International Geophysical Year (IGY), 1957–1958, and several members or their representatives were on hand for the first launching at Wallops. These individuals were R. M. Minzner and L. Kraff of AFCRC, J. W. Townsend of NRL, and R. S. Weiss of Evans Signal Corps Laboratory, along with University of Michigan representatives Jones, Hansen, E. J. Schaefer, and T. R. Pattinson. The visitors were impressed with the simplicity and ease of operation with solid-rocket vehicles at Wallops, not only with the two-stage Nike-Deacon but also with the four-stage general research vehicle. The Air Force and Army representatives appeared eager to adopt the Nike-Deacon or some other solid-rocket vehicle for all of their programs, but the Navy representative was not prepared to go quite that far because of existing commitments with the Aerobee. They felt, however, that there was a definite need for both systems (ref. 22).

The first meeting of UARRP following the initial test of the Nike-Deacon vehicle was held at the Navy Department in Washington, D. C., on June 2, 1955. At the meeting, Jones presented a description of the flight test and showed a motion picture of the operations at Wallops. He also distributed copies of a report on the Nike-Deacon test (ref. 23). In it, he estimated that the vehicle, excluding the Nike motors, would cost $4,000. This would be the cost if surplus Nike motors were available; the total cost would be about $7,000 if the Nike had to be procured—a definite saving over the Aerobee's $40,000 cost. Enthusiasm was high concerning the system, and a special subcommittee was formed to explore possible uses of Nike-Deacon during the IGY. The result was that 34 Nike-Deacons were added to the IGY program (ref. 24). Before these were procured, however, the Cajun rocket motor, a higher performance motor of the same size as the Deacon, was developed by the NACA and was substituted for some of the Deacons in the IGY program. This phase will be discussed in more detail in a later chapter, but the door had now been opened to the use of solid-rocket vehicles as sounding rockets (ref. 25).

COMPLETION OF LANGLEY RAMJET RESEARCH PROGRAM: F23 AND F29

The flight research investigation at Wallops with the F23 twin-engine ramjet vehicle was discussed initially in Chapter 7, and continued research was covered in Chapter 10. These early tests had shown the successful operation of the 6.6-inch-diameter engines, with ethylene fuel, in reaching a Mach number of 3.12 and an altitude of 67,200 feet. In addition, an effective fuel-control system had been developed.

The next step in the adaptation of this type of vehicle to a long-range missile, as planned in the F36 program, was to provide roll stabilization. Such a system was flight tested on September 24, 1954. The vehicle is shown in figure 255 with its Nike booster on the Terrier launcher. A roll stabilization system of a type used successfully in earlier D4 missile flights was incorporated in the vehicle. Wing-tip ailerons were electrically operated as flicker controls with 3-degree deflection. Displacement-plus-rate gyros were used. The vehicle was propelled to a Mach number of 2.3 by the Nike booster and then accelerated under its own ramjet power to Mach 2.7. The vehicle was attached to the booster with a free-to-roll coupling to allow freedom for the roll stabilization system to operate. The system performed as expected for the first 12 seconds and then failed, apparently from a failure of the servomotor or the aileron linkage. This type of system produced a continual oscillation in roll whose amplitude was a function of time lag of the system. In the present test, the amplitude was about plus or minus 8 degrees (ref. 26).

At the Lewis Laboratory, a research program to explore different high-energy fuels had been in progress for several years. One such fuel was a slurry mixture of JP-4 hydrocarbon liquid fuel and finely powdered magnesium. Laboratory tests of such a fuel had been made at Lewis in a connected-pipe facility (ref. 27). In accordance with the cooperative agreement between Lewis and Langley, such a fuel was incorporated into the PARD ramjet flight program; first with an engine alone, in the F29 series, and then with the F23 twin-engine vehicle. The engine was also tested in the Preflight Jet prior to flight.

The slurry was prepared at Lewis and consisted of about one-half powdered solids and one-half JP-4 hydrocarbon fuel. About 95 percent of the solid portion consisted of magnesium, with the remainder magnesium oxide and some aluminum. The mean particle size was 0.6 micron. This fine powder had to be stored within a liquid, for it would ignite spontaneously and fiercely if allowed to dry out in air.

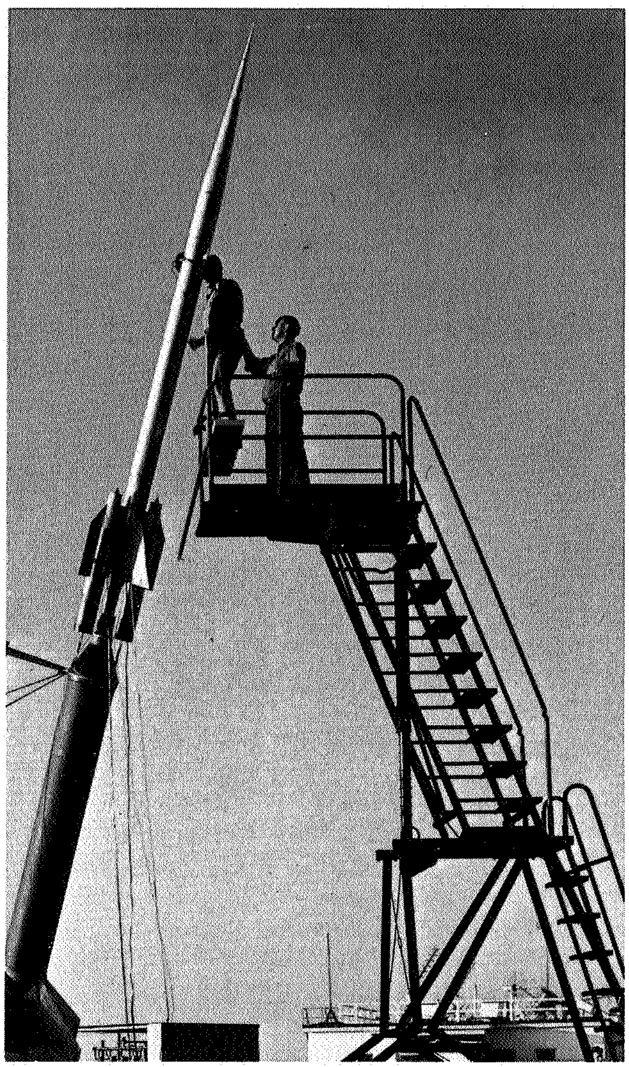


FIGURE 255. Technician Roy Hindle makes an adjustment to F23 roll-stabilized ramjet model as E. R. Matthews lends a supporting hand in preparation for Wallops launch of the model with a Nike booster, September 24, 1954.

The F29 single-engine test vehicle used in the initial slurry tests was similar to the F29 solid-fuel ramjet vehicle described in Chapter 9. Two models were flown, one on August 19, 1953, and the other on February 24, 1954. Good results were obtained in only the second flight. The test engine used in this flight was 6.5 inches in diameter and 81 inches in length, and contained 14 pounds of fuel. The booster accelerated the model to a Mach number of 1.95, after which the ramjet engine accelerated to a Mach number of 3.48.

The slurry fuel was pumped from its storage tank to the combustion chamber by a hot gas pressure system that used the products of combustion of a small charge of Cordite solid-rocket grain, stored within the tank but separated from the fuel by a free piston. This system was adapted from a similar one used earlier in a British ramjet by J. W. Orton. The rocket grain had to be sized to generate gas at a rate consistent with the rate of expulsion of the fuel. Delay squibs ignited the grain after booster separation. Ignition of the fuel was initiated by a magnesium flare ignited prior to launch. A special flame holder was used, and the usual starting disc in the exit was employed.

The tests indicated good operation of all phases of the system, and provided data on performance of the slurry fuel to a Mach number of 3.48. A fuel specific impulse of 549 was obtained (ref. 28).

A comparison of this impulse for the slurry with that for other systems was shown to be as follows:

Fuel Specific Impulse

System	*Mass*	*Volume*
Solid Rocket	200	320
Solid Ramjet	412	530
Ethylene Ramjet	1050	307
Slurry Ramjet	549	593

Although the slurry was inferior to ethylene on a mass basis, it had a marked advantage on a volume basis.

In the tests of the slurry fuel in the F23 twin-engine vehicle, the same types of flame holder and ignition system were used, but the rocket-grain gaseous expulsion system was replaced by pressurized helium stored within the fuel tank without a separating piston. The vehicle is shown in figure 256 with its Nike booster. The booster accelerated the model to a Mach number of 2.23, after which the ramjet engines propelled the vehicle to a Mach number of 2.56. The results of this test were rather disappointing in that the thrust obtained was lower than that obtained earlier in Preflight Jet tests or that calculated from theory. Uneven fuel flow with accompanying erratic burning was held responsible. Some clogging of fuel lines was also suspected (ref. 29).

This F23 vehicle was the last of the series on hand. A new series of F23 twin-engine vehicles was designed for further evaluation of slurry and other fuels. The 8-inch diameter of the fuselage was increased to 10 inches in this new series, and several vehicles were constructed, but only one was ever flown (see figure 257). This one, on October 9, 1956, reached a Mach number of 3.8. The flight data were never analyzed, and the remaining vehicles were declared surplus after this part of the ramjet program was canceled. One of the surplus vehicles was donated to the War Memorial Museum in Newport News, Virginia.

Although the twin-engine F23 ramjet vehicles were phased out, the simpler F29 single-engine models were flown until mid-1958. The slurry-fueled F29 engine that reached a Mach number of 3.48 had a conical-shock inlet designed for a Mach number of 2.1. In order to achieve even high speeds, an inlet designed for a Mach number of 4.1 was used in a follow-on test. Except for the inlet, the model was identical to the one flown to Mach 3.48. In this new test, a Mach number of 3.84 was reached with the ramjet, which was to be the highest speed reached by a ramjet at Wallops, at least through 1970. Fuel specific impulse, based on mass, was 770, about 40 percent higher than the value obtained in the earlier test with the inlet designed for Mach 2.1 (ref. 30).

The final models of the F29 type flown at Wallops were used in a cooperative program with Army Ordance as one phase in the study of a ducted rocket. (A ducted rocket is simply a solid-fuel ramjet, with the fuel being a solid-rocket grain. The ramjet air combines with the fuel-rich rocket exhaust in the combustion chamber, which, in effect, becomes an afterburner.) Army Ordance had a contract with Thiokol Chemical Corporation to develop such a rocket; and on April 4, 1957, Army's Redstone Arsenal asked NACA Headquarters to approve a flight program of six ducted rockets at Wallops. Upon receiving concurrence from the Chief of Ordnance on April 18, 1957, the NACA approved the program. Three of the models had twin side inlets, while the remaining three had nose inlets.

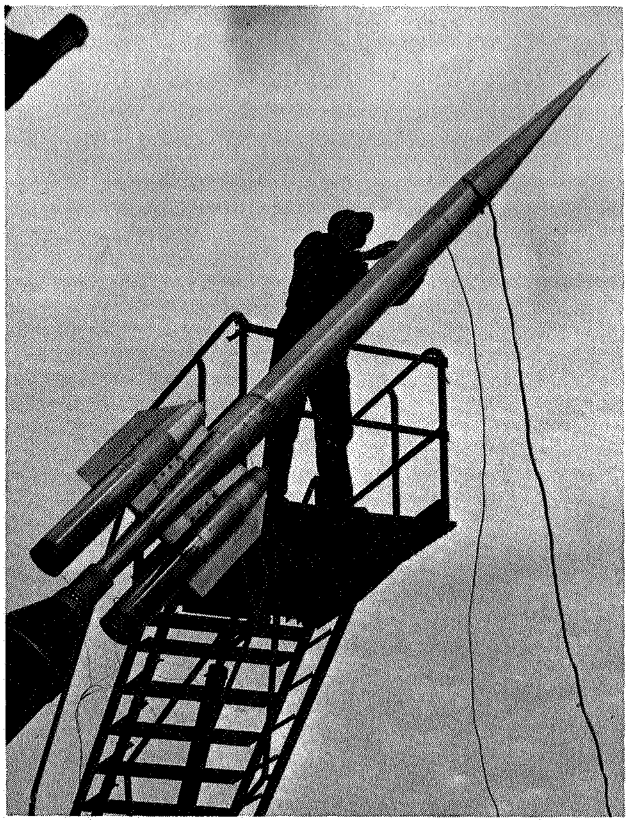


FIGURE 256. Technician makes final adjustment to F23 ramjet test vehicle with slurry fuel. Vehicle is shown with its Nike booster prior to launch, January 5, 1955.

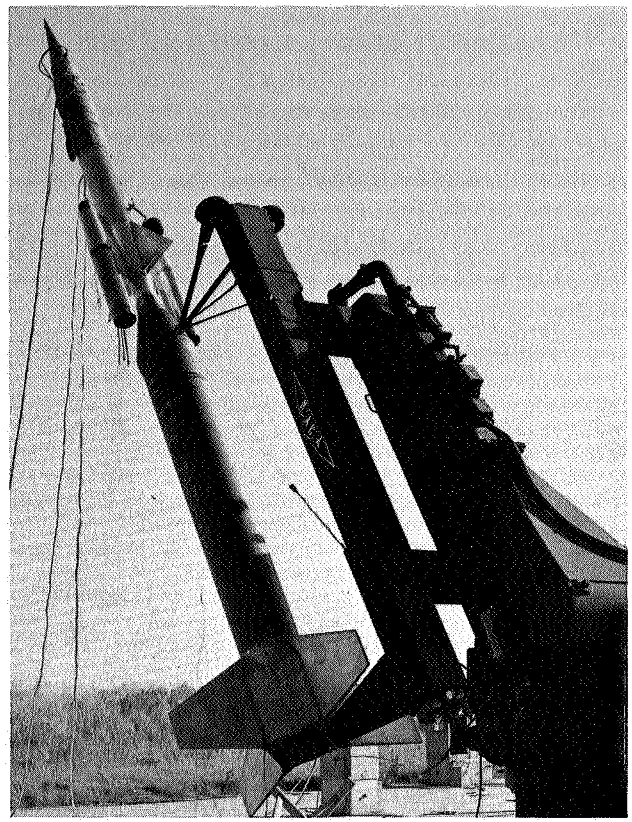


FIGURE 257. First of a new series of F23 ramjet test vehicles shown at Wallops, October 9, 1956. Vehicle had a body 10 inches in diameter.

The models were generally similar to the F29 models except for the fact that only three stabilizing fins were used. The program incuded tests in the Preflight Jet, as well as flight tests.

The tests began in the Preflight Jet in February 1958, using the models with twin side inlets. After the first model failed in the Jet test, a strengthened model was tried, but twin-duct instability was encountered, and the combustion chamber failed during a short run with the rocket burning. Tests were than shifted to the models with conical-shock nose inlets. Following successful tests in the Preflight Jet, three flight tests were made. Figure 258 shows the first model ready for flight. It was flown on March 5, 1958, but broke up in flight. After a second model, flown July 15, 1958, veered sharply after separation from its booster, the fins were enlarged on the third model, and it was flown with some success on July 17, 1958.

In the flight test, a T55 rocket motor was used as the booster to propel the vehicle to a Mach number of 1.56, after which the ramjet accelerated to Mach 2.14. The combustor shell burned through toward the end of the flight, 8 seconds after launch. Prior to this time, operation of the ramjet appeared normal although the specific impulse calculated from the flight data was somewhat less than that measured in the tests in the Preflight Jet (ref. 31).

EFFECTS OF JET EXHAUST ON ADJACENT SURFACES

Miscellaneous rocket-model tests in 1950 indicated the favorable effect produced by a jet exhaust on drag—and thereby on performance—through changes in pressure on the base annulus of a nozzle and the boattail of the afterbody. (See discussion in Chapter 8.) A research program specifically aimed at this problem included testing both in the Preflight Jet and in flight (as discussed in Chapter 11). These first tests were chiefly concerned with the effects of rocket exhaust. Of greater interest were the effects of a turbojet engine, because of the applicability to jet airplanes. Consequently, the jet-effects program was extended to turbojet simulation.

FIGURE 258. Photographer John Rumer examines ducted solid-fuel rocket with T55 booster on launcher, March 5, 1958.

The main difference between the jet from the usual solid-rocket motor used at Wallops and that of a turbojet engine was that the rocket motor operated at much higher pressures. Because the use of solid-rocket motors in jet simulation fitted in well with other aspects of the rocket-model program, a method was developed for modifying the exhaust of a solid-rocket motor to simulate that of a turbojet engine.

Following analysis of the parameters involved, a series of turbojet simulators was designed and tested in the PARD rocket test area at Langley (ref. 32). A standard 3.25-inch rocketmotor case was used in constructing the simulator, with the rocket grain replaced by a Cordite grain of reduced size. The essential element of the simulator that controlled the exhaust pressure was the use of a second throat of smaller diameter ahead of the normal turbojet nozzle. A plenum chamber of rather large diameter separated this small nozzle from the converging channel leading to the sonic exit. The general arrangement of the simulator is shown in figure 259. The primary parameters to be considered were the jet thrust, the jet weight flow, and the jet total pressure. A given full-scale condition (size, altitude, thrust, etc.) could be simulated by proper selection of throat areas with a given rocket fuel.

By 1956, the supply of Cordite rocket-motor grains was exhausted, and Thiokol T44 rocket motors were substituted. The higher operating pressure of the T44 motor necessitated some redesign of the turbojet simulator (ref. 33). Although the T44 simulator was successfully developed, it was used in only a few tests toward the end of the program.

The first flight use of the Cordite turbojet simulator was with three models of an engine nacelle with a closed, pointed nose and four stabilizing fins. The three models differed only in the size of the jet exit in relation to the base of the model. In figure 260, one of the models is shown with its 65-inch HVAR booster on a rail lancher at Wallops. Large reductions in drag in the power-on condition were obtained at transonic and low supersonic speeds, for all jet sizes, and resulted from large increases in base and afterbody pressures. Apparently the jet static pressure of 3.65 in these tests caused the jet to expand beyond the base area, which, in turn, induced separated flow on the afterbody and allowed the increased pressure in the jet to act ahead of the exit (ref. 34). In two additional tests with the jet

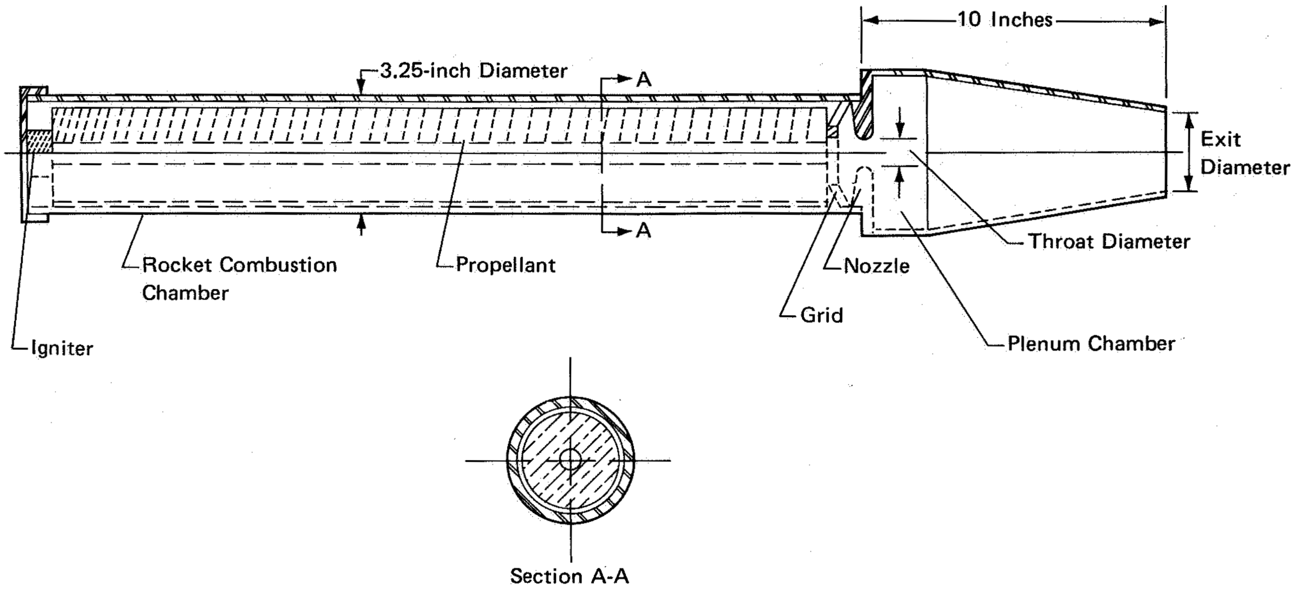


FIGURE 259. Cross section of 3.25-inch rocket motor modified to simulate a turbojet engine.

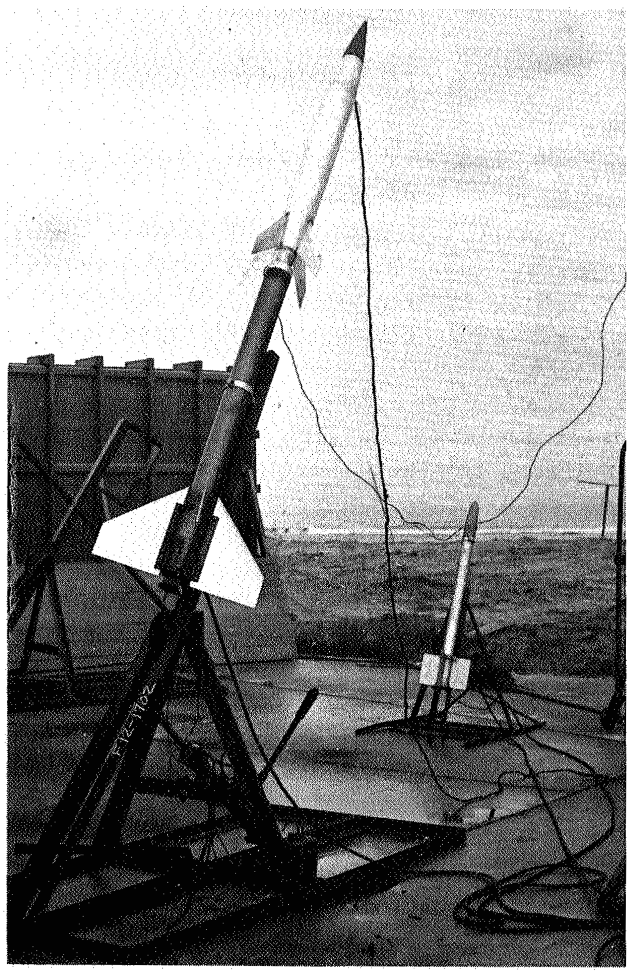


FIGURE 260. Basic research model with turbojet simulator set for launching with 65-inch HVAR booster. Model is shown on launcher at Wallops, January 21, 1954.

static-pressure ratio lowered to about 2.0, reductions in drag were likewise obtained, but were of lower magnitude (ref. 35).

In 1955, the effects of secondary air exhausting from the base just outside the primary jet exhaust were investigated with a series of four F12 models. The models were similar to those just described except for the secondary airflow. In the tests, the secondary airflow was induced by small, external, scoop inlets. The jet static-pressure ratio was about 4.0 in these tests, and the drag reductions obtained were comparable to those obtained in the earlier tests without secondary airflow simulation (ref. 36).

The investigation of jet effects on typical nacelles was extended to a twin-jet arrangement. In these tests, ignition of the jet simulator was delayed until after the model had slowed to about Mach 0.8, to allow coverage of a power-on condition from that speed to about Mach 1.2. Reductions in drag with power on were considerably less than those experienced with the single-engine nacelles (ref. 37).

At supersonic speeds, the jet issuing from the rear of a nacelle produced strong disturbances in the external flow, which were responsible for the formation of shock waves downstream of the jet exit. In the case of a nacelle located beneath a large delta wing, such shock waves could impinge upon the wing surface and create additional loads. Such was the reasoning that led to a series of tests in the Wallops Preflight Jet, in which a small propulsive nacelle was located beneath a flat plate fitted with numerous pressure orifices. A typical installation in this series is shown in figure 261. Tests at Mach 1.39 and 1.80 were made in the 27-inch-square nozzle of the Preflight Jet, while tests at Mach 2.02 were made in the 12-inch nozzle. In every case, the vertical location of the nacelle, as well as the jet pressure ratio, was varied. Helium was used as the exhaust gas to simulate the turbojet engine, and a range of pressures was obtaned by allowing the pressure of the helium source to be exhausted. In the tests at Mach. 1.39, a hot exhaust was also used, created by burning hydrogen in air. Both supersonic and sonic nozzles were used. The principal investigator in this program was Walter F. Bressette (refs. 38, 39, and 40).

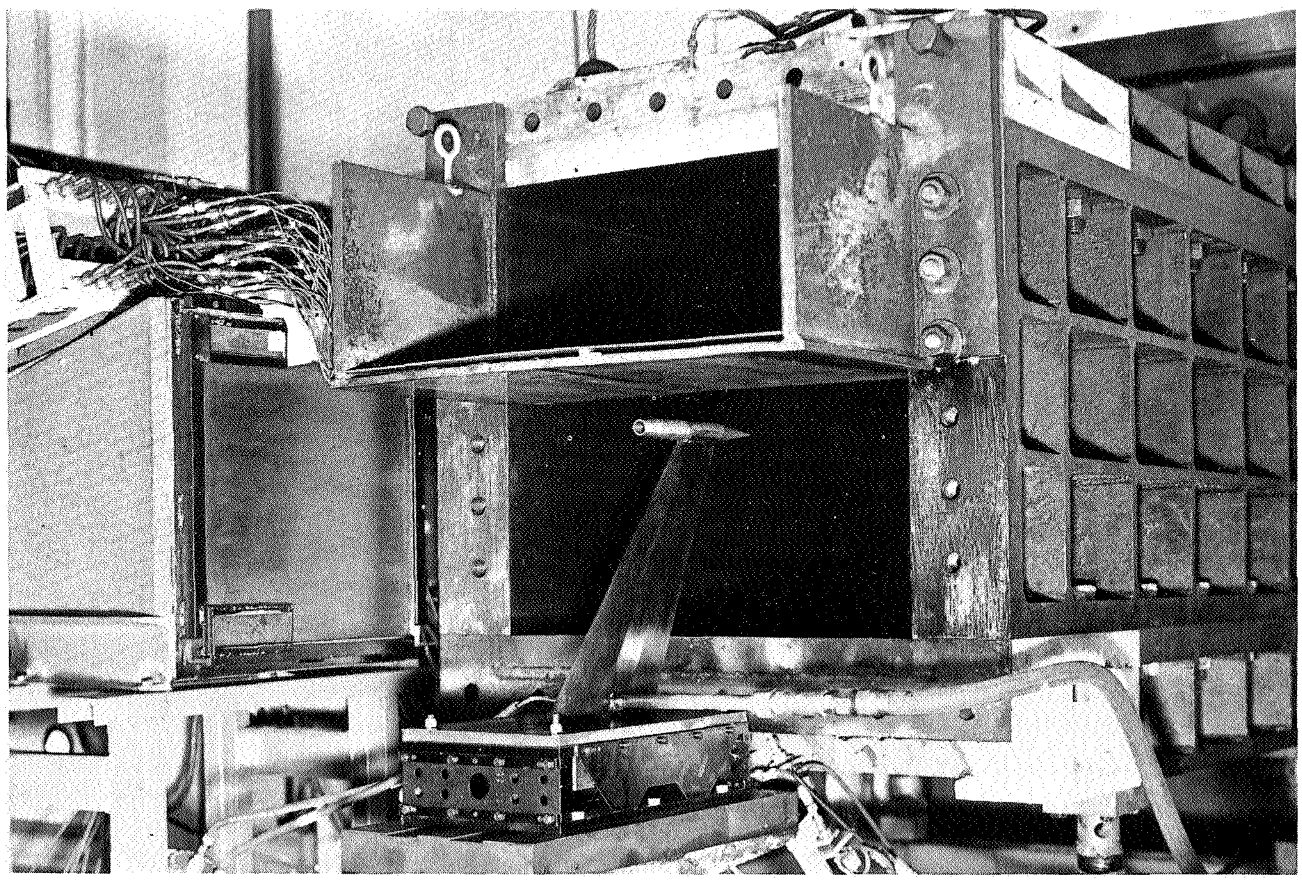


FIGURE 261. Simulated propulsive jet nacelle installed in Preflight Jet beneath a flat wing surface, for the purpose of investigating jet-induced loads.

From extensive tabulations made available of pressures induced on the wing surface, loads on full-scale airplanes could be calculated for a wide range of conditions. A typical pressure field induced by a jet is shown in figure 262. Peak pressures were induced, not only by the primary exit shock wave but also by a secondary jet shock developed downstream of the exit. Extensive use was made of shadowgraph equipment at Wallops to define the shock patterns. The initial findings of this program were presented to the NACA Conference on Aircraft Loads, Flutter, and Structures in March 1956 (ref. 41).

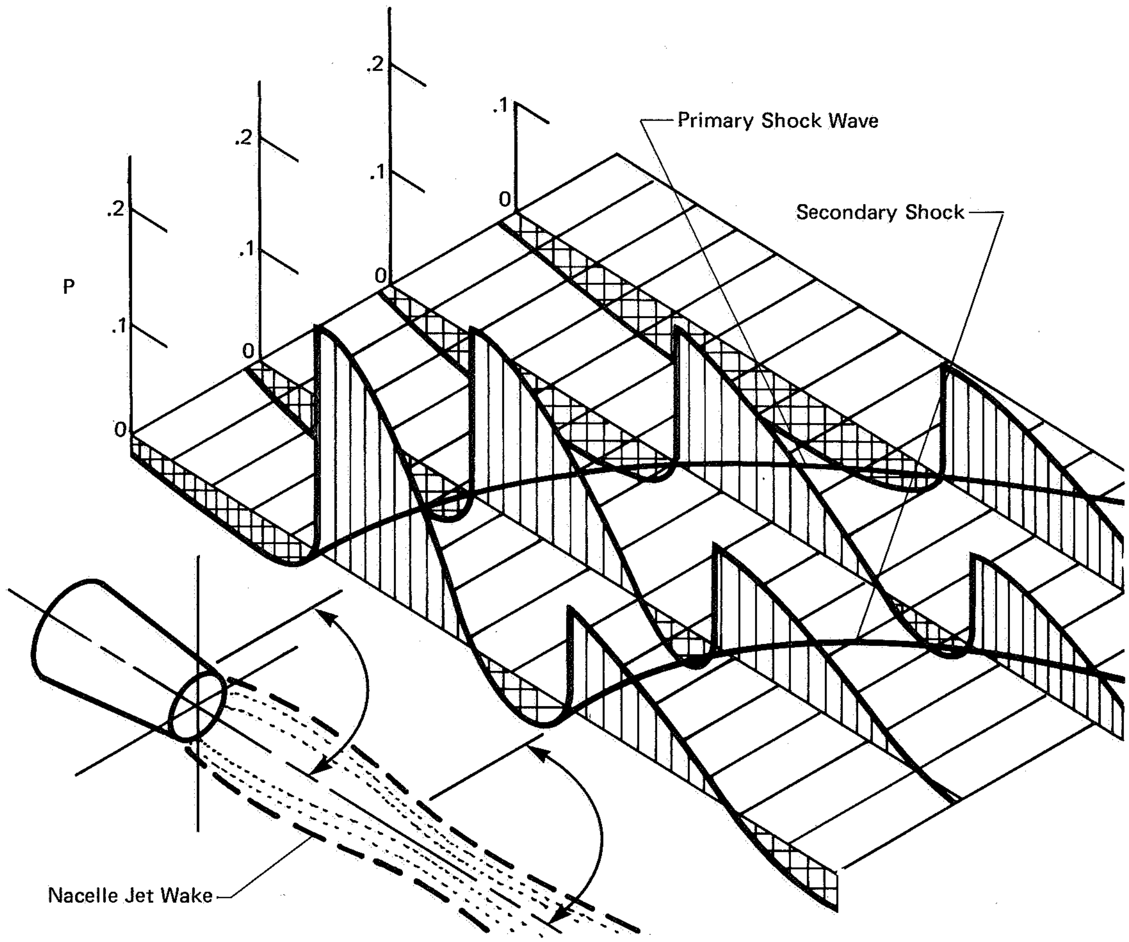


FIGURE 262. Representation of typical pressure field induced upon a flat plate by a simulated jet engine operating in the Preflight Jet at supersonic speeds.

The lift created on the wing surface by the pressure field induced by the operating jets was obtained by integration of the pressure distribution. This lift varied from 1.45 times the thrust for a pressure-ratio of 2.0, to 0.65 times the thrust for a pressure ratio of 6.0. Methods were developed by which the data could be applied to various arrangements of wings and nacelles.

In these laboratory tests, cold helium was used to simulate the operating jet engine in most cases. In other wind-tunnel tests, cold air had been used (ref. 42). In either simulation, the static pressure ratio of the hot exhaust could be duplicated, but the parameters affected by temperature could not.

A special series of tests was made at Mach 1.8 in the Preflight Jet at Wallops to explore the effects of the variables. In these tests, four methods of jet simulation were used: (1) hydrogen burned in air, (2) cold air jet, (3) cold helium jet, and (4) a mixture of cold hydrogen and carbon dioxide. Pressure interaction on a flat plate was determined for a range of jet-pressure ratios from 1.0 to 9.0 with each method of simulation. The density, velocity, and ratio of specific heats varied widely in the different conditions. It was found that jet-exit static-pressure ratio was the major variable, as expected, while jet velocity or density for a given pressure had no effect. The ratio of specific heats was found to affect the location of the shock field on the wing through changes in the inclination of the shock wave although the effect on the pressures was only minor (ref. 43). This research defined the important factors of a simulated jet exhaust and showed how a hot jet could be simulated by a cold gas. In addition, the findings made it possible for other institutions, such as universities, to make power-on tests in their wind tunnels quite readily.

During 1956, the research in the Preflight Jet at Wallops on the loads produced by jet exhausts on adjacent surfaces was extended to the condition simulating the launching of an air-to-air rocket-propelled missile from a large airplane. For bomber defense, it was invisioned that such missiles might be launched rearward as well as forward. The Preflight Jet program covered the case of firing a rocket downstream and upstream. In the initial tests, a solid-rocket motor with a burning time of 0.6 second and an exit Mach number of 3.0 was used in the 27-inch Mach 2 nozzle of the Preflight Jet. The results were presented at the NACA Conference on Aircraft Loads, Structures, and Flutter in March 1957 (ref. 44).

The results obtained with the rocket exhausting downstream were similar to those obtained previously with the turbojet simulator for the same static-pressure ratio. When the rocket was fired upstream, simulating a rearwardly lanched missile, a large bow shock was formed ahead of the penetration zone of the exhaust, about two to three jet-diameters ahead of the exit. Between this bow shock and the exit, the fuel-rich exhaust of the rocket motor continued to burn with a brilliant flame. Large pressures were induced on the flat plate, yielding a load equal to 2.3 times the rocket thrust. The next series of tests and the results were similar except that the tests were made in the Mach 1.39 nozzle (ref. 45).

Another study of the effects of jet exhaust in inducing pressures on adjacent surfaces was related to the use of a jet for control of a missile. This program was initiated in the Preflight Jet after it was found that, with a rocket model in flight, a pulse rocket fired laterally beneath a wing to produce a side force also induced a vertical force on the wing. A flat-plate wing equipped with pressure orifices was mounted in the 27-inch nozzle. A second flat plate, equipped with small rocket motors arranged to fire from flush nozzles, was mounted at right angles to the main wing. Three vertical locations of the nozzles were tested. The rocket motors were designed to cover a wide range of pressures in a single test. The burning time was 0.8 second with the pressure increasing from 400 to 1,800 pounds per square inch in the first 0.4 second and then falling to 400 pounds during the remaining 0.4 second.

The flow pattern created by the crossstream firing was quite complex and consisted of a primary shock ahead of a curved mixing region and boundary-layer separation ahead of the shock. A jet shock wave was also present. Pressures on the flat plate at right angles to this flow produced lift forces up to twice the rocket thrust. (ref. 46).

A similar series of tests was made with jets exhausting perpendicularly to the airstream, except that in this case the pressures were measured on the flat plate through which the jets were firing. This simulated the case in which a jet was fired perpendicularly from the bottom of a wing. There was the same flow field about the nozzle as before, with both negative and positive pressures acting on the plate. The negative pressures predominated, however, and produced negative lift loads on the plate up to 4 times the jet thrust (ref. 47).

The finding of favorable base and afterbody pressures from jet exhausts plus the finding of strong induced pressure fields on surfaces adjacent to jets in a supersonic stream led PARD researchers to attempt to capitalize on these effects with complete airplane models. The first model was designed to take advantage of the positive pressure field around the jet to decrease the drag by an application of the area rule. In the jet-on condition, the jet was considered a solid body and was used to fill the cross-sectional area distribution and reduce the slope at the rear. For the test, a 60-degree delta wing, mounted with a single vertical tail on a parabolic body of revolution in a midwing location, was, in turn, attached to the top of a longer body containing a Cordite turbojet simulator. The turbojet exit was at the trailing edge of the wing. An inverted vee tail was mounted beneath the simulator.

At launch, this combination was mounted atop a single Deacon booster. A six-channel telemeter transmitted pressures, accelerations, and angles of attack during the flight test. In flight, the Deacon booster accelerated the model to Mach 1.63 and then separated from it. After a deceleration period of about 12 seconds at which time the Mach number had reduced to 0.82, the turbojet simulator was ignited and the speed was increased to Mach 1.35. The tests showed a strong favorable effect of the jet in reducing the drag in the transonic region, as expected from the area rule. At Mach 1.0, for example, the drag coefficient was reduced from 0.046 to 0.031. The favorable effect decreased as the speed increased, with no reduction being obtained beyond Mach 1.26 (ref. 48).

A similar test was made with a model having a 52.5-degree sweptback wing of aspect ratio 3.4, a taper ratio of 0.20, and conventional tail surfaces. The exit of the turbojet simulator was about halfway between the trailing edge of the wing and the horizontal tail, as shown in figure 263. Again, appreciable drag reductions were obtained in the transonic region up to a Mach number of 1.26. In addition, a nose-down trim change was encountered with power on, because of induced positive pressures on the horizonatal tail. The direct effect of the jet thrust on trim was eliminated in the test by canting the exit nozzle 5 degrees so that the thrust would pass through the center of gravity (ref. 49).

A similar finding of a large nose-down trim change from a jet exhausting ahead of and below a horizontal tail was made with an airplane model having a 55-degree delta wing and a conventional tail. This model was the first of a new series of E15 dynamic stability models designed to achieve a higher speed than the earlier cold models. The model contained an internal rocket motor and was boosted by a twin, underslung Deacon booster, as shown in figure 264. The large trim change with power on was encountered in the first test of this new series with a dummy model. The internal rocket motor was operated in the usual manner with a supersonic nozzle and did not simulate a turbojet. Nevertheless, the same effect was obtained, i.e., a shock wave in the external flow, due to the presence of the jet, produced large lift loads on the horizontal tail and fuselage (ref. 50).

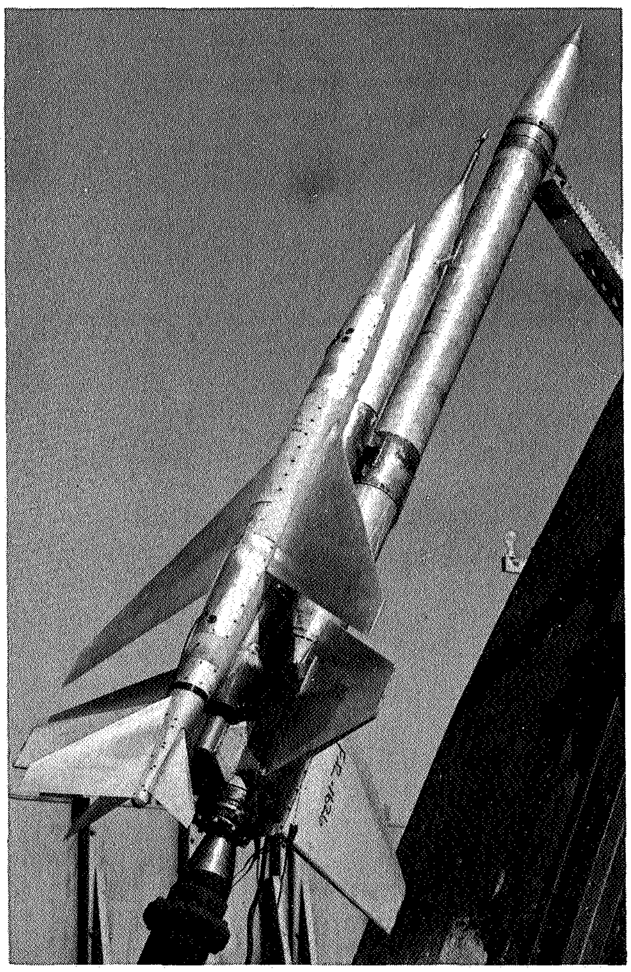


FIGURE 263. Airplane model with conventional tail surfaces and turbojet simulator in long nacelle beneath the fuselage. Model is shown mounted on underslung Deacon booster, April 21, 1955.

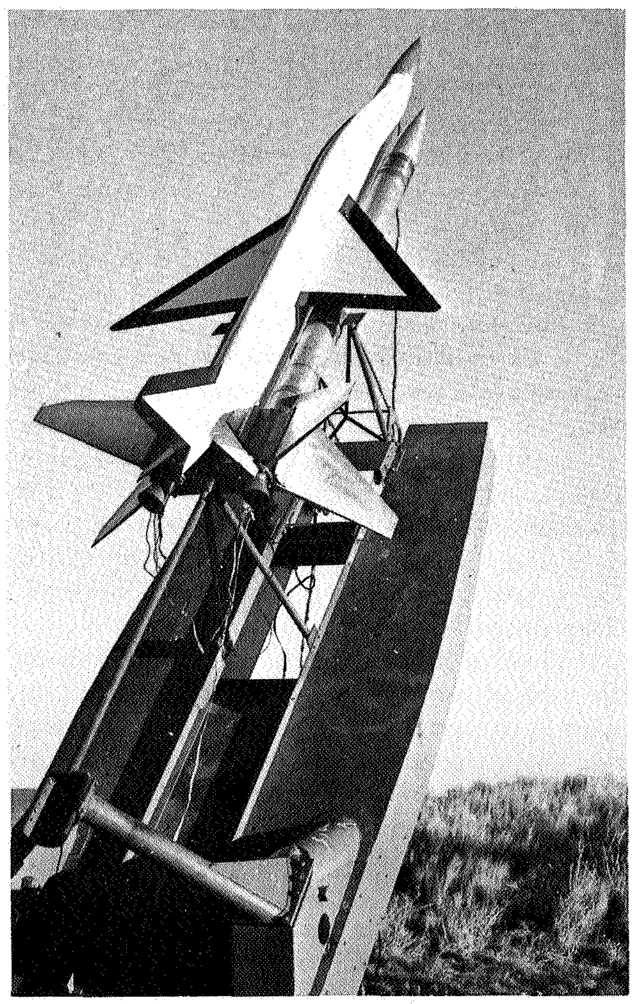


FIGURE 264. Dummy airplane model with internal rocket motor, seen in mounted position on underslung double Deacon booster, December 7, 1953.

The finding of strong jet effects on the horizontal tail led to the initiation of a research program by the General Aerodynamics Branch of PARD to investigate stability, as well as trim, for a sweptback-wing model having its tail surfaces on a boom overhanging the jet exit. Several locations of the horizontal tail were studied. Two additional models were flown, one with the horizontal tail located further aft and one with a larger tail located on the fuselage centerline just ahead of the jet exit. All of the models had Cordite turbojet simulators and were boosted by single Deacon rocket motors to cover a Mach number range, power on, from 1.1 to 1.4. Stability, lift, and drag were determined, as well as pressures on the flat bottom of the overhanging boom.

The only measurable effect was that due to shock interaction in producing large pressure changes on the boom and horizontal tail. The tail located ahead of the exit was not affected by jet effects. Of the two rear locations, the one nearest the exit showed the larger effect. The changes in trim were nose down about 2.5 degrees for the tail just behind the exit, 1.5 degrees for the rearmost tail, and less than 0.5 degrees for the tail ahead of the exit (refs. 51 and 52).

The research in the Preflight Jet regarding jet effects on an adjacent flat plate had direct application to the design of four-engine delta-wing supersonic bombers. Three complete models were flight tested to study such jet effects on trim and lift characteristics.

The first of these models had two side-by-side clusters of two nacelles, each on struts beneath a 60-degree delta wing. The fuselage was contoured in accordance with the area rule. There was no horizontal tail, and the jet exits were located at the two-thirds chord station. Small Cordite turbojet simulators were in each nacelle and, in addition, an HPAG rocket motor was mounted in the fuselage for additional speed. A single tandem Deacon booster was used. Power-on effects were obtained from a Mach number of 0.6 to 1.36. A nose-down trim change, plus an increase in lift, was noted (ref. 53).

A similar model, differing only in that the four nacelles were separated and staggered chordwise to provide a better area distribution, showed only small changes in trim due to jet effects (ref. 54). (See figure 265).

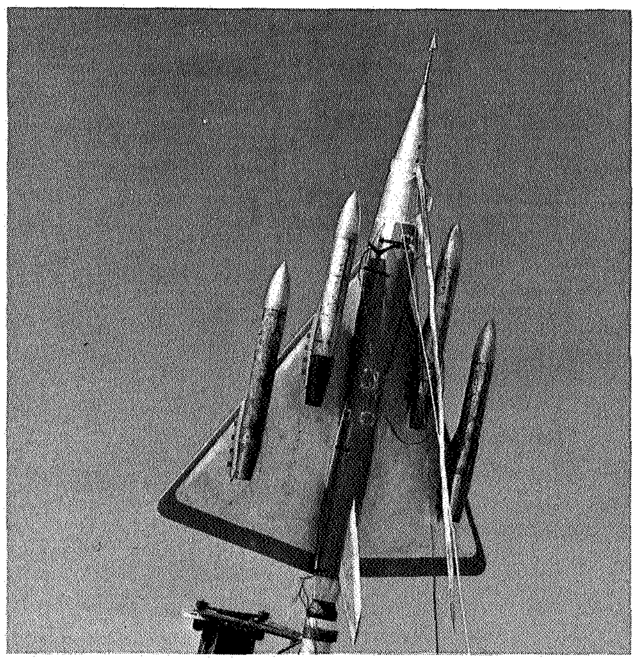


FIGURE 265. View of delta-wing airplane model with simulated turbojet engines in four nacelles beneath wing, February 13, 1957.

The third delta-wing model simulated a unique arrangement of four engines. The difficulty in providing a small cross-sectional area for a delta-wing bomber with four external nacelles led to consideration of an arrangement consisting of two engines in the rear of the fuselage plus two engines in the forward part of the fuselage. The two forward engines were sloped slightly downward and outward and exhausted beneath the wing on each side of the fuselage. In the flight test simulating this design, only the two forward engines were simulated. A single Cordite grain was used with twin exhaust jets. Space considerations dictated that the Cordite motor be located aft of the nozzles, and necessitated the use of a unique reverse-flow duct system between the grain and the two engine nozzles. A double Deacon booster was used, as shown in figure 266. Although there was a slight nose-up trim change due to the jets in flight, the main effect was a sizable increase in lift at a given angle of attack. A slight increase in lift-curve slope was also noted (ref. 55).

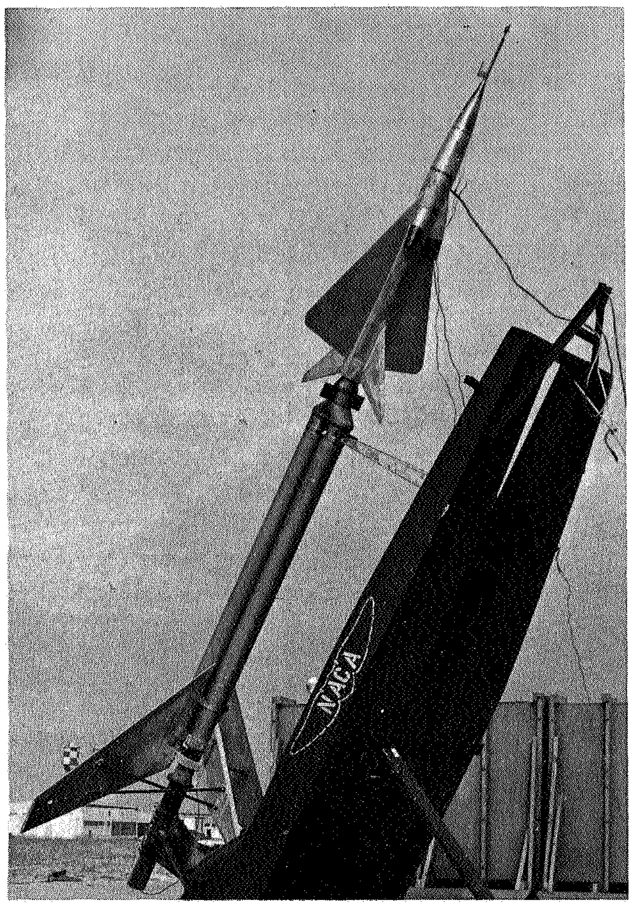


FIGURE 266. Delta-wing airplane model with two simulated underwing propulsive turbojet engines. Model is shown on launcher with double Deacon booster, January 28, 1955.

In summation, the flight tests with rocket models and the tests in the Preflight Jet showed the powerful influence of jet exhausts on supersonic flow, creating shock waves that induced considerable pressure on any surface within the field. Such pressures not only were of interest in the structural design of the surface, but also resulted in positive thrust increments or reduced drag, increases in lift, and changes in longitudinal trim. It was also found that the propulsive jet should be considered in area-rule calculations. Methods for predicting jet effects were developed from this research.

TRANSONIC CONTROL SURFACE BUZZ: D27

The phenomenon of control surface buzz, a form of single degree of freedom flutter, was first encountered with the ailerons on the Lockheed F-80 airplane in 1944, during high-speed dive tests being conducted at the NACA Ames Aeronautical Laboratory. A fix was developed in the Ames 16-foot high-speed wind tunnel in the use of a mechanical damper, but the phenomenon remained a latent source of trouble. The phenomenon—a high-frequency oscillation or buzz of an aileron about its hinge axis, if left free to move—was associated with a shock wave that passed over the surface in the transonic speed range. Because of its association with a shock wave, it was expected that the intensity of buzz would be affected by such things as wing thickness and sweepback, which had been found to affect the strength of shock-induced separation over a wing.

As an extension of the flutter program of the Stability and Control Branch of PARD, a research program, designated D27, was established to study transonic buzz with rocket models. The program was rather brief in number of flight tests, eight in all, but it extended over a period of more than 6 years, from September 15, 1950, to February 15, 1957. All flights were successful. The models consisted of three half-span wing panels, equally spaced around an ogive-cylinder fuselage. In figure 267, one of the models is shown ready for launch. A mass-balanced, spring-restrained, trailing-edge aileron was fitted to one of the wing panels. A 5-inch HVAR booster, plus an internal Cordite rocket motor, accelerated the models to a Mach number of about 1.2.

FIGURE 267. Technician W. A. Roberson prepares to pull the external-power plug from a rocket model designed to investigate aileron buzz. The model is shown in launch position at Wallops, July 9, 1951.

The first series of wings consisted of three with 35-degree sweepback and 6-, 9- and 12-precent thickness, and a fourth with no sweep and 4-percent thickness. The ailerons on the first three wings buzzed or fluttered throughout the transonic range, and some coupling with wing motion was evident. The aileron on the thin, unswept wing only buzzed over a narrow Mach number range (0.97 to 1.00), which was related to the passage of a shock wave over the control, as evidenced by pressure measurements on the surface (ref. 56).

The wings on the next series of flight models had 60-degree delta planforms with trailing-edge ailerons, and were equipped with a control "plucking" device that allowed determination of control-surface hinge moments and damping following deflection and release of the control by the plucker. A maximum Mach number of 1.9 was provided in the tests by a single Deacon booster. Two such flights were made in 1955 and provided data for comparison with theory and wind-tunnel measurements (ref. 57). Some of the data were presented in a paper at the NACA Conference on Aircraft Loads, Flutter, and Structures in March 1955 (ref. 58). The experimental measurements of control-surface damping indicated instability in the transonic range and at low supersonic speeds, in general agreement with two-dimensional theory. The measurements were of value in designing an artificial damper to alleviate the buzz condition on fullscale aircraft.

The potential-flow theory that predicted unstable damping at low supersonic speeds also predicted that a control surface having its hinge at the 55-percent chordwise location would not be unstable. Two such controls were flown on two rocket models with 60-degree delta wings, with the control-plucking device used as before. The flight results indicated that the damping was, indeed, close to zero, although the actual magnitudes were somewhat influenced by indeterminate friction effects (ref. 59).

COMPLETION OF DRAG RESEARCH BY AEROPULSE TECHNIQUE: D35

Chapter 9 has discussed preliminary tests of rocket models in the D35 program, which utilized a unique "aeropulse" technique for automatically pulsing the horizontal tail to induce an oscillation in pitch and allow determination of lift and drag at angles of attack. Eight additional rocket models in the program were flown between January 1953 and October 1955, all being successful.

Two of the models were flown without wings, to provide component data. Of the two, one also was without tail surfaces. The model with only four small 60-degree delta fins was flown with a double Deacon booster. This booster, plus an internal HPAG motor, accelerated the model to a maximum Mach number of about 3.0. The fuselage had a fineness ratio of 16.9. One set of fins was hinged behind its center of pressure to allow automatic step movements between stops as the angle of attack changed sufficiently to reverse the lift on the fins. A 12-channel telemeter was used to transmit continuous data on normal, longitudinal, and lateral accelerations; angles of attack and sideslip; hinge moments; and total pressure. Pitching moments were obtained from differences in readings of normal accelerometers located some distance apart. Ground rollsonde equipment, operating with the directional telemeter antenna signal, indicated model rolling velocity. Mach number, Reynolds number, and dynamic pressure were obtained from ground-based Doppler and tracking radars and radiosonde equipment. Data were obtained on lift, drag, and static stability at angles of attack from 0 degrees to 6 degrees. With the small fins used, neutral stability was indicated for a center-of-gravity location of 0.46 body length at a Mach number of 3.0. The data were of value for the design of an aerodynamically stabilized ballistic missile, as well as for component data for later complete models (ref. 60).

The second model, with neither wings nor tails, had its center of gravity at the 0.28 body station to prevent excessive angles of attack during the test. This model was flown with only the double Deacon booster. Although the body alone was unstable at low angles of attack, the crossflow lift forces on the body at higher angles were sufficient to provide stability and trim at a finite angle. At a Mach number of 1.74, for example, the model trimmed at about 12 degrees. The crossflow lift forces agreed well with those calculated by the method of H. J. Allen in NACA RM A9I26. At other Mach numbers, the range of instruments or severe cross-coupling prevented analysis of the data (ref. 61).

The remaining six models of this program had similar fuselages and tail surfaces but had different wing arrangements. The horizontal tail was arranged as an "autopulse" tail. Most of these models were flown to a Mach number of about 2.3 with double Deacon boosters and internal HPAG rocket motors, although two were flown without the internal motor, and one had only a single Deacon booster plus the internal motor.

The first wing tested in this series was similar to that of the Douglas X-3 research airplane—an unswept, tapered wing of aspect ratio 3.0 with a hexagonal section 3 percent thick. The lift, drag, and pitching moment data were obtained to Mach 2.0 for angles of attack up to 10 degrees near Mach 1.0 and 4 degrees at Mach 2.0. The results indicated no leading-edge suction on the wing, as would be expected. Lift-curve slopes were linear, but pitching moments had some nonlinearities (ref. 62).

The next three models had differing modifications to the basic wing S6 of a new supersonic series of research planforms. The basic wing had 52.5-degree sweepback, an aspect ratio of 3.0, a taper ratio of 0.2, and a NACA 65A004 wing section.

The first model of this series had the basic wing, as shown in figure 268. This model had about the same drag at zero lift as the model with the X-3 wing, but drag due to lift was from 11 to 25 percent higher, even though this rounded-nose section did exhibit some leading-edge suction. The sweptback wing had a lower lift-curve slope (ref. 63).

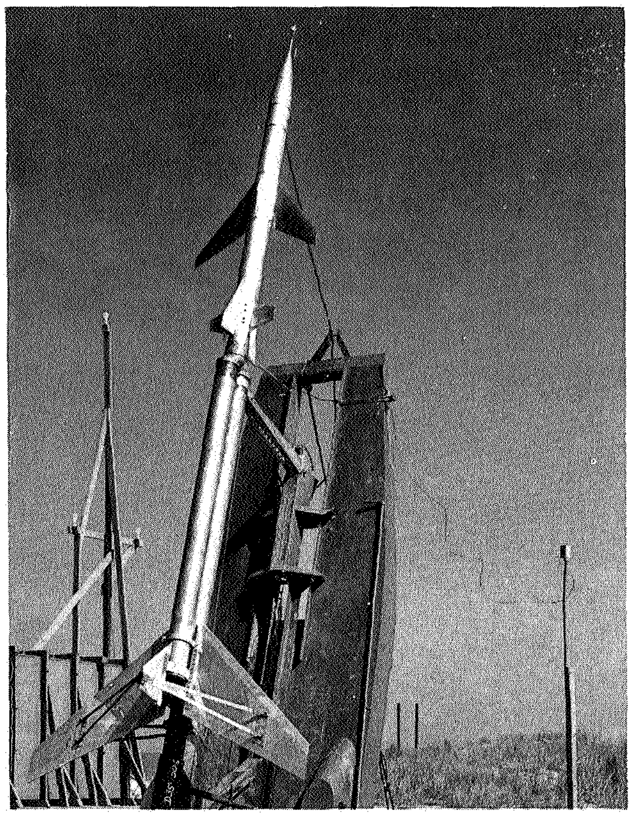


FIGURE 268. Aeropulse model with general research supersonic wing S6. View shows model mounted on launcher with double Deacon booster, April 21, 1954.

The second model had the same wing planform, but it was cambered and twisted to reduce the drag due to lift. The use of conical camber had been investigated by Charles F. Hall in wind tunnels at the Ames Laboratory. A variation of this method, termed compound warp, developed by Warren A. Tucker, Langley PARD theoretician, was used in the present test. The wing was warped to yield a calculated low drag at a Mach number of 1.46 and a lift coefficient of 0.3. The results were disappointing in that, although the drag due to lift was reduced somewhat, the minimum drag was increased and tended to nullify this gain over the flat or untwisted wing (ref. 64).

The third model of the series employed a different modification to improve the lift to drag ratio. This change consisted of extension of the chord forward and rearward in the inboard area of the wing. The basic model's centerline root chord was extended three-fourths of the root chord forward and three-fourths rearward, tapering to zero extension of the local chord at the semispan. The thickness of this modified root section was 2 percent. A reduction in minimum drag coefficient was noted over the Mach number range from 1.0 to 2.2, and a considerable reduction in drag due to lift was found above a Mach number of 1.5 (ref. 65).

The last two models in the program had modified 67.5-degree delta or arrow wings, with and without twist and camber. The model with the flat wing is shown in figure 269 with its double Deacon booster. The combination of this highly swept wing with the body of fineness ratio 20 was selected as an alternate method of creating a low-drag configuration at supersonic speeds. The reasoning behind the selection was based on results of the tests of bodies of high fineness ratio discussed in Chapter 8. The

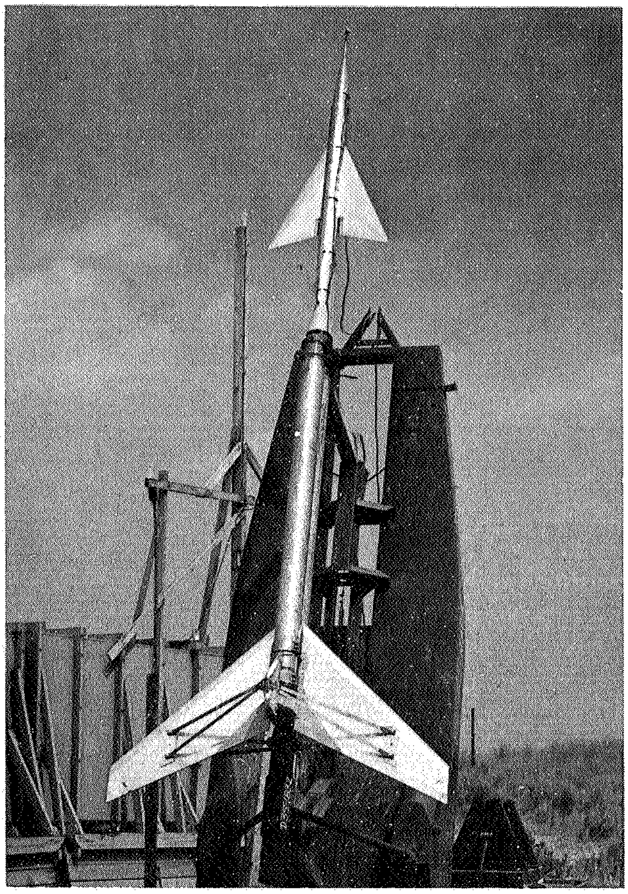


FIGURE 269. Rocket model with 67.5-degree arrow wing on a high-fineness-ratio parabolic body having no horizontal tail. The model is shown on its launcher with double Deacon booster, June 28, 1955.

tests had shown that, on a volume basis, the drag decreased at high fineness ratios, at least up to a value of 25. The present test indicated that the configuration, indeed, would be a good one for supersonic flight, for the minimum drag coefficients were quite low, with a value of 0.0130 from a Mach number of 1.2 to that of 2.0 (ref. 66). The second model incorporated twist and camber for low drag at a design Mach number of 1.57 and a lift coefficient of 0.2, using the design procedure of Tucker. In the tests, it was found that the total drag was reduced at a lift coefficient of 0.2 and above, and the maximum lift-to-drag ratio was increased about 10 percent when compared with that of the flat wing (ref. 67).

COMPLETION OF AIRPLANE LONGITUDINAL STABILITY RESEARCH

The E15 general-research rocket-model program was phased out during the current period with the last launch on September 8, 1958. In this program, longitudinal stability, lift, and drag were determinded with models having power mechanisms to pulse the horizontal tail in a square-wave pattern to induce transient oscillations in pitch. A standard body, 7 inches in diameter and having a cylindrical midsection, was successively fitted with different wing shapes and tail arrangements. The model had no internal propulsion but was propelled to about Mach 1.5 with either a single or a double Deacon booster. The initiation of this program has been described in Chapter 6, with a discussion of the continuing program of research in Chapters 8 and 10. Additional tests with this standard body were made, and tests also were made with three new series of models designed to provide data to much higher Mach numbers. The final model, although unsuccessful, was designed for a Mach number of 4.5.

The last models of the standard series were all equipped with a rather large sweptback vertical tail and a sweptback horizontal tail with negative dihedral. The horizontal tail, mounted low on the fuselage, had been introduced into the program earlier. (See Chapter 10). The low horizontal tail was found to be beneficial in reducing the pitch-up characteristic of sweptback and delta wings in the transonic range.

The first model in the present series including this tail arrangement had a 45-degree sweptback wing of aspect ratio 4.0 and taper ratio of 0.3. The flight results agreed well with wind-tunnel results where available, and indicated that the low tail eliminated the pitch-up associated with this wing planform (ref. 68). A comparable improvement in stability was next demonstrated over a wide angle-of-attack range with a model having a 52.5-degree delta wing (ref. 69). Similarly, the low tail eliminated the pitch-up on a model with a 60-degree delta wing (ref. 70).

The first attempt to extend the E15 program to higher speeds was to increase the size of the model to allow use of a large sustainer rocket. A 55-degree modified delta or arrow wing, 3 percent thick, was located on the centerline of a fuselage the same width as the standard E15 body, but twice as high and considerably longer. With this design, a Deacon rocket motor could be located inside the fuselage and below the wing. Such a model was flown atop a twin underslung Deacon booster to provide data to Mach 2.3. The same swept vertical tail and low horizontal tail arrangement of the standard series was used. A dummy model flown during the booster development program provided some data regarding jet effects on trim, which have been discussed in an earlier section of this chapter. The model was shown in figure 264 and had the same external dimensions as the instrumented test models.

In addition to this dummy, two complete models were flown. In the first test, the horizontal tail was knocked off upon hitting the booster fins at separation, and no usable data were obtained. In the second test, only one-half of the horizontal tail was knocked off, and a considerable amount of data was obtained and reported (ref. 71). Because the dummy model had experinced a large nose-down trim change due to jet effects on the horizontal tail, a short extension or blast tube was added to the nozzle of the internal rocket motor to cause the shock wave from the jet to pass behind the tail and eliminate the jet effects. The lift, drag, and stability characteristics as measured agreed well with theoretical calculations.

The second series of models designed to attain higher Mach numbers consisted of smaller models (5-inch-diameter bodies) mounted on twin, underslung, Deacon boosters supplemented by twin tandem Deacon boosters. Such an arragement is shown in figure 270. It was designed for Mach 3 and reached Mach 2.8 in the test. Four models of this type were flown, but only the one with a 52.5-degree delta wing was successful. The normal mechanism for pulsing the horizontal tail to provide pitch disturbances was not used in this series of models, for lack of room. Instead, small, electrically operated pitch-disturber vanes were mounted inside the nose cone and were arranged for periodic extension and retraction. This system failed to operate, and the only disturbance in flight was that at booster separation, which limited the pitch data to a narrow range between Mach numbers of 2.6 and 2.8. The data in this range, however, agreed well with calculated values (ref. 72).

Attempts to extend the data on airplane models to Mach numbers in excess of 4 were made during the 1956–1958 period without much success. First, several E15 models were designed to contain two Loki rocket motors in simulated engine nacelles located along the bottom of the fuselage, with Nike motors as first-stage boosters. The first of these, shown in figure 271, was flown on September 8, 1958, but it broke up at the end of Nike burning, and the remaining models were canceled.

A more successful series of Mach 4 models was flown with combinations of two or more Nike and Honest John[8] motors as boosters. These models, a part of the E41 program, were quite small and contained no internal propulsion. They were sturdily constructed of steel and were similar in appearance to th X-15 research airplane. They were equipped with pulse rockets or air jets to provide a pitch disturbance. Three models were flown with increasingly powerful boost systems. The first, on June 7, 1956, shown in figure 272, had a two-stage Nike-Nike booster. The second, flown May 16, 1958, had a two-stage Honest John-Nike booster, as shown in figure 273. The third, flown on October 13, 1958, had a three-stage Honest John-Nike-Nike booster, as shown in figure 274. Although all three flights appeared to be successful, the data were never analyzed or reported. By the time the last model was flown, interest had shifted to space projects, and throughout the nation there was a general lack of interest in airplanes in this speed range, except for the X-15 research airplane itself.

In summary, the E15 program, spanning a period of 10 years, provided much needed aerodynamic design data for transonic and supersonic airplanes. Such items as lift, drag, pitching moment,

8. See Chapter 13 for details on the Honest John rocket motor.

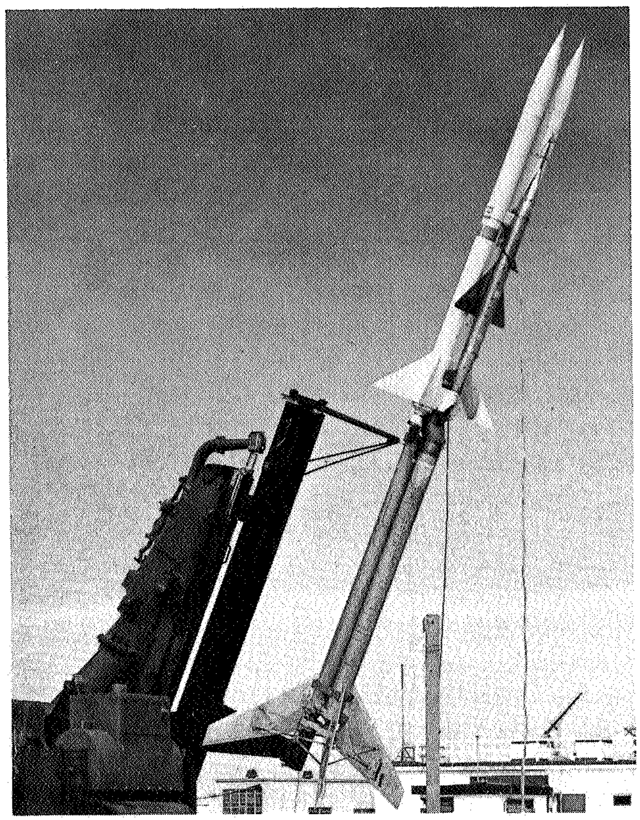


FIGURE 270. High-speed E15 longitudinal stability model mounted atop an underslung double Deacon booster plus a double Deacon tandem booster. The model was launched at Wallops on January 26, 1956.

FIGURE 271. Technician Durwood Dereng installs firing leads to one of two Loki motors in enlarged fuselage of an E15 longitudinal stability model, shown with a Nike booster, September 8, 1958.

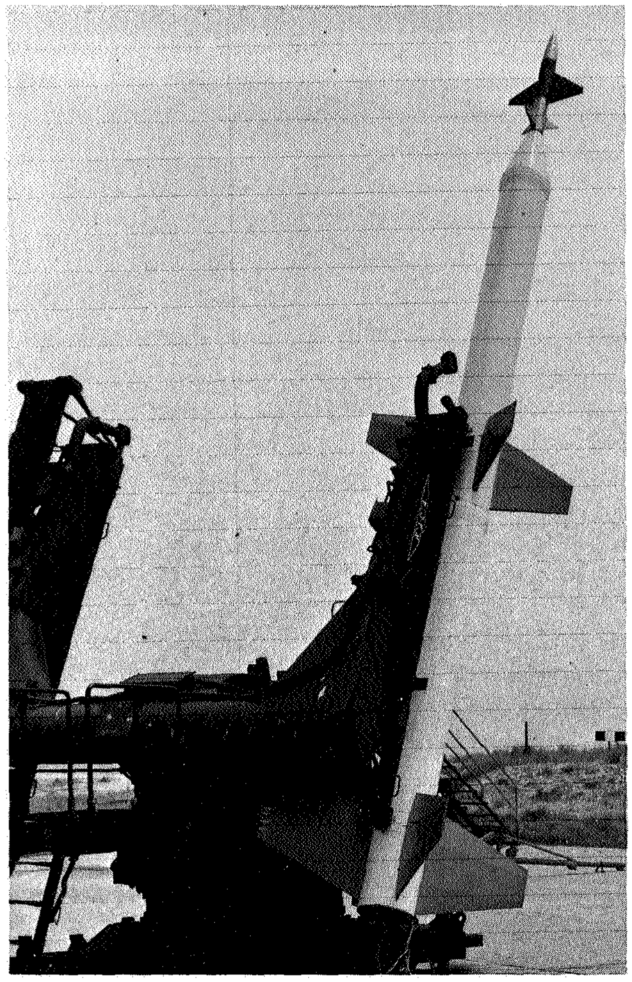


FIGURE 272. High-speed airplane model in longitudinal stability program. View shows model with Nike-Nike booster, June 7, 1956.

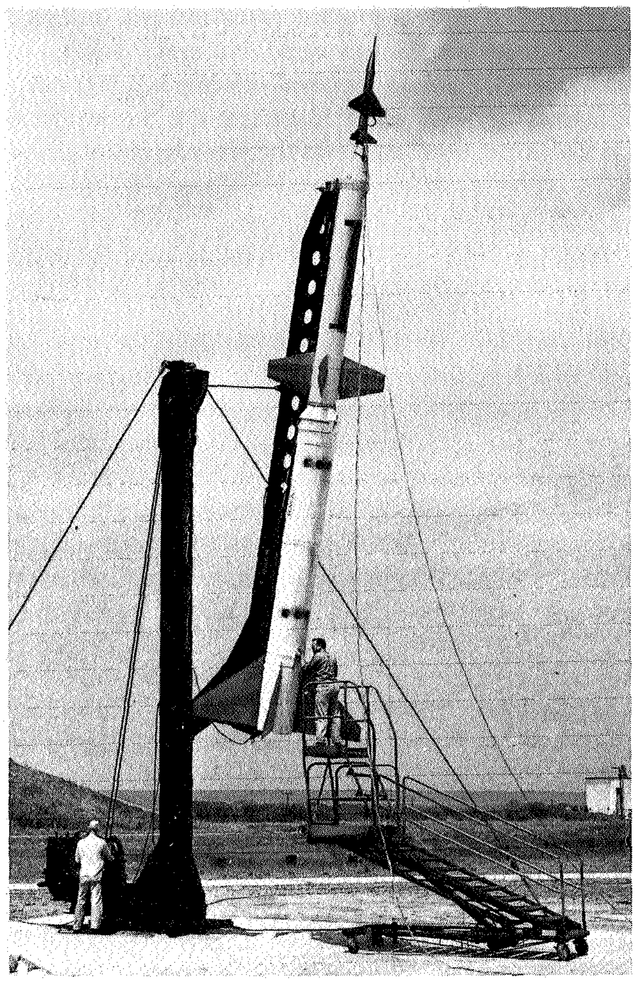


FIGURE 273. High-speed airplane model, shown with Honest John-Nike booster, May 16, 1958.

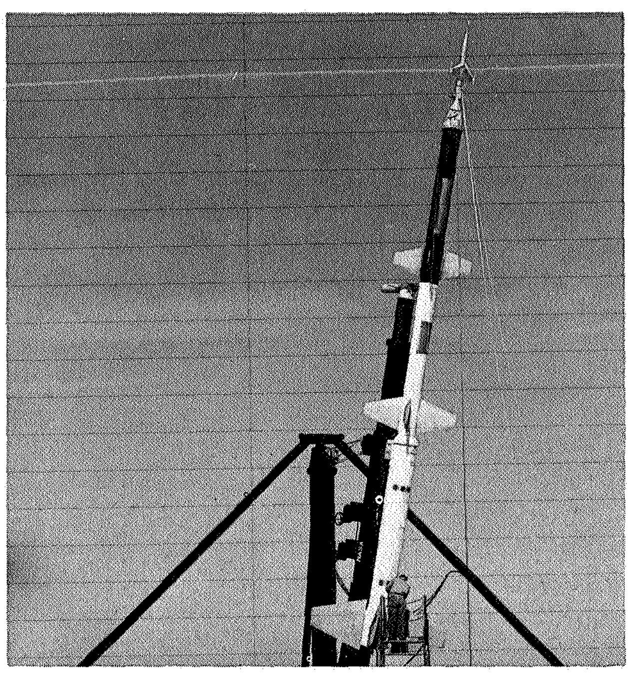


FIGURE 274. Technician Harry Bloxom connects firing leads to Honest John-Nike-Nike booster for test of high-speed airplane model, October 13, 1958.

dynamic stability, control effectiveness, buffeting, and trim changes over wide Mach-number and angle-of-attack ranges were evaluated for a variety of wing and tail configurations. The techniques developed in this general research program were also applied to specific airplane and missile development projects. In fact, it was one of the major techniques that established rocket-model testing as an important phase in the development of new airplanes and missiles.

PREFLIGHT JET RESEARCH ON BOMB EJECTION AT SUPERSONIC SPEEDS

The Preflight Jet at Wallops was used for many research programs in addition to ramjet development, for which it was designed. One of these was an extensive program to study the dynamic behavior of bombs or stores released or ejected from airplanes at supersonic speeds. The open jet was particularly suitable for such tests because the stores could be ejected without causing any damage to the facility.

In subsonic operation of military aircraft, it was customary to simply release a bomb or store, and gravity alone would pull it safely away. As flight speeds increased, however, aerodynamic forces became appreciable in relation to the weight, and some interference resulted. In fact, under some conditions, bombs released from within a bomb bay had been known to assume large angles and, in some cases, had actually reentered the bay for a brief moment.

At its meeting on December 6, 1951, the NACA Subcommittee on High-Speed Aerodynamics recommended that studies be made of the problems of jettisoned stores at transonic and supersonic speeds. Particularly mentioned were the problems of "bomb drops from internal bomb-bays," and the jettisoning of "empty external wing-mounted fuel tanks and ejection seat plus pilot." Member John Stack "informed the subcommittee that some wind-tunnel work along these lines will be conducted in the near future at Langley" (ref. 73). These preliminary tests in the Langley 9-inch supersonic tunnel indicated that releasing a bomb at a Mach number of 1.62 could cause serious trouble (ref. 74).

In view of the difficulties with simply releasing bombs at supersonic speeds, the Republic F-105 airplane was designed for forcible ejection of bombs from within the bomb bay to avoid this trouble. Tests of the system in the Wallops Preflight Jet were requested by the Air Force on June 29, 1954, and were approved by NACA Headquarters on August 6, 1954, with the issuance of RA A74L139. The original program, which began in August 1954, was enlarged considerably by the addition of different shapes of stores or bombs, and the program then became a general research effort that extended through September 1956. The general program, as well as the specific project requested by the Air Force, will be discussed in this section.

For the F-105 tests, a simulated one-half fuselage of the airplane, with the bomb bay, was attached to the top plate of the nozzle and to an extension of the top plate, as shown in figure 275. On the airplane, the store was to be carried inside a closed bomb bay. For lack of room, the fins on the bomb were to be folded for storage and opened after ejection from the bomb bay. When release of a store was desired, the bomb bay doors were to be opened and the store accelerated by a piston and push-rod acting in line with the center of gravity. The store was restrained from lateral motion on the ejection rod and the fins were to be opened just pior to separation of the push-rod from the store. One of the purposes of the Wallops test was to determine the time allowable for the opening of the fins before excessive pitch attitudes were reached.

In the model tests, the bomb bay was open all the time. The motion of the store was determined from a series of pictures of the store at millisecond intervals superimposed on a single sheet of film. A bank of 20 Strobolights, a type of flash bulb, were fired in sequence by a 1,000-cycle timer while the shutter of the camera was opened for 1/20 second, a slightly longer time than the test period. The models were 1/17-scale and were tested at Mach numbers of 0.8, 1.4, and 1.98. The ejection velocity of the store was 30 feet per second.

In a dynamic test such as this, it was necessary to consider the laws of dynamical similitude, or the scaling laws, in arriving at the appropriate weight of store to be ejected. Regardless of the weight, the center of gravity had to be in the proper relative position, and the radius of gyration had to be the same percentage of the length of the store as that of the full-scale article.

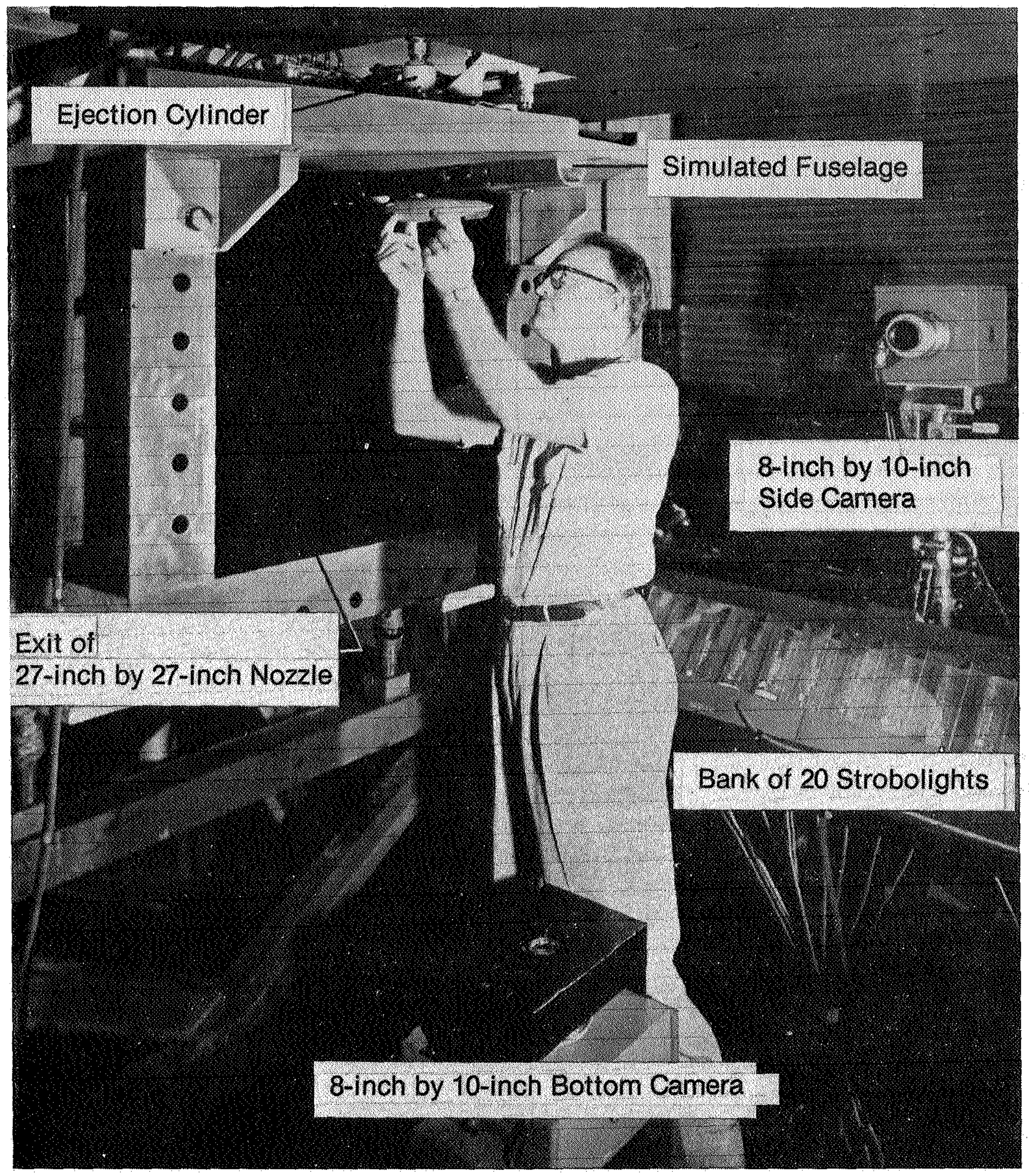


FIGURE 275. Engineer E. H. Helton inserts bomb model in bomb bay of simulated fuselage, for ejection tests in Preflight Jet.

In the initial program, the so-called "light-model" method of scaling was used, in which the ratio of store density to dynamic pressure was kept the same for the model as for the full-scale store. Since the Preflight Jet operated at near sea-level pressure in the test section, this meant that, for a given Mach number, the weight of the model was proportional to the cube of the scale factor for sea-level simulation. For simulation of the full-scale store at some altitude, the weight of the model was increased in inverse proportion to the pressure ratio i.e., high-altitude simulation required a heavier model. The models in the present tests weighed from 0.40 to 1.14 pounds and were constructed of wood, with concentrated masses of metal to obtain the desired weight and radius of gyration.

The light-model method gave the correct motions due to aerodynamic forces, but was deficient in that accelerations from such forces were too high in relation to vertical accelerations due to gravity. In the present tests, in which the stores were ejected at 30 feet per second, this deficiency was inconsequential, whereas for a free drop, it would be intolerable. An analysis made of different scaling methods showed that the deficiency could be overcome by accelerating the parent airplane vertically as the store was dropped, or by going to a so-called "heavy-model" method (ref. 75). The heavy-model method required that the weight be increased in inverse proportion to the scale factor (an increase of 17 times in the present case). The method was difficult to follow and, in addition, was deficient in that damping of rotary motions was less than the correct rate.

The initial tests in the F-105 program were made with a store having a streamlined shape, a fineness ratio of 7.0, and three stabilizing fins. At a Mach number of 1.4 and a simulated altitude of 3,400 feet, violent motions were observed, with the store pitching up and striking the bomb bay, and breaking up shortly after ejection. Apparently, large pitching moments were induced by the flow field in the vicinity of the bomb bay and the ejection mechanism. Some improvement was obtained by replacing the high-aspect-ratio fins with a low-aspect-ratio fin of greater area, and by orienting the store so that the vee tail emerged first. At a Mach number of 0.8, no difficulty was encountered, and the time available for opening the fins to avoid trouble was found to be 4 milliseconds, for the model. At the highest Mach number, 1.98, and an altitude simulation of 29,000 feet, the store was physically stronger and stiffer in relation to the loads, and successful ejections were achieved. Again, 4 milliseconds were indicated to be the maximum allowable opening time for the fins (ref. 76). The drag acting on the stores at supersonic speeds in the vicinity of the bomb bay was found to be higher than that expected for isolated stores, as determined from tests in the Helium Gun (ref. 77).

Some additional data on the drag of isolated stores were obtained from a supplementary series of tests of eight models in the Helium Gun, representing a streamlined store of fineness ratio 5.6, and a slightly blunted store of fineness ratio 7.0. The tests were requested by the Air Force to determine modifications to the stores that would allow the drag to be varied as desired. The Air Force planned to use small dummy models of the actual stores as practice bombs for training purposes, and wanted to ensure that the trajectory of the scaled store would duplicate that of the full-size bomb. Interest centered around the drag at high subsonic speeds. The tests showed that blunting the trailing edge of the fins on the store had a great influence on the drag. At the Reynolds numbers of these tests, 5 to 10 million, based on body length, the flow was essentially turbulent, and the drag increased with increases in roughness (ref. 78). Any desired drag curve could be duplicated by appropriate design.

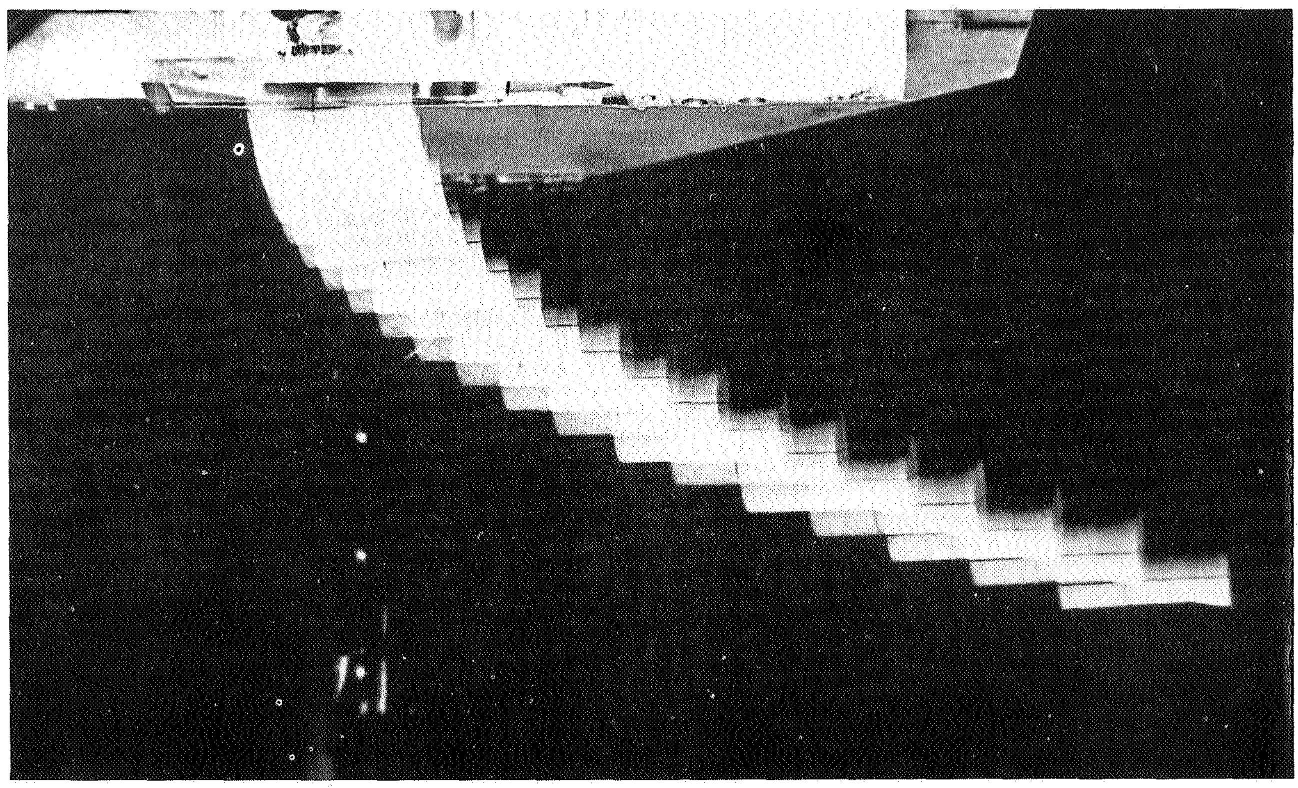


FIGURE 276. Stroboscopic pictures of a cylindrical bomb with a stabilizing flare. Pictures were taken in the Preflight Jet after ejection of the bomb from a bomb bay at supersonic speeds.

The large positive pitching motion of a streamlined store ejected from a bomb bay at supersonic speeds was believed to be the result of positive loads on the nose of the store as it emerged from the bomb bay. It was reasoned that removal of the ogival nose might alleviate this condition, and some tests were made with the nose of the streamlined body blunted by cutting off a small section. Tests of this modification were disappointing, however, in that little improvement was noted. More drastic changes in shape were then considered.

In consideration of the basic requirement for an internally carried bomb, a series of bluff shapes, starting with a simple cylinder, were tested with the same F-105 components that had been used in the streamlined store tests. After all, the streamlined shape was dictated by considerations of external carriage, and if a cylindrical shape could be ejected safely and stabilized after ejection, it might prove to be a more satisfactory solution for an internally carried bomb. In addition, a cylinder would provide a minimum-size carrier for existing warheads. During this same period, Otto Walchner and his coworkers at Wright Air Development Center had been exploring means for stabilizing bluff bombs (ref. 79), and some of their more promising shapes were included in the present program.

The bluff bomb developed at WADC was more of a spool shape than a simple cylinder, and had a thin flat plate called a stabilizer, mounted on struts ahead of the nose. The fineness ratio was 2.58. In the Preflight Jet tests, several modifications to this shape were tested with and without the stabilizer plate. A series of cylinders with fineness ratios from 1.55 to 3.04 was tested with a stabilizing plate; and finally a simple cylinder of fineness ratio 2.71 was tested with a small flare at the base for added stability. For the WADC shape and the simple cylinders, the center-of-gravity location was about 35 percent of the length; for the flared cylinder it was 40 percent. The tests were made at Mach numbers of 0.8, 1.39, and 1.98, and with a bomb ejection velocity of 30 feet per second.

The tests showed conclusively that going from a streamlined shape to a bluff cylinder eliminated the interference problem associated with ejection of a store at supersonic speeds. All of the stores tested had smooth trajectories after release, and at no time did any of them come close to striking the fuselage. The main difference found between the different blunt shapes was in the amount of pitch oscillation experienced in free flight. The best shape found was the flared cylinder without a front plate. The behavior of this model after ejection may be seen in figure 276. Very little oscillation was noted. In these tests, the WADC spool shape was no better than the simple cylinder, and the addition of the stabilizer plate had little effect (ref. 80). The drag characteristics of bluff cylinders with and without stabilizing plates and windshields were determined in a separate investigation in the Wallops Helium Gun (refs. 81 and 82).

The excellent behavior of the simple flared cylinder was to have a profound effect on the design of nose cones for ballistic missiles in the years ahead.

Following the successful ejection of bluff stores, the program aimed specifically at the F-105 airplane was extended to include modifications to the original streamlined store, a streamlined store of fineness ratio 8.5, designated TX-28, and additional tests of the WADC spool shape, without the stabilizer plate. In addition, a blunt, reduced-length modification of the TX-28, termed turnabout TX-28, was tested.

The tests showed that the original shape could be ejected safely if stiffer fins were used along with a higher ejection velocity and a longer stroke to get the store farther from the fuselage at release. The WADC spool and the turnabout TX-28 store were both ejected satisfactorily, but the basic TX-28 store was unstable in its tested configuration (ref. 83).

It was of interest that oscillations of the bluff store affected its trajectory much less than oscillations of the streamlined store affected its trajectory, no doubt because of the lower lift-curve slope of the bluff store.

Additional tests made of the turnabout TX-28 store consisted of adding a ring around the nose and decreasing the size of the fins. A flared cylinder of fineness ratio 4.40, termed bluff TX-28, was also tested. Both shapes were ejected satisfactorily, but the turnabout shape required higher ejection velocities than the flared cylinder (ref. 84).

The ejection tests in the Preflight Jet were supplemented by special tests in the Langley 4-foot supersonic tunnel, in which the forces and moments acting on a store were measured for various positions of the store with respect to the airplane. From such tests, it was hoped that the motion of the store could be calculated and a better insight into the loads acting on the store could be obtained. The test used a generalized model consisting of a cylindrical fuselage with a streamlined nose and a sweptback wing. Tests were made with four generalized bomb shapes varying in fineness ratio from 2.5 to 10. After the tunnel tests were completed, the same airplane model was mounted in the Preflight Jet, and one of the stores was ejected for purposes of comparison.

Some preliminary results were presented at a Conference on the Aerodynamics of High-Speed Aircraft in December 1955. A comparison of the motion of a streamlined store obtained by the two methods showed good agreement in the trajectory, but the angular motions were somewhat different (ref. 85).

These preliminary comparative tests were followed by more extensive tests in which more of the details were simulated. In particular, the ejection rod and push-plate were found to have a large effect on store interference. In these tests, made at a Mach number of 1.61, two of the bombs had fineness ratios of 4 and 7, respectively, while the third was the WADC bluff bomb without stabilizer plate. The results of the tests showed that actual motions could be calculated from the force and moment data with fair accuracy, thereby indicating the necessity for duplicating all the features of the system (ref. 86).

The complete model used in the comparison tests was believed to be more representative of flight conditions than the earlier halfspan model of the F-105 fuselage. Additional tests were made, therefore, of four shapes believed to be of general interest. One was a streamlined body of fineness ratio 8.60, similar to the TX-28 tested earlier except for an increase in fin area; one was a bluff shape of finesess ratio 4.06, similar to the turnabout TX-28; the third and fourth were flared cylinders of fineness ratio 3.75 and 4.40, respectively.

The tests were made at a Mach number of 1.39, with a simulated altitude of 3,400 feet; at a Mach number of 1.60, with a simulated altitude of 16,400 feet; and at a Mach number of 1.98, with a simulated altitude of 29,000 feet. In some of these tests, the recording system was changed from the bank of Strobolights to a single, longer burning light used in conjunction with a rotating disc with slits, which was mounted in front of the camera. All of these models cleared the fuselage after ejection and successfully moved out of the way, although there were some disturbances in the early period that showed the necessity for forced ejection at supersonic speeds (ref. 87). The trajectory of the streamlined store is shown in figure 277.

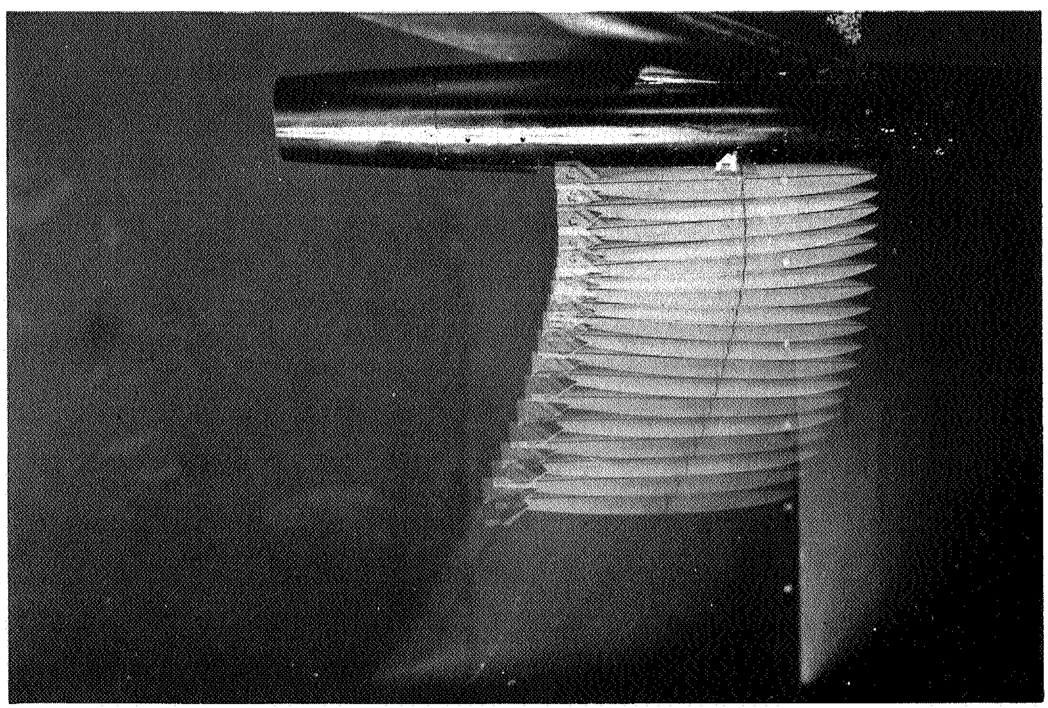


FIGURE 277. **Preflight Jet high-speed photographs of a streamlined store ejected from a simulated bomb bay at Mach 1.39.**

BLAST FACILITY AND BLAST LOADS RESEARCH

The location and nature of Wallops Island made it ideal for projects involving explosives as well as rockets. The Blast Research Project, which began there in 1953, was one such project.

In September 1953, representatives of the Armed Forces Special Weapons Project (AFSWP)[9] approached the NACA with the problem of developing a rational method for calculating loads on aircraft from blast-induced gusts, created particularly by nuclear explosions. Interest was related to the safety of weapons-carrying aircraft as well as to destruction of intercepted aircraft.

After the problem was referred to Langley, R. R. Gilruth, Assistant Director, with cognizance over dynamic loads research, called a meeting on September 21, 1953, to formulate an experimental program. In attendance were Philip Donely and Harold B. Pierce of the Dynamic Loads Division, Macon C. Ellis and Paul W. Huber of the Compressibility Research Division, and Shelton T. Peterson of IRD, in addition to Gilruth. They recommended an immediate trial test in the Langley Gust tunnel. In this tunnel, a scaled model of an airplane is launched horizontally by a catapult and passes over a rising jet of air simulating a gust. In the present proposal, the air jet was to be replaced by a small explosive charge. An accelerometer in the model was to provide the response to the disturbance.

Pierce, under Donely's supervision, was assigned the project, and a preliminary test was made on September 24, 1953. In the test, a 39-gram charge of pentolite was exploded beneath a 1/20-scale gliding model of the Douglas DC-4 airplane in flight. It was quickly found that this system would not be satisfactory because the facility was limited to use of such a small charge of explosive that the time the model was exposed to the blast was far too short for a meaningful test. The test also showed that a fuselage-mounted accelerometer was inadequate to measure the highly transient loads on the wing.

With the realization that an explosive of the proper size would wreck the facility, plans were made for an outdoor test at Wallops Island (ref. 88).[10] This was the beginning of a blast research program at Wallops that was to continue until the facility was wrecked by a storm in 1962. Approval of the program was given by the NACA on December 23, 1953, with issuance of RA C21L85. Pierce was to remain head of the project to the end.

The tests at Wallops began on December 9, 1953, with the explosion of two sticks of dynamite. A location about 6,000 feet north of the Service Building (Cafeteria) was selected for the test site. The explosive was later changed to Composition C-3, and several sizes of charges were detonated to test the instrumentation. A 15-pound charge was decided upon for the initial model tests.

The first model was launched over such a charge on January 20, 1954. It was launched by a catapult, as in the gust-tunnel tests, and contained a pressure gauge as well as an accelerometer. No data were recorded in this test, however, because the lamp in the recorder burned out. On the following day, a second test was made and good data were recorded. In this test, as well as in several subsequently made, the superiority of pressure measurements in the wing over acceleration measurements was clearly demonstrated.

The explosive charges were initially detonated while on a thick steel plate on the ground, with the earth serving as a reflection plane to double the effective size of the blast. After several explosions, it was found that although the charge produced a depression on the upper surface, the plate appeared to be relatively intact. Upon examination of the lower surface, however, it was found that the plate had practically disintegrated. The plate was then eliminated, and the 15-pound charges were detonated from atop a simple wood platform about 30 inches above the ground. Although such a structure was completely demolished at each use, it could be rebuilt easily. The distance above the ground was determined from blast theory, which indicated that a discrete distance, related to the size of the charge, would yield a nearly perfect hemispherical blast wave, at the test position of the model, approximately the same size as that from a free-air burst of twice the charge.

The initial tests with the preliminary model showed that outdoor testing near a blast was feasible, but indicated the need for several major changes. First, a much larger explosive charge was needed to provide a larger blast wave that would allow more time for a test. The 15-pound charge was replaced by

9. Later named the Defense Atomic Support Agency (DASA).
10. The author's interview with H. B. Pierce, Langley, July 22, 1969.

a 150-pound charge, which required the model to be located 200 feet away. Second, the catapult would not provide a satisfactory trajectory for the test model, so an internal rocket was substituted. Third, the need for the high-frequency measurement of a series of pressures along a wing chord was indicated. A number of high-frequency NACA inductance gauges were installed in the wing to measure differential pressure between the upper and lower surfaces. On March 1, 1954, IRD was assigned the responsibility for development of the instrumentation, including a 10-channel telemeter. The development of the system was carried out very successfully under the direction of G. B. Graves. Fourth, a more rugged model was required to withstand the blast loads as well as the launching loads. A model was constructed of fiberglass and plastic to meet this requirement. Finally, a parachute was provided for the redesigned model to allow recovery and reuse of the model and its instrumentation.

The first 150-pound charge of Composition C-3 was detonated on May 19, 1954, atop a wood platform 5.3 feet above the ground. The charge was moulded by hand at Wallops and was exploded by means of electric blasting caps. The handling of these explosives was a more hazardous task than the handling of the solid-rocket motors and their igniters used in rocket models at Wallops, but no accidents resulted.

The same system of operation was followed with the blast research as with rocket models. The model was designed, constructed, and instrumented at Langley. The Project Engineer from Langley traveled to Wallops to supervise the tests, while Wallops mechanics and propulsion and telemeter technicians performed the necessary tasks.

J. C. Palmer, head of the Wallops research crew, witnessed the first 150-pound explosion and described it as follows (ref. 89):

> The 150-pound charge made a large fire ball which resulted in a cloud mushrooming up and finally becoming a large smoke ring rising rapidly. The vegetation for a radius of 100 feet was badly battered and a large number of leaves from the bushes were sucked into the blast area. The wood tower on which the charge rested was reduced to hot ashes in a 16-foot-diameter depression.

This blast caused no comment from local residents but, by February 1955, after 12 charges had been exploded, complaints were received from a distance of 5 miles away that pictures were being knocked off walls. In one case, the picture had fallen into an empty baby crib.

Since consideration was being given to using even larger charges (up to 4,000 pounds), a telephone call was made to the Army's Ballistic Research Laboratory (BRL) at Aberdeen, Maryland, to learn how to avoid this focusing of the blast wave at far distances. BRL was successfully using a criterion developed by Beauregard Perkins of BRL, which stated that focusing would not occur if the sum of the speed of sound at a given altitude and the wind velocity at that altitude (both determined from radiosonde balloon soundings) decreased continuously as altitude increased to 10,000 feet (ref. 90). Wallops adopted this criterion, postponing tests if the conditions were not met, and no further complaints were received.

The 1/20-scale simplified model of the Douglas DC-4 airplane was rebuilt with more rugged construction and equipped with the 10-channel telemeter and a rocket launch motor. In preliminary trials of the new telemeter, it was found that the blast disrupted the radio link and, pending correction, a trailing wire was substituted for the radio link to the ground receiver. The trailing wire was so effective that development of the radio link was abandoned.

The 150-pound explosive charge on its wood platform is shown in figure 278. In the background may be seen the trailer used to house the programmer and data recorder. The first flight of the model over the 150-pound charge, made on November 4, 1954, is shown in figure 279. A maximum speed of 110 feet per second was reached by the model as it flew along an 11-degree zero-lift trajectory tangent to the blast wave. In this test, the trailing wire broke and the parachute cords failed, but on the following day a successful test was made, and from that time on, this sytem provided accurate measurements of pressures at frequencies up to 1,000 cycles per second. Use of the system continued through March 1958, for a total of 35 flights.

In each test, high-frequency blast gauges were mounted near the launcher and on 50-foot poles, for calibration of each explosion. These gauges consisted of an NACA high-frequency pressure gauge mounted in the center of an aluminum disk 18 inches in diameter. The path and velocity of the test

FIGURE 278. Technician E. R. Matthews connects firing leads to 150-pound hemispherical explosive charge in preparation for blast loads test, November 4, 1954.

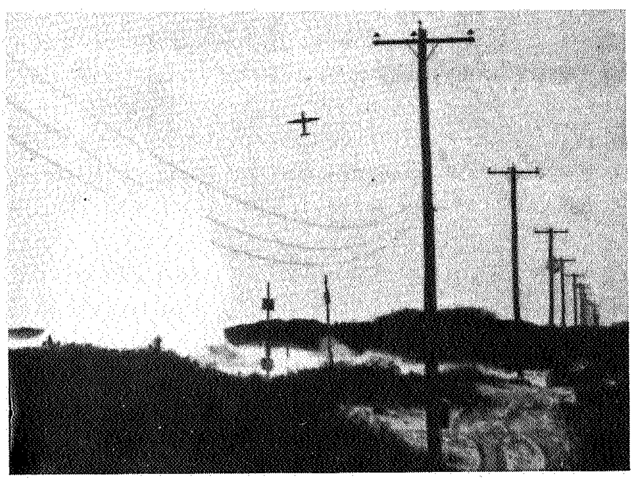


FIGURE 279. First flight test of 1/20-scale model of Douglas DC–4 airplane over a 150-pound explosive charge, November 4, 1954. Picture shows the model after detonation of the charge.

model were obtained from analysis of photographs obtained with two fixed 70mm Hulcher cameras. A typical model weighed about 31 pounds and was propelled to its flight speed of 110 feet per second by a shortened 2.25-inch solid-rocket motor. Later, this motor was replaced by specially cast motors produced in the PARD rocket test area at Langley. A programmer was used to initiate all of the events except the explosion itself, which was actuated through a delay timer. As it left the ground, the model activated the delay timer through a break-wire system.

In the initial tests, the differential pressure between the upper and lower surface of the wing was measured at 10 points along one wing chord. Prior to the test, the pressures along this chord, as well as the total lift, drag, and pitching moment, were measured in the Langley 300-mile-per-hour 7-foot by 10-foot tunnel over an angle-of-attack range of 0 degrees to 45 degrees. When the blast wave struck the model, there was an immediate effect from the overpressure and, in addition, a large change in angle of attack of the model. Part of the uncertainty regarding blast effects had to do with whether large instantaneous changes in angle of attack would produce the normal stall or would result in much higher maximum lift coefficients. The present tests shed some light on this question.

The 150-pound charge created a maximum overpressure of 1.4 pounds per square inch at the model location, and a gust velocity of 75 feet per second. Combining this gust velocity with the 110-feet-per-second forward velocity of the model produced an angle-of-attack change of about 35 degrees. Both the overpressure and angle of attack dropped to zero in about 25 milliseconds. In addition to large direct pressures on the lower surface of the wing, a large traveling pressure peak was found, which was believed to be associated with a vortex that formed at the leading edge when the pressure wave passed it and then moved chordwise along the upper surface of the wing. The total-pressure coefficients on the wing in the presence of this vortex were found to be much greater than those either measured in the wind tunnel or calculated from two-dimensional flow considerations. This finding was believed to be significant for a case in whch the blast velocity was great enough to produce an angle of attack above the stall (ref. 91).

In the next series of tests, pressures were measured at one chord station on the horizontal tail, and again the blast velocity was sufficient to increase the angle of attack byond the stall. The same type of traveling vortex phenomenon was experienced on the tail as had been found on the wing, with resulting high loads. The pressure-time history for the wing and tail correlated quite well when time was expressed nondimensionally in terms of chord lengths traveled. Some effect of downwash from the wing in reducing the load on the tail after about 13 milliseconds was noted (ref. 92).

To determine the response of the model to a blast that did not raise the angle of attack beyond the stall, a flight was made with a reduced charge. In this test, the traveling wave was not present, and the measured pressures were found to be close to those calculated from unsteady lift considerations. This result, along with the earlier findings, was presented at a high-speed aircraft conference at Langley in November 1955 (ref. 93).

The finding of the traveling pressure wave at high angles of attack was of sufficient importance that a separate investigation of this phenomenon was conducted on a blast-wave table in the Gas Dynamics Laboratory at Langley. The table had a flat surface 12 feet by 15 feet, and was 2 inches thick. A wing, one-twentieth the size of the flight model, was placed in an airstream issuing vertically from a slot in the table to simulate forward motion. Small spherical charges of pentolite (15 to 50 grams) were detonated, and the flow pattern around the wing was recorded by schlieren photography. The blast wave was sufficient to produce a maximum angle of attack of 30 degrees on the wing, and some remarkable pictures that were taken verified the existence of a traveling vortex that correlated well with the traveling pressure peaks of the flight tests.

The research with the blast-wave table was conducted by Donald R. McFarland, and the results were presented as part of a paper on blast loads at a conference on Aircraft Loads, Structures, and Flutter held at Langley in March 1957 (ref. 94).

In the initial test with a model flying over an explosive blast, temporary wiring was used and power was provided by a portable gasoline-driven generator. To simplify operations and provide a power source of constant voltage and frequency, a request to NACA Headquarters was made on September 24, 1954, for approval of a project to connect the blast facility with the existing 12,500-volt powerline on the island by means of a suitable transformer and other equipment. The proposed work was approved on October 5, 1954, as Project 1580 and was completed on February 29, 1956, by outside contract, with the expenditure of general operating funds amounting to $2,095.

By 1956, the need was recognized for a shelter at the test area to replace the trailer temporarily being used for the protection of instrumentation and equipment. Approval was obtained from NACA Headquarters on February 20, 1956, for Project 1748, construction of a minimum shelter. It was completed on March 31, 1957, by contract, for a cost of $7,498 supplied from general operating funds. The shelter is shown in figure 280. It was 20 feet by 40 feet and contained an instrument room and a combined shop and storage room. It had a flat roof, and was constructed on a concrete slab. The outer wall was simple sheathing covered with waterproof felt. While the shelter was under construction, authorization was obtained, as Project 1782, to install underground firing and control cables connecting the shelter with the test area, cameras, explosive charge, and instrumentation. This work was performed by contract, with the NACA furnishing the material. The project was completed January 31, 1958, at a total cost of $13,655 provided from general operating funds.

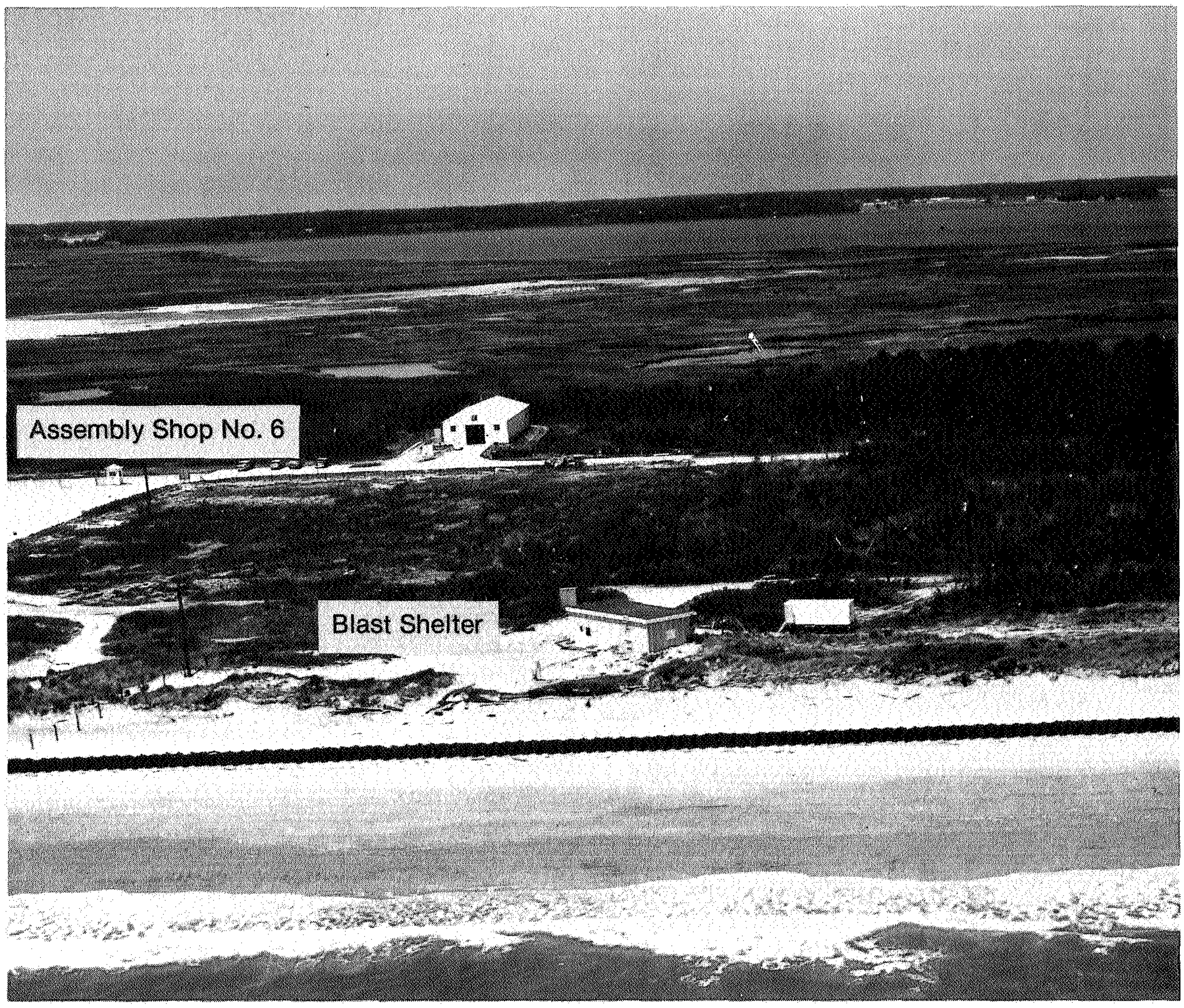


FIGURE 280. Aerial view of north area of Wallops Island showing blast shelter and Assembly Shop No. 6.

The flight tests at low speed were continued through 1956 and 1957 with the model of the DC-4 as well as with a new model having a 45-degree sweepback. By this time, however, interest had developed in research at higher speeds, and the low-speed tests were terminated in March 1958.

The Armed Forces, particularly members of AFSWP and BRL, had kept in touch with the blast research project at Wallops. While they were pleased with the results obtained at low speed, they encouraged Langley to extend this research to high-speed configurations flown at near sonic speeds. A model was constructed at Langley for such tests, to be powered with a T55 rocket motor to Mach 1.0. Preliminary calculations indicated that a 4,000-pound charge of explosive would be required to obtain the desired blast wave.

In February 1955, Pierce and J. G. Thibodaux visited the Naval Weapons Station, Yorktown, Virginia, and discussed such a charge with J. T. Manley, Chief of Research at that station. Manley recommended casting a hemispherical charge from Composition B and agreed to do this if Langley provided the mold. This was done, and on September 11, 1956, a 4,000-pound explosive charge arrived at Wallops. It was never to be used in a model test, however, because by that time a new technique had been developed. After the 4,000-pound charge had been kept in storage at Wallops for other possible use, it was finally disposed of by detonation at the blast site on May 8, 1959. It was exploded at 9:19 a.m. under ideal meteorological conditions for minimum propagation. No complaints were received from private citizens, and only minor damage was experienced at Wallops. Pierce paid Wallops a fine compliment when, in his report on the event, he said:

The author is continually impressed by the efficient cooperation of the Wallops personnel in organizing and completing firing operations. This cooperation was again demonstrated in the disposal of the 4,000-pound charge (ref. 95).

Extension of the initial rocket-model technique to sonic speeds, accompanied by the use of 4,000-pound explosive charges, appeared to be expensive, particularly when a parachute-recovery method at such speeds had not been developed. The only safe direction for a high-speed launch at Wallops was out to sea, and this situation added to the recovery problem. The alternative scheme adopted allowed employment of a fixed, reusable model.

The success of McFarland with the blast-wave table in duplicating flow conditions of flight with a fixed model and a moving airstream led the blast research team to consider such a scheme for the high-speed problem at Wallops. In May 1957, a proposal was presented to NACA Headquarters for approval of a shock tube 10 feet in diameter and 80 feet long, which could provide a high-speed jet of air for aproximately one-tenth second, within which a test model could be mounted and then exposed to the desired blast wave. The justification given for the proposal was that it would be far less costly than using rocket models.

The proposal was approved by NACA Headquarters on May 24, 1957. The project, identified as Ground Blast Apparatus, Project 1915, was completed at a cost of $66,918. Funding was provided from general operating expenses. All of the apparatus except the blowout diaphragm was constructed by Thomas Crooks Company under contract No. NA1-3233, and preliminary testing began in early 1958. The first test with a model in the airstream was made on August 19, 1960. Calibration of the flow in the jet was made with the model replaced by a survey rake containing total and static pressure probes.

The general arrangement of the Ground Blast Apparatus is shown in figure 281. It consisted of the 10-foot by 80-foot shock tube, an outside explosive charge, blast gauges, and instrumented test model, and (not shown) an instrumentation and control shelter. The 10-foot diameter of this shock tube made it the largest shock tube in existence at the time. Facilities were provided to compress and heat the air within the tube so that, when released, the air upon expansion to atmospheric pressure would also be at atmospheric temperature.

The most difficult part of the shock tube to develop was the blowout diaphragm, which acted as a very fast opening valve. In operation, a blowout diaphragm at the end of the tube was burst to allow the compressed air to exhaust rapidly over the model. At Mach 1.0, the flow time was approximately 0.10 second. It was necessary, therefore, that the diaphragm open quickly, get out of the way of the airflow, and not send any broken parts downstream to damage the model.

After numerous trials, including some with a 2-foot diameter tube, a system that met the requirements was developed. It consisted of a 1/16-inch steel sheet 10 feet in diameter, clamped firmly

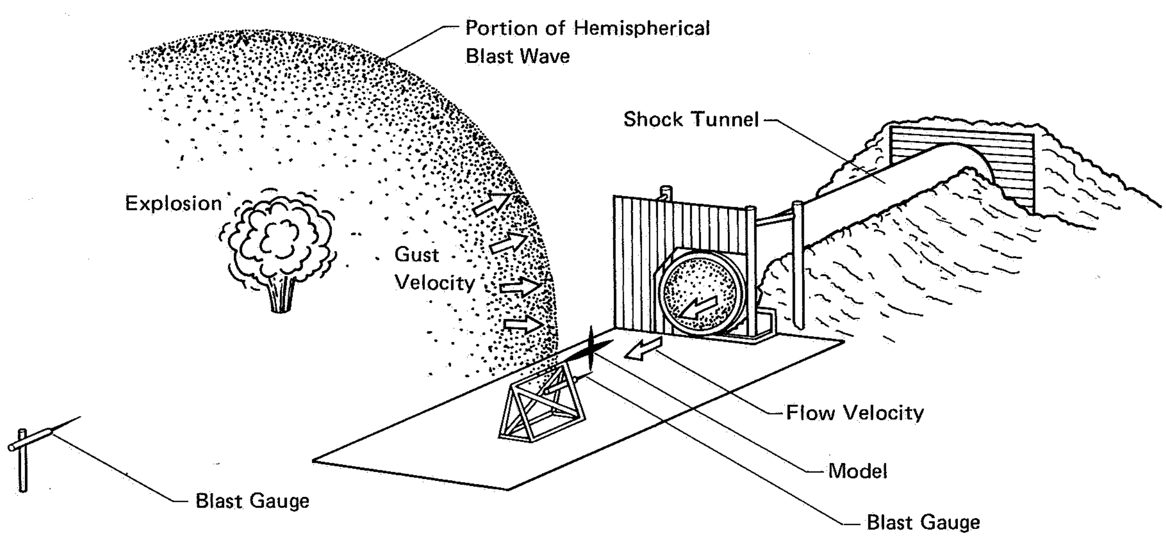


FIGURE 281. Sketch of Ground Blast Apparatus at Wallops Island.

at its edge and split open into eight pie-shaped wedges by means of eight radial lines of primacord. Pressures of up to 38 pounds per square inch were used in the tube, which was enough to cause the diaphragm to bulge out about 18 inches in the center. An indication of the loads on the diaphragm is given by the fact that 100 bolts almost 2 inches in diameter were required to clamp its edges. With the primacord located on the inner face, and detonation initiated at the center of the diaphragm, opening time was between 5 and 10 milliseconds.

A description of the shock tube was given by Pierce at the Third Shock Tube Symposium held at Ft. Monroe, Virginia, March 10–12, 1959 (ref. 96). In an appendix to Pierce's paper, R. W. Morton described the special high-frequency pressure gauges and associated instrumentation used in this facility. In Part II of the paper, McFarland described his research on the vortex patterns, conducted with use of the wave table. By this time, McFarland had extended his research to a Mach number of 0.7 by using a 1/20-scale model of the Wallops shock tube mounted on the table. The pressure measuring system described by Morton, which had a flat frequency response to 22,000 cycles per second, was described in more detail in a later report (ref. 97).

In the operation of the tunnel, a programmer was used as before to start cameras and recorders and to arm firing circuits. The programmer also started a millisecond time-delay system used to coordinate the blast-wave arrival with the operation of the shock tube. It was found that the primacord explosion and diaphragm rupture required about 20 milliseconds. An additional 20 milliseconds were required to develop stable flow, and steady flow conditions continued for 70 milliseconds more, at the end of which time a shock wave from the primacord explosion had traveled to the closed end of tube and then had been reflected back to the model area. This ended the test. The explosive charge was normally ignited immediately after the primacord was ignited, and the blast wave passed through the test area sometime during the 70-millisecond period of steady flow, depending on the location of the explosive charge. Typically, a charge of 650 pounds located 125 feet away would pass through the area during the last 10 milliseconds of the 70-millisecond period. In some tests, when the explosive charge was located at a greater distance, detonation preceded primacord ignition by a few milliseconds.

Although the tunnel was designed for tests up to sonic speeds, most runs were made at a Mach number of 0.7, which required a storage pressure of about 22 pounds per square inch.

The explosive charge was located to one side of the model and was usually a 650-pound hemispherical charge cast from HBX-1 aluminized explosive mixture. Such charges were mounted atop a 12-foot wood tower and were located at varying distances from the model, depending upon the strength of blast wave desired. These large charges were cast by the Naval Weapons Station in molds supplied by Langley. As shown in figure 281, the blast pressure from the explosion was measured in two locations, one just beneath the model and the other the same distance from the blast but outside the jet from the shock tube. The blast gauges consisted of the same type of inductance pressure gauge used in the model, but were mounted in a brass disc 2.75 inches in diameter and oriented edge-on with respect to the direction of travel of the blast wave. In the calibration tests, it was found that the blast gauge inside the airstream near the model gave readings of overpressure about 30 percent lower than the other gauge located in free air. This reduction was attributed to reflections from the mixing zone between the airstream and the undisturbed air. The gauge inside the airstream was used, therefore, in analysis of test data.

When the blast wave reached the shock tube, the first effect was to move the airstream sideways, which was how the angle-of-attack change was created. To ensure that the model remained within the airstream, it was positioned laterally about 18 inches from the centerline of the tunnel in the direction of blast wave passage. To prevent a reflected shock from the side of the tube from reaching the test area, a baffle or wall was placed around the exit of the tube, extending about 5 feet above the tube and about 5 feet from the side first struck by the blast wave, as may be seen in figure 281. There remained a weaker reflected shock from the open end of the tube. To minimize the effect of this wave, the model was positioned downstream about 15 feet from the exit. At this distance, there was considerable mixing between the air from the jet and the outside air, but there still remained an 8-foot diameter test area of uniform flow. The test model, as shown in figure 281, was normally mounted with its wings in a vertical plane to simulate the condition of an airplane in level flight being struck by a blast from below.

In figure 282 a typical test is shown by a sequence of photographs taken by a Hulcher camera. Note the model and the explosive charge in the first picture, the primacord explosion opening the

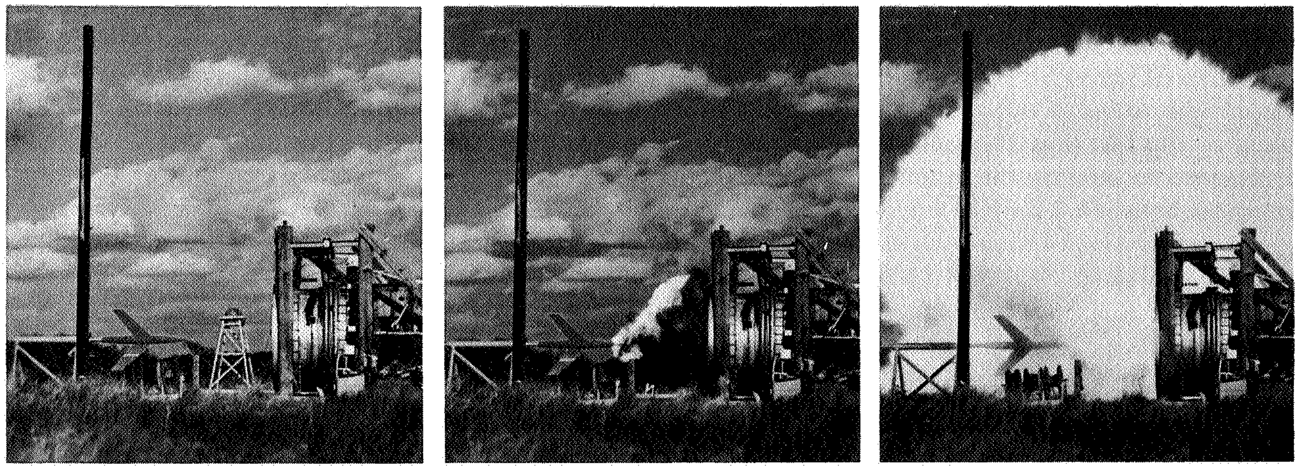


FIGURE 282. Sequenced pictures of the test of an airplane model in the Ground Blast Apparatus, November 30, 1960.

diaphragm in the second view, and the fireball from the explosive charge in the last picture. In this test, the third with the facility, made on November 30, 1960, the explosive charge was located 125 feet from the test model.

Between the initial test in August 1960 and the termination of the program in February 1962, a total of 14 general research tests were made with a 650-pound charge of HBX-1 located at distances of from 90 to 180 feet from the test model. The last series of tests was made with the model rotated 45 degrees to either side of normal, simulating either a banked flight condition or a condition in which the explosion was below and to one side of the airplane.

The same airplane model was used in all tests. It was a transonic airplane model with wing C, which had been tested earlier in the 16-foot transonic tunnel at Langley. It was mounted on the wind-tunnel sting support from the rear of the fuselage and was instrumented with flush-mounted diaphragm pressure transducers on both the upper and lower surfaces of the wing along one chord plane. Twenty-six transducers were installed in the wing, of which 12 were selected for a given test. The wing and fuselage both were made of steel.

In the first test with the 650-pound charge located 125 feet from the model, the induced gust velocity was 271 feet per second, and the blast overpressure was 5.78 pounds per square inch. The induced angle of attack was 20 degrees (ref. 98). This and subsequent tests confirmed the earlier finding of a strong vortex that formed in a diffraction of the blast wave around the leading edge and traveled back along the upper surface of the wing. The associated negative pressure on the upper surface, plus the direct blast pressure on the lower surface, gave total load coefficients of approximately twice those found under steady conditions in a wind tunnel at the same angle of attack.

The loads from an even stronger blast wave were determined from tests with the 650-pound charge located 90 feet from the model. In this case, the blast overpressure was 9.1 pounds per square inch, and the induced gust velocity was about 400 feet per second, which induced an angle-of-attack change of 28 degrees (ref. 99). The traveling vortex on the upper surface was again shown, and the total loads were now about three times the wind-tunnel values for this large angle of attack. The normal-force coefficients for different angles are shown in figure 283 for the two conditions just described. The static values from the wind-tunnel test are also shown for comparison. The coefficients for the blast conditions are based on instantaneous resultant velocities and static pressures from the shock tube and the blast pressure wave.

In addition to the general research tests just described, a series of 13 tests was made in this facility between June 8 and August 24, 1961, as part of a joint Army, Navy, Air Force project, termed JANAF. The model tested was one that had been tested earlier on the high-speed sled at Edwards Air Force Base, California. It was a halfspan wing of aspect ratio 6, taper ratio 0.5, and 35-degree sweepback. The planform was generally similar to that of the Boeing B-47 or B-52 airplane. The wing was of rigid construction and was mounted for the Wallops tests on the same structure that had been used in the sled tests. In figure 284, it is shown mounted in front of the shock tube at Wallops.

Pierce had kept abreast of the sled program initiated by AFSWP from September 1954, when R. C. DeHart of AFSWP visited Langley and solicited comments on a BRL proposal to use the Inyokern sled

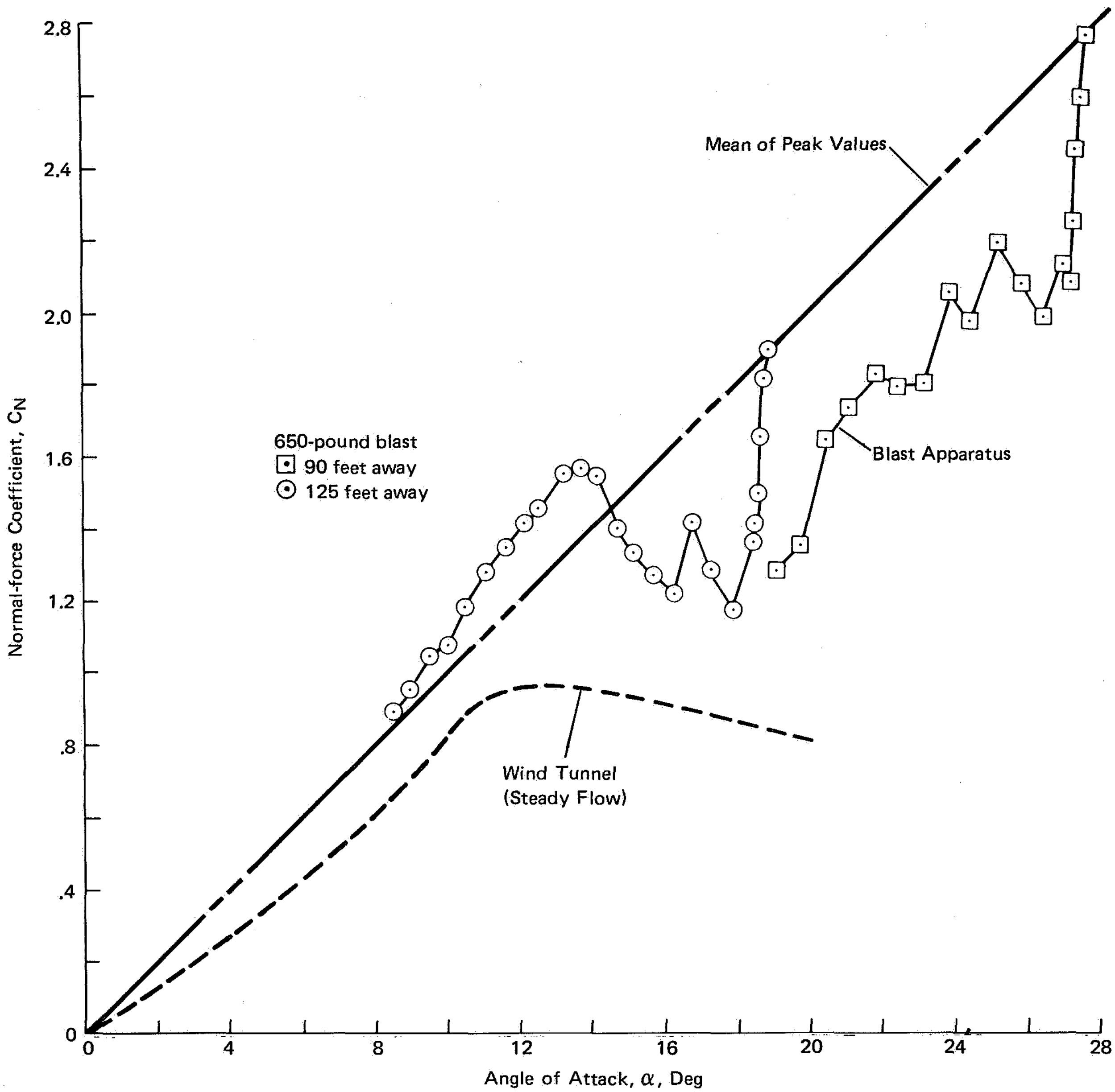


FIGURE 283. Graph showing comparison between normal-force coefficients obtained from tests in the Ground Blast Apparatus and those obtained in a wind tunnel. The curves are seen as a function of the angle of attack.

to obtain blast loads data. Other sled programs were planned for Eglin Air Force Base, Florida; and in December 1960, Pierce visited Edwards to witness tests of a model on the high-speed sled there. This model was one-half of the horizontal tail of a Republic F-84F airplane and was rather flexible. The model used pressure gauges provided by NASA, in addition to strain gauges and accelerometers provided by the Air Force.

The sled tests demonstrated that a tail surface could be subjected to an explosive blast while traveling at high speed, but they failed to provide aerodynamic loads from the blast because the recording equipment was not adequate for the high-frequency pressures. The rough vibration environment of the sled did not allow the use of the NASA recording equipment, and the one substituted was not compatible with the NASA pressure gauge. A follow-on program with wings of different stiffnesses was initiated, with WADD as the prime investigator. Again, the pressure measurements were unsatisfactory.

Following the failure of the Edwards sled tests to provide the desired pressure measurements, DASA, on February 15, 1961, asked NASA to allow tests of one of the wings of the JANAF program to

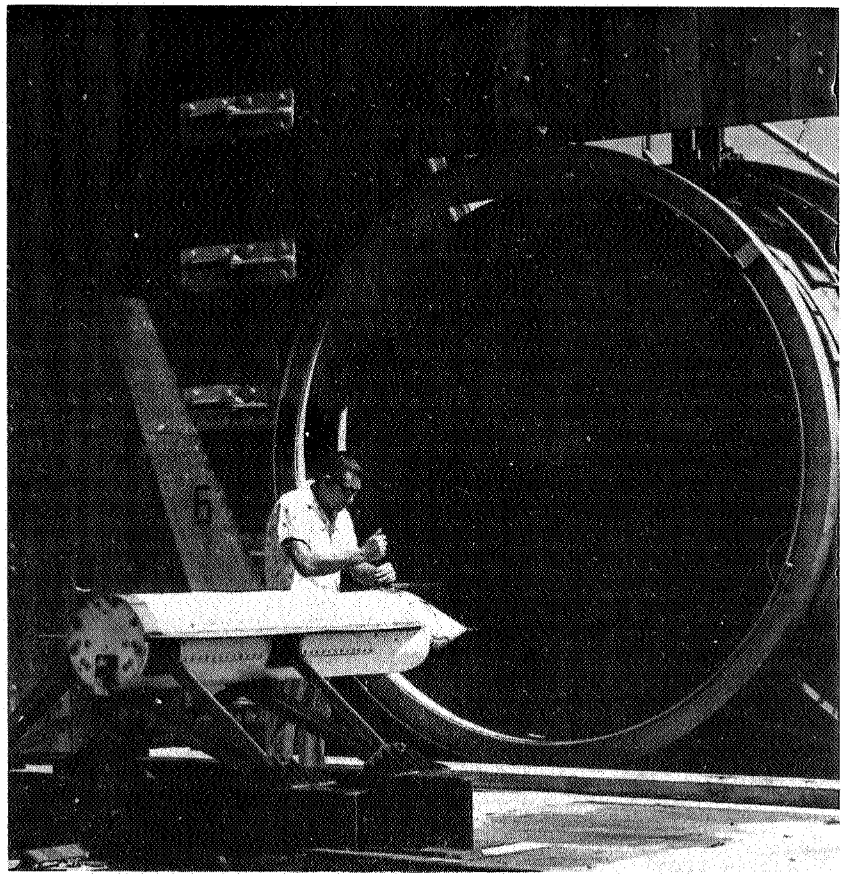


FIGURE 284. Technician dismantles instrument on JANAF sweptback wing model in Ground Blast Apparatus following blast loads test. Ruptured diaphragm is visible in the exit of the shock tube.

be made in the Wallops shock tube.[11] This DASA request was followed by a WADD request on April 5, 1961, for a series of six tests of the rigid wing of the WADD series. WADD was to furnish the instrumented specimen airfoil, recording equipment, and explosives. In addition, WADD was to furnish the required engineers and mechanics.

In the Wallops tests, model 6L of the sled program was used. Personnel from the Edwards sled team came to Wallops and handled the installation. BRL furnished the explosives and some instrumentation. The contractor for WADD in their sled program, Aircraft Armaments, Inc., Cockeysville, Maryland, was responsible for the instrumentation and data recording. Wallops personnel operated the shock tube and provided other services as needed.

Thirteen tests were made in the JANAF series between June 8, 1961, and August 24, 1961. These tests used either 650-pound charges of HBX-1 at distances of 98 to 258 feet, or 18-pound charges of pentolite at distances of 27 to 70 feet. Angle-of-attack changes ranging from 8 degrees to 30 degrees were induced. Six of the tests provided good data (ref. 100). Following this experience, the sled team at Edwards were able to improve their pressure-measuring instrumentation to equal that of the Wallops blast facility.

The results from these tests were analyzed and compared with theory by personnel from M.I.T. (ref. 101). The effectiveness of the NACA-developed pressure instrumentation was recognized as follows:

> Regarding the airload measurements on the wings, the quality and response time of the measurements represented a definite advance in the state of the art for measuring blast loads on structures in the field.

11. Letter from DASA to NASA, Feb. 15, 1961, regarding tests desired in NASA Blowdown Wind Tunnel, Wallops Island Facility.

The measured pressure coefficients, expressed in terms of a dynamic pressure that included the effect of the blast wave, were found to be in reasonable agreement with a semi-empirical quasi-unsteady method for predicting blast loads at subsonic speeds, and such a method was recommended for use.

In a later development of analysis procedures for predicting shock loads on a helicopter blade, the general research data obtained by Pierce and Manning were to be given greater recognition than the JANAF results (ref. 102). In fact, the recommended procedure involved direct use of the load and moment data obtained in the general research tests, particularly the data shown in figure 283.

1. Purser, Paul E.; and Heldenfels, Richard R.: *Presentation on Facility Problems in High-Temperature Structures Research.* Report presented to NACA Subcommittee on Aircraft Structures, Sept. 11, 1955. Reissued as NACA RM L56O24.
2. Thompson, F. L., Memorandum for All Concerned, Aug. 23, 1956, regarding change in organization of Structures Research Division.
3. Hill, Paul R.; Adamson, David; Foland, Douglas H.; and Bressette, Walter E.: "High-Temperature Oxidation and Ignition of Metals." Paper presented at NACA Conference on Aerodynamics of High-Speed Aircraft, Langley Field, Nov. 1–3, 1955. Reissued as NACA RM L55L23b.
4. *Jane's All the World's Aircraft, 1958–1959,* p. 337.
5. Hastings, Earl C., Jr.; and Mitcham, Grady L.: *Flight Determination of the Longitudinal Stability and Control Characteristics of a 0.125-Scale Rocket-Boosted Model of the McDonnell F–101A Airplane at Mach Numbers From 0.82 to 1.84.* NACA RM SL55F24.
6. Hollinger, James A.; and Coltrane, Lucille C.: *Lateral-Stability Flight Test of a 0.125-Scale Rocket-Propelled Model of the McDonnel F–101A Airplane at Mach Numbers From 1.0 to 1.9.* NACA RM SL56D20.
7. Kennedy, Thomas L.: *Flight Investigation to Determine the Effect of Jet Exhaust on Drag, Trim Characteristics, and Afterbody Pressures of a 0.125-Scale Rocket Model of the McDonnell F–101A Airplane.* NACA RM SL56B03.
8. English, Roland D.: *Some Effects of Aeroelasticity on the Rolling Effectiveness of a 10-Percent-Scale Model of the McDonnell F–101A Airplane at Mach Numbers From 0.5 to 1.2.* NACA RM SL55I22a.
9. Mitcham, Grady L.: *A Summary of the Longitudinal and Lateral Stability and Control Characteristics Obtained From Rocket-Model Tests of a Swept-Wing Fighter-Type Airplane at Mach Numbers From 0.5 to 1.9.* NACA RM L56K19.
10. Stevens, Joseph E.: *Low-Lift Drag of the Grumman F9F–9 Airplane as Obtained By a 1/7.5-Scale Rocket-Boosted Model and By Three 1/45.85-Scale Equivalent-Body Models Between Mach Numbers of 0.8 and 1.3.* NACA RM SL55D15.
11. *Jane's All the World's Aircraft, 1958–1959,* p. 307.
12. Chapman, Rowe, Jr.: *Aerodynamic Characteristics at Mach Numbers From 0.7 to 1.75 of a Four-Engine Swept-Wing Airplane Configuration as Obtained From a Rocket-Propelled Model Test.* NACA RM L55F23.
13. Niewald, Roy J., Memorandum for Assistant Director, Mar. 2, 1954, regarding visit of BuAer and Martin representatives to NACA Headquarters to discuss Bullpup missile.
14. Krieger, R. L., Memorandum for Associate Director, Apr. 7, 1954, regarding visit of Emil Nyitray and V. J. Crouse, Jr., of Martin Company, to discuss tests of Bullpup missile at Wallops.
15. Brown, C. A., Jr., Memorandum for Associate Director, Feb. 1, 1955, regarding visit of Martin representatives to Wallops to discuss Bullpup test details.
16. Krieger, R. L., Memorandum for Associate Director, Sept. 9, 1955, regarding visit of NOL representatives to Wallops.
17. Lanford, Wade E., *Flight Tests of Two Smoke-Producing Devices Having Deacon Rocket Boosters.* NACA RM SL58E23.
18. O'Sullivan, W. J., Jr., Memorandum for Associate Director, May 4, 1953, regarding discussions at meeting of UARRP on April 29, 1953.
19. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Oct. 29, 1953, regarding discussions at meeting of UARRP on Oct. 7, 1953.
20. Rumsay, Charles B., Memorandum for Associate Director, July 15, 1954, regarding visit of L. M. Jones and W. H. Hansen on April 7, 1954, to discuss sounding rockets.
21. Heitkotter, Robert H.: *Flight Investigation of the Performance of a Two-Stage Solid-Propellant Nike-Deacon* (DAN) Meteorological Sounding Rocket. NACA RM SL55L27. Reissued as NACA TN 3739, July 1956.
22. Heitkotter, Robert H., Memorandum for Associate Director, Apr. 18, 1955, regarding flight test of Nike-Deacon vehicle for AFCRC.
23. Jones, L. M.; and Hansen, W. H.: *The Nike-Deacon Sounding Rocket.* Engineering Research Institute, University of Michigan Report, May 25, 1955.
24. O'Sullivan, W. J., Jr., Memorandum for Associate Director, June 15, 1955, reporting on UARRP meeting of June 2, 1955.
25. Jones, L. M.; Hansen, W. H.; and Fischbach, F. F.: Chapter 11, "Nike-Cajun and Nike-Deacon." *Sounding Rockets,* Homer E. Newell, Jr., ed., McGraw-Hill, 1959, p. 190.
26. Kennedy, Thomas L.; and Trout, Otto F., Jr.: *Flight Investigation of a Roll-Stabilized Ramjet Test Vehicle Over a Mach Number Range of 2.3 to 2.7.* NACA RM L55H11.
27. Branstetter, J. Robert; Gibbs, James B.; and Kaufman, Warner B.: *Magnesium-Slurry Combustion Performance in a 6.5-Inch-Diameter Ramjet Engine Mounted in Connected-Pipe Facility.* NACA RM E53E27.

28. Bartlett, Walter A.; and Hagginbothom, William K., Jr.: *Flight and Preflight Tests of a Ram Jet Burning Magnesium Slurry Fuel and Utilizing a Solid-Propellant Gas Generator For Fuel Expulsion.* NACA RM L55A24.
29. Trout, Otto F., Jr.; and Kennedy, Thomas L.: *Preflight and Flight-Test Investigation of a 50-Percent-Magnesium 50-Percent JP−4 Slurry Fuel in a Twin-Engine Ramjet Vehicle.* NACA RM L56C06.
30. Bartlett, Walter A., Jr.; and Merlet, Charles F.: *Flight Investigation of a Ramjet Burning Magnesium Slurry Fuel and Having a Conical Shock Inlet Designed For a Mach Number of 4.1.* NACA RM L56I24a.
31. Kouyoumjian, Walter L.; and Tolefson, Donald C.: *Preflight and Flight Investigation on a Ducted Solid-Propellant Rocket Configuration at Mach Numbers From 1.56 to 2.14.* NASA TM X−29, June 1959.
32. de Moraes, Carlos A.; Hagginbothom, William K., Jr.; and Falanga, Ralph A.: *Design and Evaluation of a Turbojet Exhaust Simulator, Utilizing a Solid-Propellant Rocket Motor For Use in Free-Flight Aerodynamic Research Models.* NACA RM L54I15.
33. Leiss, Abraham: *Design and Evaluation of a Turbojet-Exhaust Simulator With a Solid-Propellant Rocket Motor For Free-Flight Research.* NACA RM L57E10a.
34. Falanga, Ralph A.: *A Free-Flight Investigation of the Effects of Simulated Sonic Turbojet Exhaust on the Drag of a Boattail Body With Various Jet Sizes From Mach Number 0.87 to 1.50.* NACA RM L55F09a.
35. Falanga, Ralph A.: *A Free-Flight Investigation of the Effects of a Sonic Jet on the Total-Drag and Base-Pressure Coefficients of a Boattail Body of Revolution From Mach Number 0.83 to 1.7.* NACA RM L55L21.
36. Falanga, Ralph A.; and Leiss, Abraham: *Free-Flight Investigation at Transonic Speeds of Drag Coefficients of a Boattail Body of Revolution With a Simulated Turbojet Exhaust Issuing at the Base From Conical Short-Length Ejectors.* NACA RM L56H23.
37. Leiss, Abraham: *Free-Flight Investigation of Effects of Simulated Sonic Turbojet Exhaust on the Drag of Twin-Jet Boattail Bodies at Transonic Speeds.* NACA RM L56D30.
38. Bressette, Walter E.: *Investigation of the Jet Effects on a Flat Surface Downstream of the Exit of a Simulated Turbojet Nacelle at a Free-Stream Mach Number of 2.02.* NACA RM L54E05a.
39. Bressette, Walter E.; and Leiss, Abraham: *Investigation of Jet Effects on a Flat Surface Downstream of the Exit of a Simulated Turbojet Nacelle at a Free-Stream Mach Number of 1.39.* NACA RM L55L13.
40. Leiss, Abraham; and Bressette, Walter E.: *Pressure Distribution Induced on a Flat Plate By a Supersonic and Sonic Jet Exhaust at a Free-Stream Mach Number of 1.80.* NACA RM L56I06.
41. Bressette, Walter E.; and Faget, Maxime A.: "An Investigation of Jet Effects on Adjacent Surfaces." Paper presented at NACA Conference on Aircraft Loads, Flutter, and Structures, Langley Field, Mar. 2−4, 1955. Reissued as NACA RM L55E06.
42. Englert, Gerald W.; Wasserbaur, Joseph F.; and Whelan, Paul: *Interaction of a Jet and Flat Plates Located in an Airstream.* NACA RM E55G19.
43. Bressette, Walter E.: *Some Experiments Relating to the Problem of Simulation of Hot Jet Engines in Studies of Jet Effects on Adjacent Surfaces at a Free-Stream Mach Number of 1.80.* NACA RM L56E07.
44. Bressette, Walter E.; and Leiss, Abraham: "Effects on Adjacent Surfaces From the Firing of Rocket Jets." Paper presented at NACA Conference on Aircraft Loads, Structures, and Flutter, Langley Field, Mar. 5−7, 1957. Reissued as NACA RM L57D19a.
45. Leiss, Abraham: *Pressure Distribution Induced on a Flat Plate at a Free-Stream Mach Number of 1.39 by Rockets Exhausting Upstream and Downstream.* NASA TM X−129, Dec. 1959. Reissued as NASA TN D−1507, Nov. 1962.
46. Falanga, Ralph A.; and Janos, Joseph J.: *Pressure Loads Produced on a Flat-Plate Wing by Rocket Jets Exhausting in a Spanwise Direction Below the Wing and Perpendicular to a Free-Stream Flow of Mach Number 2.0.* NACA RM L58D09. Reissued as NASA TN D−893, May 1961.
47. Janos, Joseph J.: *Loads Induced on a Flat-Plate Wing by an Air Jet Exhausting Perpendicularly Through the Wing and Normal to a Free-Stream Flow of Mach Number 2.0.* NASA TN D−649, Mar. 1961.
48. Judd, Joseph H.; and Falanga, Ralph A.: *Flight Investigation of the Effect of a Propulsive Jet Positioned According to the Transonic Area Rule on the Drag Coefficients of a Single-Engine Delta-Wing Configuration at Mach Numbers From 0.83 to 1.36.* NACA RM L56A16.
49. Blanchard, Willard S., Jr.: *Free-Flight Investigation of Jet Effects on the Low-Lift Drag and Longitudinal Trim of a Supersonic Interceptor-Type Airplane Configuration With an Overhanging Tail Boom at Mach Numbers from 1.09 to 1.34.* NACA RM L57G11.
50. Peck, Robert F.: *Jet Effects on Longitudinal Trim of an Airplane Configuration Measured at Mach Numbers Between 1.2 and 1.8.* NACA RM L54J29a. Reissued as NASA TN D−177, Dec. 1959.
51. Jackson, Bruce G.; and Crabill, Norman L.: *Free-Flight Investigation of Jet Effects at Low Supersonic Mach Numbers on a Fighter-Type Configuration Employing a Tail-Boom Assembly, Longitudinal Stability and Trim.* NACA RM L57F19.
52. Jackson, Bruce G.: *Free-Flight Transonic Model Investigation of Jet Effects on a Fighter-Type Configuration Employing a Tail Boom and Three Horizontal-Tail Positions.* NACA RM L57J31.
53. Judd, Joseph H.; and Falanga, Ralph A.: *Free-Flight Investigation at Transonic Speeds of the Power-On Characteristics Including Some Effects of Sonic Propulsive Jets of a Four-Engine Delta-Wing Configuration.* NACA RM L57E31.
54. Falanga, Ralph A.; and Judd, Joseph H.: *Low-Lift Flight Tests of Four-Engine Delta-Wing Configurations to Obtain Wing Pressures and Aerodynamic Coefficients Including Some Jet Effects From Mach Number 0.5 to 1.5.* NASA TM X−282, May 1960.
55. Falanga, Ralph A.; and Judd, Joseph H.: *Flight Investigation of the Effect of Underwing Propulsive Jets on the Lift, Drag, and Longitudinal Stability of a Delta-Wing Configuration at Mach Numbers from 1.23 to 1.62.* NACA RM L55I13.
56. Henning, Allen B.: *Results of a Rocket-Model Investigation of Control-Surface Buzz and Flutter on a 4-Percent-Thick Unswept Wing and on 6-, 9-, and 12-Percent-Thick Swept Wings at Transonic Speeds.* NACA RM L53I29.

57. Martz, C. William: *Experimental Hinge Moments on Freely Oscillating Flap-Type Control Surfaces.* NACA RM L56G20.
58. Martin, Dennis J.; Thompson, Robert F.; and Martz, C. William: "Exploratory Investigation of the Moments on Oscillating Control Surfaces at Transonic Speeds." Paper presented at NACA Conference on Aircraft Loads, Flutter, and Structures, Mar. 2–4, 1955, Langley Field. Reissued as NACA RM L55E31b.
59. Martz, C. William: *Experimental Hinge Moments on Two Freely Oscillating Trailing-Edge Controls Hinged at 55 Percent Control Chord.* NACA RM L57J25.
60. Gillespie, Warren, Jr.: *Supersonic Investigation of the Lift, Drag, Static Stability, and Hinge-Moment Characteristics of a Rocket-Powered Model of a Ballistic-Missile Configuration.* NACA RM L56G24.
61. Gillespie, Warren, Jr.: *Free-Flight Determination of Force and Stability Characteristics of an Inclined Body of Fineness Ratio 16.9 at a Mach Number of 1.74.* NACA RM L54G28a.
62. Gillespie, Warren, Jr.: *Lift, Drag, and Longitudinal Stability at Mach Numbers From 0.8 to 2.1 of a Rocket-Powered Model Having a Tapered Unswept Wing of Aspect Ratio 3 and Inline Tail Surfaces.* NACA RM L55B10.
63. Gillespie, Warren Jr.: *Lift, Drag, and Longitudinal Stability at Mach Numbers From 1.4 to 2.3 of a Rocket-Powered Model Having a 52.5° Sweptback Wing of Aspect Ratio 3 and Inline Tail Surfaces.* NACA RM L55I12.
64. Gillespie, Warren, Jr.: *Effect of Wing Camber and Twist at Mach Numbers From 1.4 to 2.1 on the Lift, Drag, and Longitudinal Stability of a Rocket-Powered Model Having a 52.5° Sweptback Wing of Aspect Ratio 3 and Inline Tail Surfaces.* NACA RM L56C16.
65. Henning, Allen B.: *Effects of Wing Inboard Planform Modifications on Lift, Drag, and Longitudinal Stability at Mach Numbers From 1.0 to 2.3 of a Rocket-Propelled Free-Flight Model With a 52.5° Sweptback Wing of Aspect Ratio 3.* NACA RM L57D29.
66. Gillespie, Warren, Jr.: *Supersonic Aerodynamic Characteristics of a Low-Drag Aircraft Configuration Having an Arrow Wing of Aspect Ratio 1.86 and a Body of Fineness Ratio 20.* NACA RM L57A25. Reissued as NASA TN D–509, Oct. 1960.
67. Gillespie, Warren, Jr.: *Effects of Wing Warp on the Lift, Drag, and Static Longitudinal Stability Characteristics of an Aircraft Configuration Having an Arrow Wing of Aspect Ratio 1.86 at Mach Numbers From 1.1 to 1.7.* NACA RM L57G12.
68. McFall, John C., Jr.: *Longitudinal Stability Investigation For a Mach Number Range of 0.8 to 1.7 of an Airplane Configuration With a 45° Swept Wing and a Low Horizontal Tail.* NACA RM L55L09.
69. Kehlet, Alan B.: *Free-Flight Investigation Over a Mach Number Range From 0.74 to 1.43 at Lift Coefficients From −0.15 to 0.75 of an Airplane-Configuration Model Having a 52.5° Delta Wing and a Low Swept Horizontal Tail.* NACA RM L56G09.
70. Peck, Robert F.; and Coltrane, Lucille C.: *Longitudinal Characteristics at Transonic and Supersonic Speeds of a Rocket-Propelled Airplane Model Having a 60° Delta Wing and a Low Swept Horizontal Tail.* NACA RM L55F27.
71. Peck, Robert F.: *Results of Rocket Model Test of an Airplane Configuration Having an Arrow Wing and Slender Flat-Sided Fuselage, Lift, Drag, Longitudinal Stability, Lateral Force, and Jet Effects at Mach Numbers Between 1.0 and 2.3.* NACA RM L55L29.
72. Kehlet, Alan B.: *Aerodynamic Characteristics Over a Mach Number Range of 1.40 to 2.78 of a Rocket-Propelled Airplane Configuration Having a Low 52.5° Delta Wing and an Unswept Horizontal Tail.* NACA RM L58A23. Reissued as NASA TN D–836, May 1961.
73. Minutes, meeting of NACA Subcommittee on High-Speed Aerodynamics, Dec. 6, 1951.
74. Rainey, Robert W.: *A Wind-Tunnel Investigation of Bomb Release at a Mach Number of 1.62.* NACA RM L53L29.
75. Sandahl, Carl A.; and Faget, Maxime A.: *Similitude Relations For Free-Model Wind-Tunnel Studies of Store-Dropping Problems,* NACA TN 3907, Jan. 1957.
76. Lee, John B.: *Dynamic Investigation of Release Characteristics of a Streamlined Internal Store From a Simulated Bomb Bay of the Republic F–105 Airplane at Mach Numbers of 0.8, 1.4, and 1.98.* NACA RM SL56F01.
77. Stevens, Joseph E., and Purser, Paul E.: *Flight Measurements of the Transonic Drag of Models of Several Isolated External Stores and Nacelles.* NACA RM L54L07.
78. Stoney, William E., Jr.; and Royall, John F.: *Zero-Lift Drag of a Series of Bomb Shapes at Mach Numbers From 0.6 to 1.10.* NACA RM SL56D16.
79. Walchner, Otto; Weigand, Heinrich; and Kroeger, Herman; *Dynamic Stabilizer for the Finless Bluff Bomb.* TN WCRR 54–53, WADC, USAF, Apr. 1954.
80. Carter, Howard S.; and Lee, John B.: *Investigation of the Ejection Release of Several Dynamically Scaled Bluff Internal Stores at Mach Numbers of 0.8, 1.39, and 1.98.* NACA RM L56H28.
81. Judd, Joseph H.; and Woodbury, Gerald E.: *Free-Flight Measurements of the Transonic Drag Characteristics of Low-Fineness-Ratio Cylinders Including Stabilizing Plates and Flares and Varying Nose Bluntness.* NASA TN D–361, May 1960.
82. Blanchard, Willard S., Jr.: *Effect of Conical and Flat Sting-Mounted Windshields on the Zero-Lift Drag of a Flare-Stabilized Bluff Body at Mach Numbers From 0.6 to 1.15.* NACA RM L57G18.
83. Lee, John B.: *Investigation of Ejection Release Characteristics of Four Dynamically Scaled Internal-Store Shapes From a 1/17-Scale Simulated Bomb Bay of the Republic F–105 Airplane at Mach Numbers of 1.39 and 1.98.* NACA RM SL56I28a.
84. Lee, John B.: *Investigation of Ejection Release Characteristics of Bluff TX–28 and Turnabout TX–28 Stores From a 1/17-Scale Simulated Bomb Bay of the Republic F–105 Airplane at Mach Numbers of 1.39 and 1.98.* NACA RM SL57B05.
85. Faget, Maxime A.; and Carlson, Harry W.: "Experimental Techniques For Predicting Store Motions During Release or Ejection." Paper presented at NACA Conference on Aerodynamics of High-Speed Aircraft, Langley Field, Nov. 1–3, 1955. Reissued as NACA RM L55L20b.
86. Carlson, Harry W.; Grier, Douglas J.; and Lee, John B.: *Comparison and Evaluation of Two Model Techniques Used in Predicting Bomb-Release Motions.* NACA RM L57J23.
87. Lee, John B.; and Carter, Howard S.: *An Investigation of Ejection Release of Submerged and Semisubmerged Dynamically Scaled Stores From a Simulated Bomb Bay of a Fighter-Bomber Airplane at Supersonic Speeds.* NACA RM L56I10.

88. Pierce, H. B., Memorandum for Associate Director, Oct. 19, 1953, regarding exploratory investigation of blast-induced gusts.
89. Wallops PARD Log, May 19, 1954.
90. Pierce, H. B., Memorandum regarding telephone call, Feb. 17, 1955, to T. J. Allen of BRL concerning focusing of blast waves.
91. Pierce, Harold B.; and Reisert, Thomas D.: *Initial Experimental Investigation of the Aerodynamic Load on the Wing of a Model Caused by a Blast-Induced Gust That Increases the Angle of Attack Into the Stall Region.* NACA RM L55H22b.
92. Pierce, Harold B.; and Spahl, Raymond J.: *Experimental Investigation to Determine the Loads on a Horizontal Tail of a Model Caused by a Blast-Induced Gust.* NACA RM L57A28a.
93. Pierce, Harold B.: "An Experimental Study of Air Loads Caused by Blast-Induced Gusts." Paper presented at NACA Conference on Aerodynamics of High-Speed Aircraft, Langley Field, Nov. 1–3, 1955.
94. Pierce, Harold B.; and McFarland, Donald R.: "Experimental Results on Wing Loads Due to Blasts." Paper presented at Conference on Aircraft Loads, Structures, and Flutter, Langley Field, Mar. 5–7, 1957. Reissued as NACA RM L57D22a.
95. Pierce, H. B., Memorandum for Associate Director, May 26, 1959, regarding disposal of 4,000-pound charge at Wallops Island.
96. Pierce, Harold B.: *Interaction of Blast Waves With Wings.* Part I. Ten-Foot-Diameter Free Jet Shock Tube (Appendix A, "Point Source Transient Pressure Measurement System,"), by Richard W. Morton. Part II. Wave-Table Studies, by Donald R. McFarland. Included in *Proceedings of Third Shock Tube Symposium,* Ft. Monroe, Va., Mar. 10–12, 1959. ARDC AFSWC Report SWR-TM-59-2, p. 271.
97. Morton, Richard W.; and Patterson, John L.: *A Transient Pressure Measurement System for Blast Effect Research.* Instrument Society of America, Preprint 148–LA–61–1, September, 1961.
98. Pierce, Harold B.; and Manning, James C.: *Experimental Investigation of Blast Loading on an Airfoil in Mach Number 0.7 Airflow With Initial Angle-of-Attack Change of 20°.* NASA TN D–1603, Feb. 1963.
99. Manning, James C.: *Experimental Investigation of Blast Loading on an Airfoil in Mach 0.7 Airflow With Initial Angle-of-Attack Change of 28°.* NASA TN D–2876, June 1965.
100. Jarvis, R. L.; Kasper, J. J.; Mills, R. R.; and Wolf, I. O.: *A Program to Induce High Blast-Induced Airloads and Structural Response of Lifting Surfaces.* Aircraft Armaments, Inc., ASD–TDR–63–764, vol. II, July 1964.
101. Friedman, Manfred D.; and Reutenik, J. Ray: *An Analysis of Measured Blast Loads on Swept Wings at High Subsonic Speeds.* Massachusetts Institute of Technology, AFFDL–TR–65–170, Mar. 1966.
102. Baker, Wilfred E.; Silverman, Sandor; Cox, P. A., Jr.; and Young, Dana: *Structural Response of Helicopters to Muzzle and Breech Blast. Volume II, Structural Interaction and Response to Blast.* Southwest Research Institute, Final Technical Report 02–2029, Mar. 1969.

CHAPTER 13

FIVE-STAGE MACH 15 RESEARCH VEHICLE: 1956

CONTINUED DEVELOPMENT OF HYPERSONIC LAUNCH VEHICLES

The concentrated effort to develop a launch vehicle capable of reaching Mach 10, and the successful demonstration of such a vehicle on October 14, 1954, have been discussed in Chapter 11. This achievement satisfied the vehicle requirements to carry out the first part of the 1952 resolution of the NACA Committee on Aerodynamics, calling for an increase in research efforts "at Mach numbers between 4 and 10," as discussed in Chapter 9. The need still existed, however, for vehicles to reach even higher speeds, for part two of the resolution called for "a modest effort at speeds from Mach number 10 to the velocity of escape from the earth's gravity." In addition, the acceleration of development by the Air Force of an Intercontinental Ballistic Missile (ICBM), which would require speeds of about Mach 20, added an even stronger justification for extending the speed capabilities of the research rocket systems at Wallops. Accordingly, there was no lessening of efforts to increase the speeds obtainable with relatively inexpensive systems.

The first vehicle to reach Mach 10 at Wallops contained Nike-Nike-T40-T55 rocket motors in four stages, with the motors in tandem. The Nike booster motor was the first large rocket motor obtained for Wallops and represented the first major step toward increasing the speed capabilities. In its first use at Wallops, it did not provide the performance gain expected of it. In fact, a three-stage Nike-Nike-Deacon was needed to obtain the speed of Mach 7 expected from a two-stage Nike-Deacon vehicle. In June 1954, R. O. Piland calculated that the four-stage system would attain just over Mach 9, and recommended that steps be taken to procure some of the motors used in the Army's Honest John ground-to-ground missile, which had been developed by Douglas Aircraft Company. He calculated that a four-stage system with the Honest John motor as first stage would reach Mach 10.3 (ref. 1). When Piland's calculations proved to be conservative and Mach 10 was obtained with the Nike four-stage vehicle, plans were made to use the Honest John motor to obtain higher speeds.

The Honest John was essentially a scaled-up Nike motor and was likewise developed by the Hercules Powder Company at ABL. It used a double-base propellant with a rather heavy steel case. It was 23.4 inches in diameter and 196.8 inches in length, and produced a thrust of 83,300 pounds for 4.4 seconds. The total weight was 3,874 pounds, with a propellant weight of 2,050 pounds, for a propellant-mass fraction of 0.53. Such a low mass fraction could be tolerated only in an early stage of a launch system, but it was to find many applications at Wallops.

The Honest John missile was a military weapon at this time, and the NACA was successful in obtaining some of the motors at no cost because of the applicability of NACA research to Army projects.

The Honest John was an unguided weapon and had canted fins to induce a slow roll to minimize the effects of thrust misalignment. These fins were found to be suitable for the vehicles at Wallops, except for the cant of the fins. All motors were obtained, therefore, with the fins attached but without the warhead. It was a simple matter to remove the cant angle.

The Honest John motor, with its weight of 3,874 pounds and its thrust of 83,300 pounds, was by far the largest motor obtained so far at Wallops. The existing launchers at Wallops were too small to handle a multistage vehicle with this motor as the first stage. Accordingly, a new launcher was designed and approval for its construction was requested from NACA Headquarters on January 25, 1955. Approval was given as Project 1610 on March 1, 1955. A contract was let locally with Wyle Maddox for the concrete foundation, while the launcher itself was constructed by NACA labor. The total cost was estimated to be $10,275, but this was increased to $21,145 in November 1955, after it was found necessary to strengthen the system to allow for unexpectedly high rocket blast forces from the Honest John motor. The magnitude of these forces were realized when an attempt was made to launch an Honest John from an existing launcher at Wallops.

Pending construction of the new launcher, a two-stage vehicle consisting of an Honest John first stage and a Nike second stage was constructed to gain experience with the new motor. In addition, it was found that rather large models could be propelled to almost Mach 5 with such a system. It was felt that this two-stage vehicle could be launched from the existing Hermes launcher at Wallops. The first attempt at such use, however, on September 15, 1955, wrecked the launcher, although the vehicle was launched successfully. Figure 285 shows the vehicle on the launcher just prior to firing. The blast loads from the Honest John "hurled the heavy(5,000-pound) launcher approximately seventy feet back from the launching position. Parts of the launcher were badly bent and it is believed beyond economical repair" (ref. 2). Further tests with the Honest John were held up until the special launcher was completed.

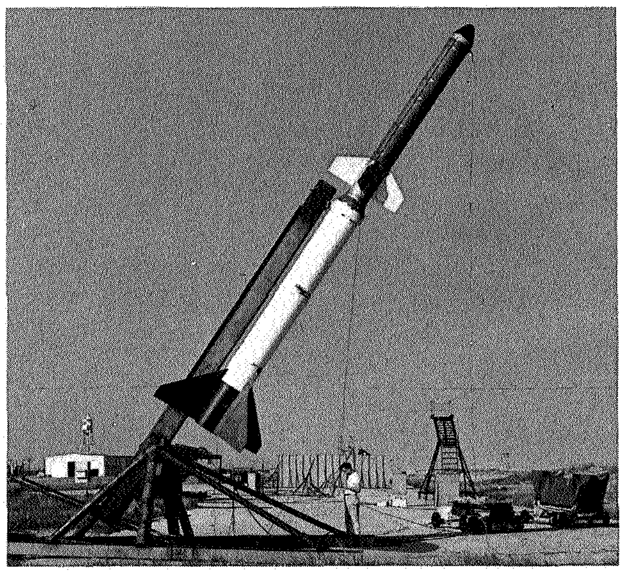


FIGURE 285. Project engineer Leo T. Chauvin examines firing leads to first Honest John-Nike launch vehicle used for heat-transfer test of blunt 50-degree cone. Vehicle is shown on Army Hermes launcher, ready for test at Wallops, September 15, 1955.

The first test with the new multistage launcher was made with a two-stage Honest John-Nike vehicle on December 21, 1955. The launcher withstood the loads without any trouble and became the standard launcher for Nike or Honest John systems. It was essentially a jib crane with provisions for attaching the test model beneath the heavy steel boom. The boom was hinged near the base of a steel column which was braced with steel cable. A motorized winch with cable and pulleys elevated the boom to its launch position. Azimuth changes could be made by manually rotating the support column. Later, a motorized azimuth-control system was added.

While the Honest John motor and its special launcher were being obtained, an attempt was made to obtain higher speeds with a Nike-boosted vehicle containing a T40 last stage. A cluster of three Deacon motors contained within a large tube equipped with stabilizing fins was added to a Nike-Nike-T40 system to make a four-stage Nike-Nike-Triple Deacon-T40 vehicle. Such a vehicle was flown on April 8, 1955, as shown in figure 286. The test was unsuccessful because of failure of the last stage to ignite.

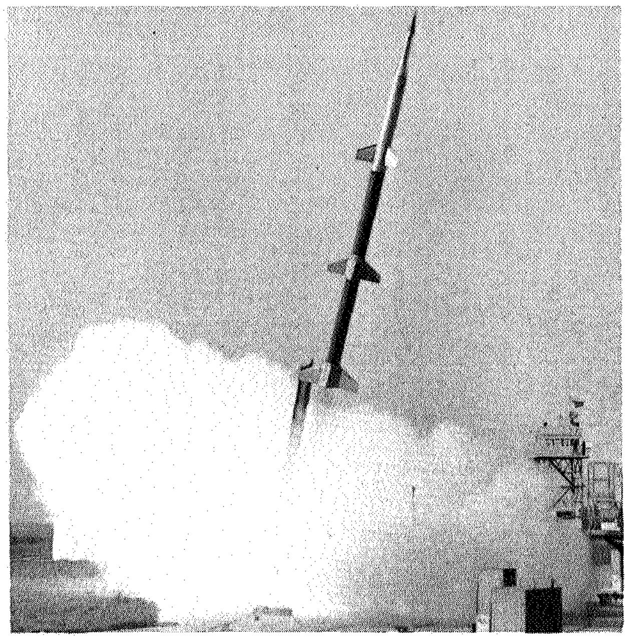


FIGURE 286. Launch of four-stage Nike-Nike-Triple Deacon-T40 heat-transfer vehicle, April 8, 1955.

Research with the successful four-stage Nike-Nike-T40-T55 system continued during the 1955–1958 period, but a change in technique was required for operational reasons. It will be recalled that with the first vehicle of this type, the four rocket motors were fired in sequence during the ascending portion of the trajectory, and the basic research results were obtained before the vehicle left the atmosphere. The high velocity produced a range of nearly 600 miles at impact. For the first test, a search of the expected sea impact area revealed an area clear of ships, explained later by the presence of a hurricane along the coast. When an attempt was made to launch the second model of this series on April 8, 1955, an entirely different picture was presented on the radar screen of the airplane searching the area. About 20 ships were within the predicted danger zone, and the launch was postponed indefinitely, pending further study of the situation.

Although there were 20 ships within the area, the vast extent of the area made the chance of hitting a vessel so small that one school of thought suggested launching without search, when impact was to be made in the open sea far from land. Before this plan was adopted, however, a better alternative was found. This was to use the first two stages to propel the vehicle to an altitude of about 100,000 feet, and delay firing of the upper stages until the apogee had been passed and the model was on a descending trajectory. By this means, the range could be kept within the Navy training area near Wallops. In addition, it would be possible to exercise more control over the test conditions at maximum speed, by varying the angle at which the upper stages were ignited. This factor was quite important in studies of survival of materials under reentry conditions. One difficulty with this system was that there had to be sufficient stability and dynamic pressure to keep the vehicle aligned with the flight direction as it went over the top. This, in effect, limited the maximum altitude of the test.

The postponed vehicle was rescheduled for use of this "over-the-top" technique and was launched on June 23, 1955, but the last two stages failed to ignite. In the next attempt, on October 7, 1955, the telemeter and beacon failed early, and no data were obtained. In the next test, on June 7, 1956, all stages fired and the instrumentation was good, but the last two stages fired early and the trajectory was too high. Nevertheless, the over-the-top trajectory was permanently adopted.

The Lewis air-launched rocket technique, first discussed in Chapter 9, could also be called an over-the-top procedure, with the launch airplane substituting for the first two stages of a ground-launched system in carrying the reentry package to the apogee.

The first adaptation of the Honest John motor to a four-stage system was in using it to replace the first Nike stage on the Nike-Nike-T40-T55 vehicle. This vehicle, shown in figure 287, was launched on March 9, 1956, but was unsuccessful because of a structural failure near the end of the burning period of the first stage.

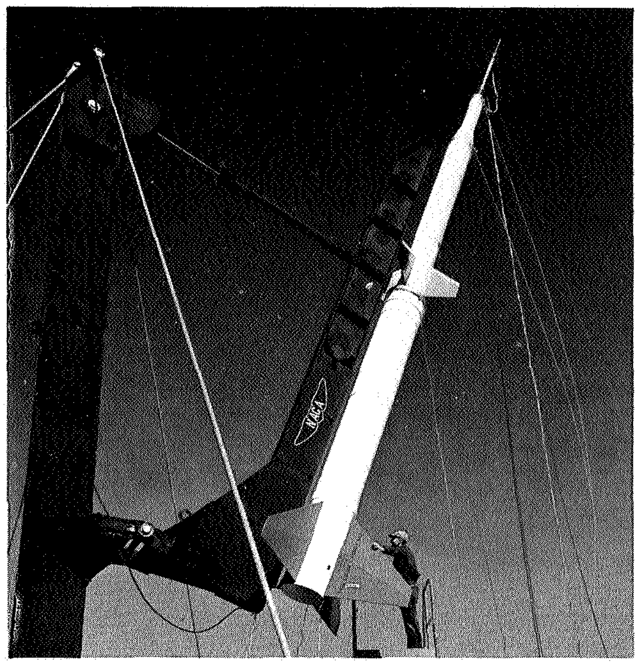


FIGURE 287. Technician Jewell Greene looks over fin assembly on the first four-stage Honest John-Nike-T40-T55 vehicle, March 9, 1956.

A. C. Bond and C. B. Rumsey continued their efforts to obtain a Mach 10 vehicle with a T40 last stage by designing a four-stage system with an Honest John first stage, a Nike second stage, three Deacons for the third stage, and a T40 for the last stage. The three Deacons were contained within a fin-stabilized cylinder. The total vehicle is shown in figure 288 as it was ready for launch on June 8, 1956. This model reached a Mach number of only 9.89 and was the last multistage hypersonic vehicle to be flown with a T40 last stage.

All efforts were now concentrated on the smaller T55 motor as the final stage. In addition, a close relationship developed between the NACA and the Air Force during 1955 in providing research data applicable to the ICBM reentry problem, and new types of rocket motors were made available for the PARD multistage systems. Plans were being made for the use of these new motors even as the vehicles just described were being constructed and prepared for test.

When the Air Force was given the go-ahead for an accelerated ICBM program, responsibility was assigned to a newly organized unit, the Air Force Western Development Division (WDD) of ARDC, under command of General Bernard A. Schriever, with the assistance of Ramo-Wooldridge Corporation. The President assigned highest priority in the nation to this program. The Convair Atlas was the first ICBM to be constructed, but in March 1956 a contract for a second ICBM, the Titan, was let to the Martin Company. The development of the nose cones for these missiles was likewise assigned to dual companies, General Electric Company and Avco Corporation.

Initial efforts were concentrated on a large-diameter, blunt shape proposed by H. J. Allen of Ames (ref. 3). At this stage, a simple copper heat sink was envisioned as a heat protector for the warhead and, consequently, measurements of heat transfer under full-scale reentry conditions were sorely needed. The flight measurements made at Wallops of heat transfer at speeds above Mach 10 were, therefore, of especial interest to the ICBM team. Before the program was completed, Wallops was to participate in many phases of the ICBM program in addition to the nose heating problem as will be discussed in later chapters.

On February 1, 1955, Langley was notified that representatives of WDD, Ramo-Wooldridge, and Lockheed would visit Langley to discuss the applicability of the PARD rocket program to the Convair

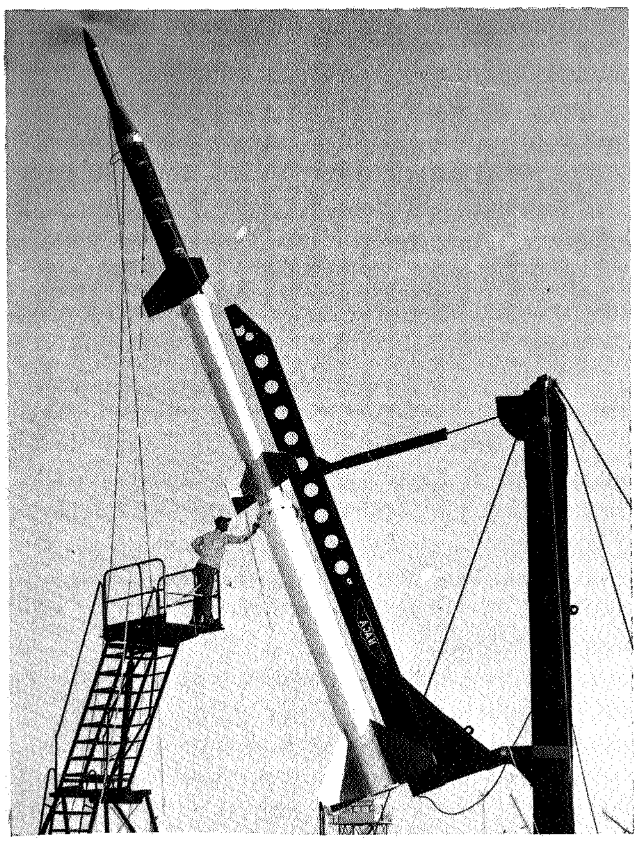


FIGURE 288. Technician Durwood Dereng measures elevation angle of four-stage Honest John-Nike-Triple Deacon-T40 vehicle, June 8, 1956.

missile.[1] At the visit, on February 17, 1955, Major Donald R. Latham of WDD represented General Schriever; Dr. George E. Solomon represented Ramo-Wooldridge; and Willis Hawkins, Ralph Morgan, Ralph J. Haven, and Stanley W. Burris represented Lockheed. This visit was only a few months after the first Mach 10 flight at Wallops, and little data had been obtained by that time.

The visitors were extremely interested in the PARD program and offered to assist in any way possible. They made known their intense need for heat-transfer data at Mach numbers near 15 and described plans to implement a new flight program, with Lockheed as the prime contractor, to obtain reentry heat-transfer data on shapes of interest to the ICBM program. This was to be the X-17 program carried out at Cape Canaveral with 26 flights, ending March 1957. One of the purposes of the visit to Langley was to find out if the program at Wallops could be expanded to meet their direct needs within their time scale. A dozen flights to Mach 15 were desired within a year. Upon learning that such a tight schedule was unrealistic for the existing PARD operation, they decided to go ahead with the Lockheed program and to fortify the PARD program by assigning some of the rocket motors from the X-17 program to Langley.

The X-17 vehicle had three stages, with a Sergeant rocket motor for the first stage, a cluster of three Recruit motors for the second stage, and a single Recruit as the last stage. The flight plan was for the Sergeant to propel the vehicle to a very high altitude, following which the remaining vehicle would reenter the atmosphere in an uncontrolled attitude but would stabilize as it reached lower altitudes in time to allow firing of the last two stages to propel the test nose cone to its maximum speed near Mach 15. The Sergeant motor was a large solid-rocket motor developed for the JPL Sergeant guided missile. The Recruit motor was a special motor to be developed for the X-17 vehicle. Both motors were to be supplied by Thiokol Chemical Corporation under the guidance of Redstone Arsenal.

PARD engineers had heard of the Sergeant motor, but the Recruit was a new addition. The plan for the X-17 was, in some respects, similar to a proposal of M. A. Faget in January 1955 (ref. 4). Faget had proposed that a Sergeant motor be used to propel a five-stage stack of solid motors outside the

1. Telegram from E. H. Hartman to H. J. E. Reid, Feb. 1, 1955, regarding proposed visit of representatives of WDD. Confirmation letter dated Feb. 10, 1955.

atmosphere where they would be fired earthward without any air-drag resistance. Stabilization was to be provided by hydrogen peroxide jets. A maximum speed of Mach 18 was predicted by Faget.

The Recruit motor was a high-performance motor with a thin-wall steel case loaded with polysulfide propellant and an oxidizer. It had a diameter of 9 inches, a length of 99.6 inches, and a thrust of 34,640 pounds for a burning time of 1.5 seconds. It weighed 334 pounds, with 268 pounds of propellant, for a propellant-mass fraction of 0.80, the highest of any rocket motor available to Wallops at this time. Certain that both of these motors could be used to advantage in the hypersonic program, Langley asked Latham for 24 Recruits and 2 Sergeants. WDD agreed to this request and asked to be kept informed of any flight data on hypersonic heat transfer.[2]

Following the visit of the WDD representatives in February 1955, many combinations of rocket motors, including the Recruit and Sergeant motors, were analyzed by the group in the PARD Propulsion Aerodynamics Branch under M. A. Faget. At the same time, the Honest John motor was being actively incorporated into the existing multistage systems by Faget's group, as well as by Piland. Three new launch vehicles evolved from these and other studies. The Recruit motor was small enough to be incorporated into existing vehicles, but the Sergeant was so large that an entirely new system was required. The Sergeant system came later and will be discussed in a later chapter. The Recruit motor was fitted into launch vehicles as soon as it became available. It was also made available to the Lewis Laboratory for incorporation into the air-launched rocket program.

The first use of the Recruit motor by PARD was in the first five-stage vehicle ever to be flown. The four-stage Nike-Nike-T40-T55 vehicle was redesigned with a Recruit replacing the T40 and an Honest John added as the first stage. A maximum speed of Mach 15 was calculated with such a system in an over-the-top trajectory. Because of the large increase in speed calculated for this system over any of the existing systems, it was given highest priority at PARD.

The first such vehicle was launched about a year later, on August 24, 1956. Although the first results from this flight indicated that all three stages fired as planned and the objectives were achieved, later analysis indicated that at ignition of the Recruit stage, the nose section ahead of the T55 motor (last stage) broke off. Since this section contained the telemeter, the only source of data from this point on was the SCR-584 tracking radar. The velocity was too high for continual tracking, but enough data were obtained to allow some analysis of events. With the last stage lightened by the loss of the nose section, the velocity increment from this stage was greater than originally calculated. Although the value had no real meaning, the estimated speed actually reached in this flight was about Mach 17.

Following a structural change, the next seven vehicles, launched through 1958, were all successful. The first of these modified vehicles, launched December 20, 1956, is shown in figure 289. Note the "cherry picker," service platform required for this size of vehicle. Before the program ended in December 1960, a total of 16 such vehicles were to be launched from Wallops. These were in addition to the large number of sounding rockets developed from this design and flown during the JASON program in 1958, to be discussed in a later chapter.

A general description of the Honest John five-stage vehicle and its uses was given by Joseph A. Shortal at the IAS National Midwestern Guided Missile meeting in St. Louis, Missouri, May 14, 1958 (ref. 5). As indicated in figure 289, the five-stage vehicle was quite large, being 55 feet long and having a gross weight of 7,000 pounds. The Honest John had its standard fins, while the two Nike stages had the special fins developed at Langley for this motor. The upper stages were stabilized by base flares that also doubled as high-altitude nozzles. Stabilization was entirely aerodynamic, and an attempt was made, by careful alignment of the fins, to prevent any spin motion. The critical design consideration was aeroelastic divergence of this long, skinny structure.

The firing plan consisted of igniting the Honest John at zero time and the Nike second stage at an altitude of about 20,000 feet, through a 13-second delay squib, energized at zero time. The remaining three stages were ignited in a rapid sequence after the combination had flown over the top and had started on its downward trajectory. Initiation of ignition of the Nike third stage was performed through a 90-second timer. The actual trajectory and speed after this point were controlled by the setting of the timer. A shorter time would raise the altitude of the trajectory and increase the speed; a longer time

2. Letter from ARDC WDD to NACA Headquarters, June 9, 1955, regarding rockets for heat-transfer program and data from flights.

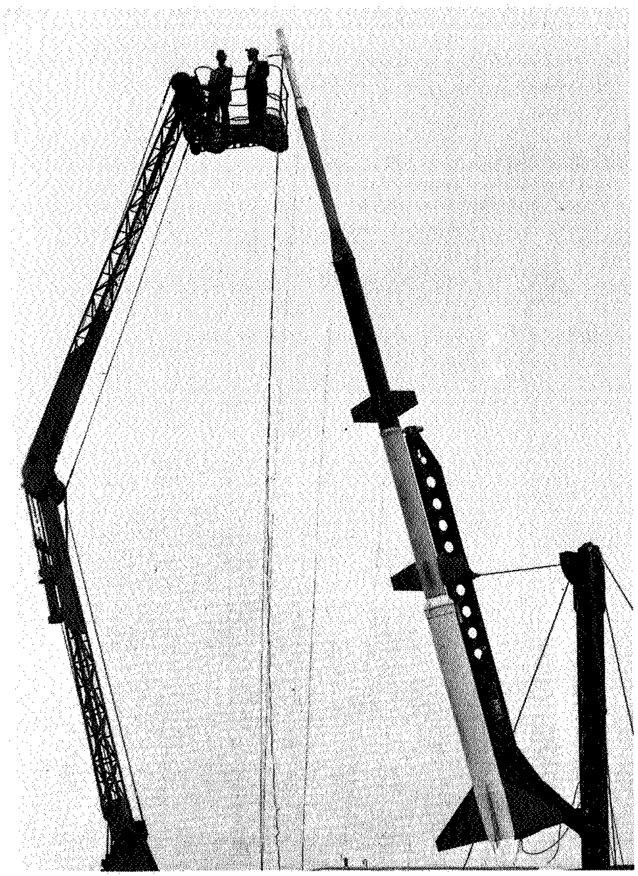


FIGURE 289. Engineer J. C. Palmer and technician Durwood Dereng on "cherry-picker" for examination of five-stage Honest John-Nike-Nike-Recruit-T55 heat-transfer vehicle prior to launch on December 20, 1956.

would decrease the altitude and reduce the maximum speed, but would increase the severity of the reentry condition.

Special locking devices between the stages were used to prevent premature separation. The Honest John was connected to the Nike stage with the normal plug adaptor, used for many years at Wallops, which allowed free separation after burnout of the Honest John. The two Nike stages were connected to each other by a similar adaptor plus a locking pin that was withdrawn by a squib-actuated piston after the second stage had burned out. It separated from the combination when its deceleration exceeded that of the total system. The Recruit and T55 stages were attached to their preceding stages by collapsible diaphragms that were blown out at ignition of the stage. The timer was started by an acceleration switch at takeoff. The final stage was ignited by a zero-delay squib activated by the closing of a pressure switch at the instant the Recruit motor stopped thrusting, as indicated by a sharp drop in pressure. This was done to prevent any loss of speed that would have resulted had there been any delay between the two stages.

Another hypersonic vehicle developed from the Recruit rocket motor reached only Mach 7, but it did so at low altitudes and provided needed data at high Reynolds numbers. This was simply a two-stage Nike-Recruit combination. The first of these was flown on October 5, 1956, and is shown in figure 290. It reached a maximum velocity of 7,600 feet per second at an altitude of 13,000 feet for a record dynamic pressure of 45,700 pounds per square foot.

DEVELOPMENT OF ETHYLENE HIGH-TEMPERATURE JET AND EXPLORATORY TESTS OF BOOSTER FINS

The formation of a High-Temperature Branch of PARD and the expansion of research at high temperatures have been discussed in Chapter 12. One phase of the increased activity in high-temperature research was conversion of the B Jet of the Preflight Jet at Wallops into a high-temperature facility by addition of an ethylene-fueled ramjet to the duct system. This facility was called the Ethylene Jet. The 8-inch air-supply duct was increased to 12 inches, and a combustion chamber with an F23-type

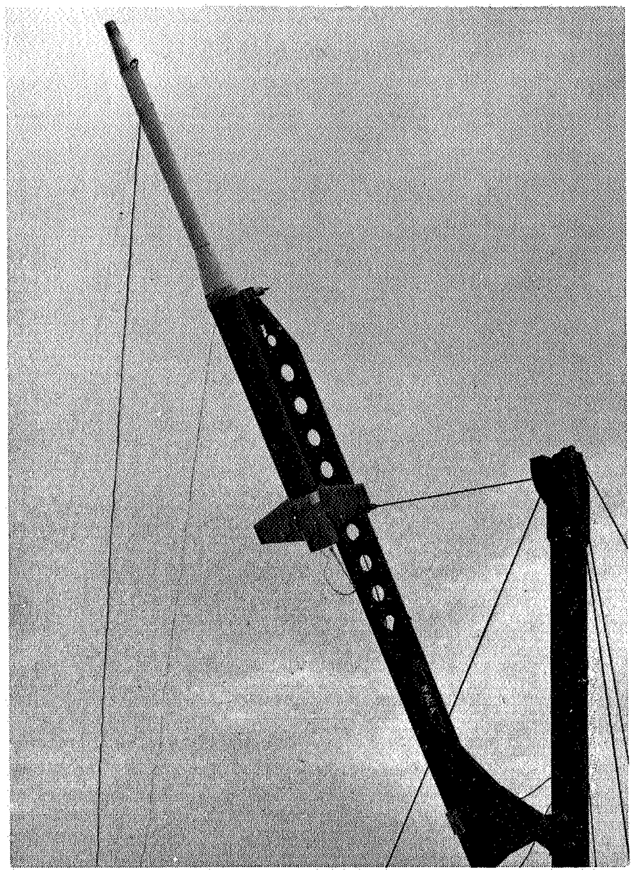


FIGURE 290. First Nike-Recruit heat-transfer vehicle at Wallops, October 5, 1956.

"donut" flame holder was added downstream, as shown in figure 291. A supersonic nozzle was added to the downstream end of the combustion chamber to provide a 12-inch circular test section having Mach 2 flow at high temperature and pressure. The complete facility, with a typical model ready for test, is shown in figure 292.

The temperature in the test area could be varied from 500° F to 4,500° F by varying the fuel rate to the ramjet burner, and the total pressure could be controlled by the pressure in the main Preflight Jet supply. Normally, a stagnation temperature of about 3,000° F and a total pressure of about 12,000 pounds per square foot were developed. Although the Mach number of the jet was only 2.0, the temperature and pressure conditions simulated a hypersonic flight condition of about Mach 6.0 at an altitude of 40,000 feet. The composition of the test medium was not the same as that of air and was, therefore, not suitable for some types of tests. Although the nitrogen content of the exhaust was about the same as that of air, about one-half the normal oxygen of air had been replaced by carbon dioxide and water vapor in the ramjet combustion process. This had the effect of lowering the ratio of specific heats; but, more importantly, by reducing the oxygen content, it introduced an error into tests of materials, in which combustion was an important factor. Any burning of test specimens would be less severe than in the corresponding flight condition (ref. 6).

Calibration of the Ethylene Jet began in February 1956, and the first test of a model was made on April 3, 1956. During 1957, a new flame holder was developed. It was found that a more uniform temperature distribution across the exit could be obtained by replacing the original four tandem rows of donuts, 8 inches in diameter, with three concentric rows of "donuts," the outer row having a diameter of 10 inches. With this flame holder, the temperature was fairly constant over an 8-inch-diameter central area of the jet (ref. 7). This facility was quite a valuable addition to Wallops and was to see extensive use until the entire Preflight Jet facility was deactivated in October 1960. By that time, a much larger test facility of the same type was under construction at Langley, and many smaller true-air high-temperature facilities were also in operation there.

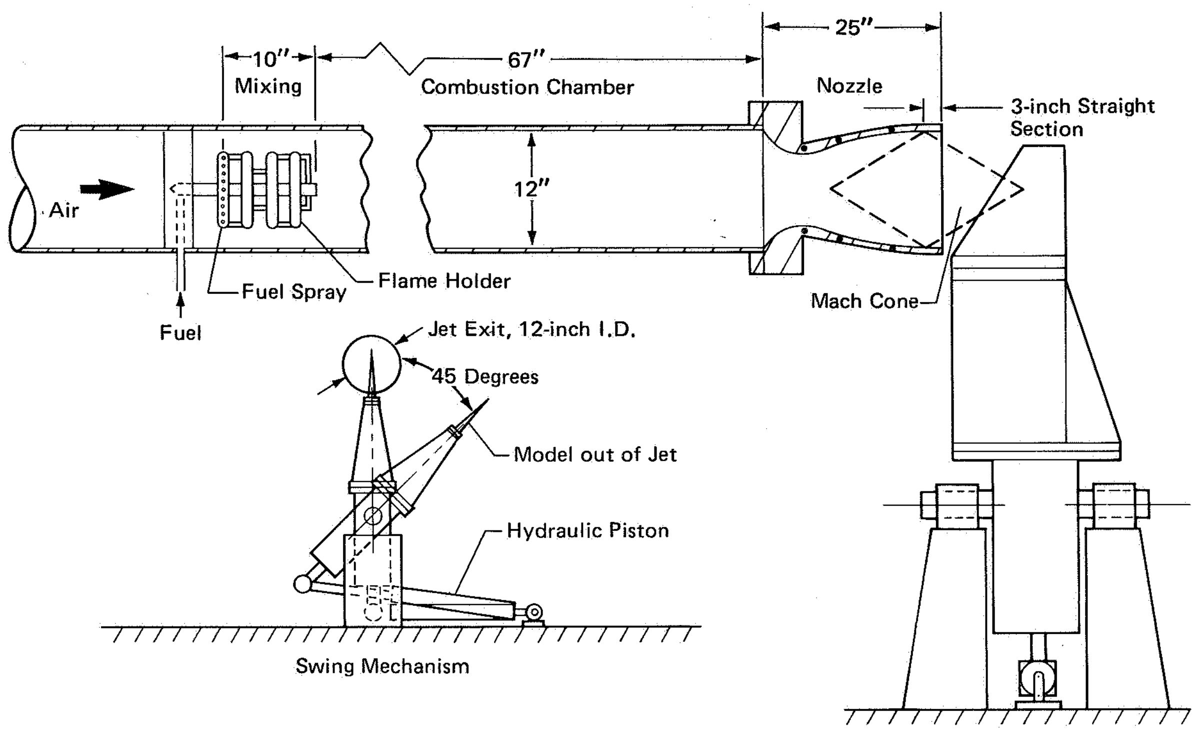


FIGURE 291. Schematic drawing of high-temperature Ethylene Jet at Wallops.

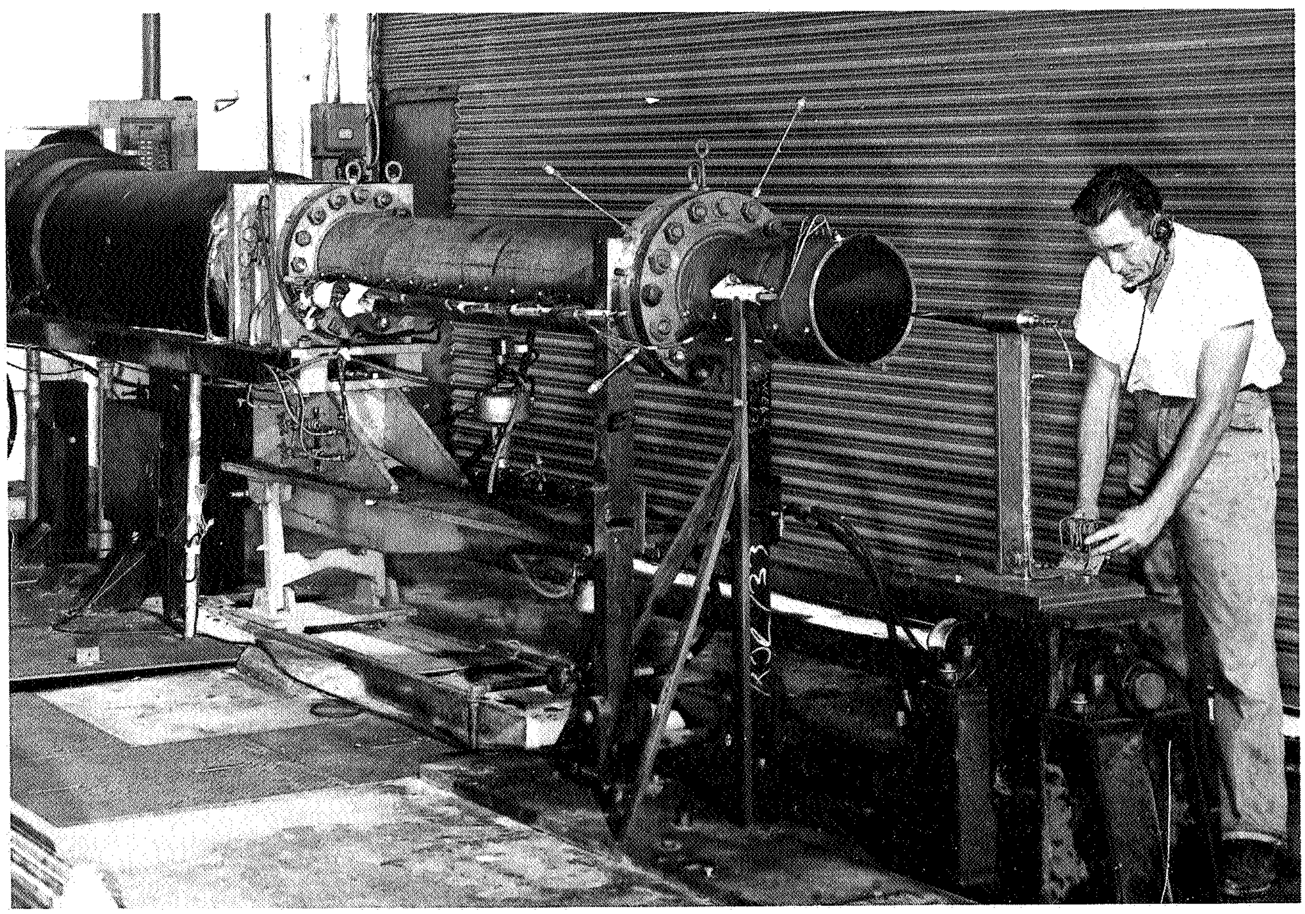


FIGURE 292. Technician Clyde Hargis checks pressure tubes for test model in Ethylene Jet, April 3, 1956.

The first models tested in the Ethylene Jet were related to the development of multistage launch vehicles for hypersonic flight research and were tested in an attempt to explain and correct a structural failure encountered in flight.

It has been mentioned earlier in this chapter that the first use of the Honest John rocket motor at Wallops was as the first stage of an Honest John-Nike vehicle in a flight on September 15, 1955. Although heat transfer data were obtained from this flight, a failure occurred near the time the Nike motor burned out. Parts of the structure were redesigned to correct the conjectured cause of failure, but in the second flight on December 21, 1955, an apparently identical failure occurred. As the Nike motor stopped burning, about 3 seconds after ignition, this stage diverged very rapidly as if it had lost a fin. Then, when the four-stage Honest John-Nike-T40-T55 vehicle, launched on March 9, 1956, broke apart during the burning of the Nike motor, a more extensive investigation of the flight conditions and structural integrity became necessary.

Examination of the design of the fins on the unsuccessful Nike stages and those on earlier successful vehicles revealed that the fins had been redesigned to reduce drag at hypersonic speeds by changing the leading edge from a rather blunt sheet steel shape to quite a sharp magnesium wedge. It was reasoned that, even if the edge melted, it would do so gradually and evenly and would simply blunt the edge.

In view of the flight failures, J. A. Shortal insisted that no further flights be made with this design until it had been tested in the new Ethylene Jet, and several models simulating the outboard tip of the Nike booster fins were prepared for test. Seven tests were made during April 3–6, 1956, of the sharp magnesium fin design, of a blunter shape, and of several versions having inconel or stainless steel leading edges.

The Ethylene Jet could duplicate the heating conditions of the flights that failed by operating at about 2,000° F. The test fin was mounted on a pivoted arm just outside the jet, and after the jet was operating properly, the arm and test fin were rotated into the jet. This support system is shown in figure 291. In the test of the sharp-edge fin (1/64-inch radius), failure was dramatic, starting at 0.6 second after insertion into the jet. The damage after only 2.3 seconds is shown in figure 293. About 8 inches of the leading edge had melted back to a maximum distance of 2 inches. A second model with a leading-edge radius of 1/16-inch also suffered damage in a test lasting only 2.3 seconds. Subsequent tests showed that a wrapping of 1/32-inch inconel around the forward 2.5 inches of the fin was sufficient to protect the fin from damage for this test period. The limit of protection of this fix was determined by additional tests at a temperature of 3,000°F, simulating a Mach 6 condition at an altitude of 40,000 feet. With these conditions, it was found that when the exposure time was increased to 3.7 seconds, the magnesium burned away behind the inconel cap (ref. 6).

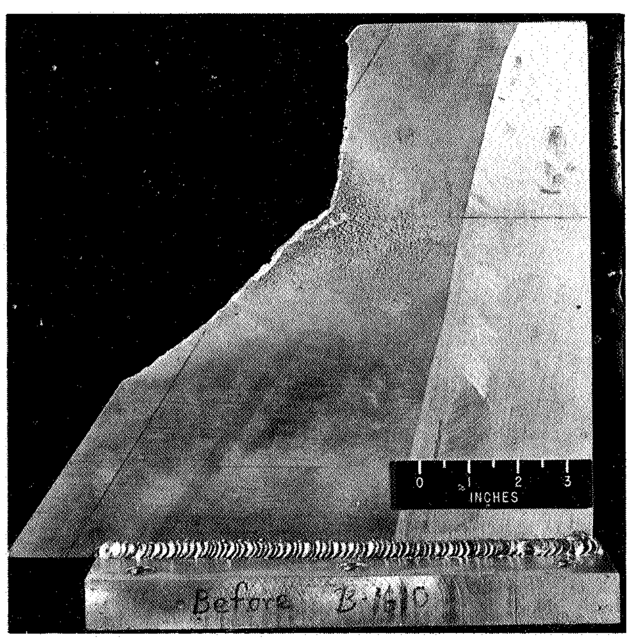


FIGURE 293. View of damage to sharp leading edge of Nike magnesium fin after 2.3 seconds of exposure in Ethylene Jet, April 3, 1956.

Following these tests, the basic fin on the Nike booster was changed to one containing an inconel cap. The same type of protective cap was later applied to other fins whose flight histories were similar to the Nike under investigation in the present case. The first flight check of this new fin was made with a dummy Honest John-Nike vehicle on April 5, 1956, just one day after the successful demonstration of the capped fin in the Ethylene Jet. The vehicle successfully demonstrated the adequacy of the new design when it followed its design trajectory without mishap.

A more leisurely program was then conducted with instrumented models in the Ethylene Jet to determine the limits of usefulness of the inconel-capped magnesium fins. It was found that the exposure time could be extended by placing insulation, such as fiberglass, between the inconel and magnesium (ref. 8).

Another approach to protecting the leading edge of a fin from structural damage due to transient aerodynamic heating was to modify the shape of the leading edge to reduce the heat input. Three unprotected magnesium fins were tested in the Ethylene Jet with different nose shapes. All fins had 17-degree sweepback of the leading edge and an 11-degree total-angle wedge basic section. The first model had a rounded leading edge with a radius of 0.06 inch. The second model had a flat leading edge of 0.12-inch width. The third model had a rounded leading edge with a radius of 0.19 inch. The larger radius was obtained by cutting back some of the forward portion of the fin. This modification was made, not only to reduce the heat input, which varied inversely as the square root of the nose radius, but to provide a greater mass at the leading edge to absorb the heat. In the tests, run at a stagnation temperature of about 2,100°F, it was found that the first model started to melt after 1.65 seconds; and the second model, after 2.30 seconds. The third model remained intact for 4.08 seconds. These times to melt corresponded roughly to results expected from the combined effects of leading-edge shape and increased mass (ref. 9).

DEVELOPMENT OF CAJUN ROCKET MOTOR

The Deacon was the first high-performance rocket motor used at Wallops. The development of this motor was completed for the NACA in 1947 and incorporated such advanced features as an insulated aluminum case and internal burning of the grain along its entire length. It had a propellant-mass fraction of 0.67 and used double-base propellant with a specific impulse of about 190.

By 1954, the grain had been changed from an extruded to a cast design for longer shelf life, but with some loss in performance. J. G. Thibodaux, head of PARD's rocket motor activity, realized that higher performance propellants were then available, particularly the cast rubber-base polysulfide used by Thiokol Chemical Corporation in the T44, T55, and other motors. He proposed that consideration be given to loading Deacon cases with such a propellant to obtain higher performance. After visiting Thiokol's new privately owned plant at Elkton, Maryland, in February 1954 (ref. 10), he was convinced of the merit of the plan and initiated plans to ask for competitive bidding on such a motor.

Three companies submitted proposals to develop the improved Deacon motor to meet the specifications prepared by the NACA. Hercules Powder Company's ABL proposed a cast double-base grain with additives; Grand Central Rocket Company proposed a polysulfide propellant with a thin-wall steel case, and Thiokol proposed a polysulfide grain along with the standard Deacon components.

Thibodaux was impressed with the Grand Central proposal because of the steel case. Thiokol was the low bidder and was awarded the contract. The Grand Central design was completed under a separate contract with the Navy Bureau of Ships and Cooper Development Company for use in the Asp sounding rocket, from which its name was derived (ref. 11). Thibodaux attached the name "Cajun" to the Thiokol motor in recognition of his home State, Louisiana.

The Cajun successfully demonstrated its performance in static tests on a thrust stand. The thrust increased progressively from about 7,500 pounds at ignition to about 9,500 pounds near burnout at 2.6 seconds, for a total impulse of about 24,000 pound-seconds, an increase of approximately 25 percent over that of the Deacon. A flight determination of performance was made of one of the motors at Wallops on June 20, 1956. For this test, a 20-degree conical nose weighing 7.5 pounds and a four-fin tail assembly weighing 16 pounds were added. The fins were made of solid magnesium welded to a cylindrical magnesium shroud. The beveled leading edges of the fins were capped with a 0.032-inch inconel sheet to prevent destruction from aerodynamic heating, a solution developed in other tests discussed earlier in this chapter.

The Cajun, ready for launching, is shown in figure 294. It was launched at an elevation angle of 70 degrees and accelerated to a maximum speed of 5,268 feet per second, Mach 4.74, at an altitude of about 7,000 feet. The thrust-time variation determined from the flight agreed well with the results of the ground firing tests (ref. 12). The empty Cajun was 6 pounds lighter than the Deacon and carried 17 pounds more propellant because of its higher density, which increased the propellant-mass fraction from 0.67 to 0.73. The fuel specific impulse was about 4 percent higher for the Cajun.

The overall rating of the Cajun was excellent, and it replaced the Deacon in all following vehicles. Another early user of the Cajun was the University of Michigan, which converted its Nike-Deacon sounding rockets to Nike-Cajuns as soon as they were available.

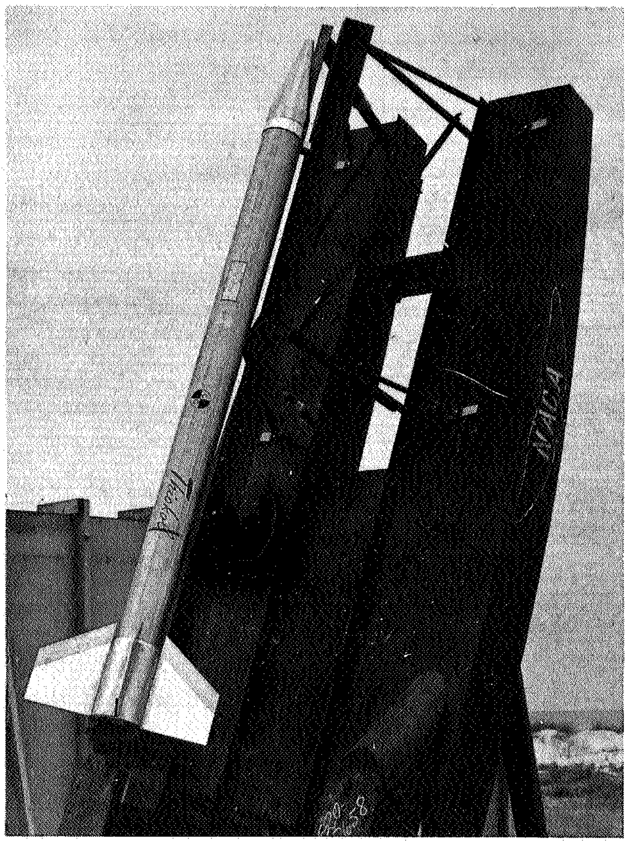


FIGURE 294. Thiokol Cajun solid-rocket motor installed on mobile launcher at Wallops for first flight test, June 20, 1956.

DEVELOPMENT OF NIKE-CAJUN SOUNDING ROCKET

The development of the Nike-Deacon sounding rocket and its initial flight test at Wallops in a joint Air Force-NACA-University of Michigan program have been discussed in Chapter 12. The substitution of the higher performance Cajun motor for the Deacon followed naturally. The possibility of increasing the performance of this rather simple solid-rocket system was eagerly anticipated by the potential users in the IGY program. In fact, J. A. Van Allen offered to share the cost of developing the Cajun motor and combining the initial orders.[3] The motors were developed solely by NACA funding, but as soon as they were available, the University of Michigan was given priority in delivery so that it was possible to flight test a Nike-Cajun system only 16 days after the initial flight test of the Cajun motor.

3. Letter from J. A. Van Allen, State University of Iowa, to Joseph A. Shortal, Oct. 18, 1955, regarding procurement of improved Deacon motors for IGY.

The Department of Aeronautical Engineering at Michigan, again represented by F. F. Fischbach, W. H. Hansen, and L. M. Jones, received further support from the Air Force Cambridge Research Laboratories to provide Nike-Cajun vehicles for its IGY program. All hardware, from the Nike fins to the nose cone attachment, was included, and attention was given to simplifying the design for ease of production. The Nike fin assembly had already been simplified for mass production by Langley engineering personnel, and the same design was adopted by Michigan. Magline, Inc., one of the contractors who had supplied these assemblies to the NACA, also became the supplier for Michigan. The assemblies consisted of four cast magnesium hinged quadrants to which four magnesium fins were welded. The assembled quadrants, except for one hinge pin, were wrapped around the nozzle of the Nike, and the final hinge pin was then inserted. A locking ring held the assembly in place.

The fin assembly for the Cajun, as developed by Michigan, utilized a unique technique. Whereas Langley had machined the tapered Cajun fins from solid material and then welded them to a cylindrical shroud, Michigan had special aluminum extrusions made that combined a fin and a quarter of the shroud in a solid piece. The four quarters were then connected by full-length hinge pins, as with the Nike assembly. The principal machining required after cutting a piece to the proper length was to shape the leading edge and to cut the hinge. The leading edge of the fins on the Cajun motor was capped with a 0.032-inch inconel sheet extending about 2 inches behind the leading edge. The caps were to protect the sharp leading edge from destruction by aerodynamic heating.

For the IGY program, Michigan ultimately procured hardware for approximately 30 Nike-Cajuns to be used by various experimenters. In addition, Michigan obtained a number of Nike launchers for use at the different launchsites, one of which was located at Wallops. The launcher is shown in figure 295 with the first Nike-Cajun sounding rocket mounted on it for the initial flight on July 6, 1956. The vehicle contained an 11-degree conical nose section 47 inches in length and 7.8 inches at its maximum diameter. It was connected to the 6.5-inch rocket motor with a short converging section. The nose cone contained a DPN-19 beacon for radar tracking, and the Michigan falling sphere with omnidirectional accelerometer, to determine density of the upper atmosphere. The nose cone, including instrumentation, weighed 55 pounds. A maximum altitude of 426,000 feet was reached with the 75-degree launch angle. It was calculated that this value would have been 490,000 feet if a 90-degree launch angle had been used.

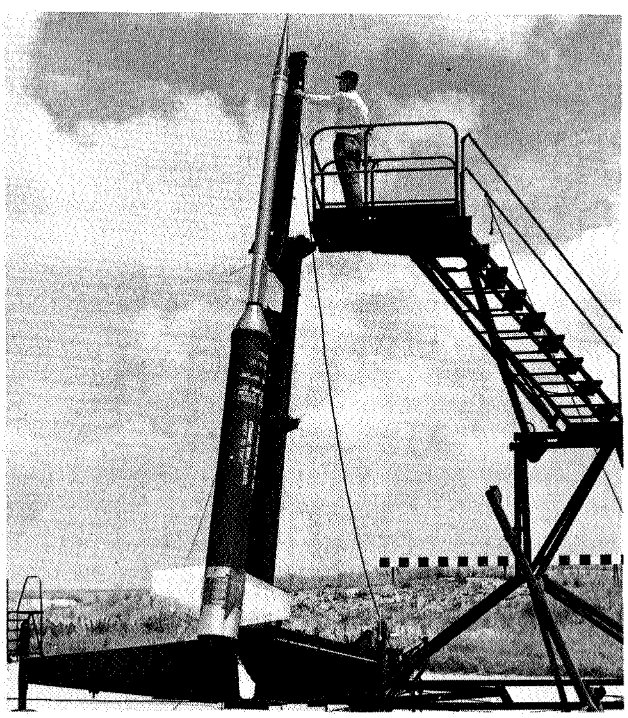


FIGURE 295. Technician Durwood Dereng checks elevation angle of first Nike-Cajun sounding rocket on standard Nike launcher at Wallops for initial test, July 6, 1956.

In this flight, there was a delay of 8.9 seconds between burnout of the Nike and ignition of the Cajun. The loads, temperature, and altitude were affected by the delay time used. In this test, the Nike accelerated the vehicle to Mach 3 in 3 seconds, after which it separated from the Cajun stage. The Cajun stage then decelerated to Mach 2.3 as it climbed to 26,000 feet at the end of 12 seconds, and then accelerated to Mach 6.4 at an altitude of 40,000 feet. Calculations indicated that the optimum coast time between these two stages was 14 seconds, but there was less than a one-percent variation between 8 and 18 seconds (ref. 13).

The Nike-Cajun sounding rocket was used extensively during the IGY, and was to see extensive use by the NASA Goddard Space Flight Center, which was to provide a total of 301 vehicles for many different users during the years between 1959 and 1968 (ref. 14). The vehicle surely lived up to the expectations of its early proponents and was certainly the workhorse of the IGY and early NASA era.

LOKI SOLID-ROCKET MOTOR

The Loki solid-rocket motor was a small high-performance motor developed by the Jet Propulsion Laboratory for Navy BuOrd. It was 3 inches in diameter and 66 inches in length, and weighed 18 pounds, including 13 pounds of propellant. It developed 3,340 pounds of thrust over a burning period of 0.8 second. Its short burning time made it a desirable rocket for achieving high velocity at a low altitude.

Under a contract with Air Force WADC, Wright Field, Ohio, William Bollay of the Aerophysics Development Corporation developed the Hypersonic Test Vehicle (HTV) from a two-stage cluster of these motors. With a cluster of seven Loki motors as the first stage, and four Lokis as the second stage, a 10-pound test model could be propelled to about Mach 7.0 at low altitude for aerodynamic heating research. A number of different vehicles, all containing combinations of Loki motors, were studied by ADC for the Air Force. The HTV test vehicle contained a tape recorder for data recording, which was recovered after impact with the aid of a small radioactive source. The HTV vehicle was designed primarily for use at White Sands Proving Ground (refs. 15 and 16).

R. R. Gilruth had learned of the Loki and the planned HTV in 1954, and was impressed with this simple approach to hypersonic flight testing. He tried to interest PARD engineers in exploring its usefulness but found little enthusiasm for these two clusters of a total of eleven rocket motors, particularly after word was received that the reliability of a Loki motor was only 90 percent. The motor was designed for top performance, with reliability a secondary consideration. Nevertheless, 70 Loki motors, 50 for Langley and 20 for Lewis, were requested from BuOrd on June 8, 1954. IRD personnel were interested in the tape recorder, and steps were taken to procure one for examination.

The Lewis Laboratory was more impressed with the promise of Loki than was Langley, and decided to try some as a part of the air-launched rocket program at Wallops. Lewis engineers assembled a two-stage system of three Lokis in the first stage and a single Loki in the last stage, and launched it from an airplane over Wallops on December 13, 1955. The flight was quite successful, and a Mach number of 9.5 was reached at an altitude of 38,000 feet; but the system was too small to provide meaningful data, and its development was not pursued further.

The Loki motors were also used by Langley in a couple of projects. In one application, discussed in Chapter 12, two Lokis were mounted as simulated jet engines at the wing-fuselage juncture on an E15 airplane stability model. In another system, flown to test the functioning of a gyro-actuated firing system, a Cajun motor was used as a booster, with two Loki motors in the second stage.

In still another program, an attempt was made to make use of the Loki's high acceleration to obtain flight data on the burning of typical metals. A Cajun-Loki combination was designed and flown, but with no success. The first model, shown in figure 296, was flown on August 1, 1956, but the Loki stage was unstable. The standard fins on the Loki were used, but were not adequate at the high Mach number of this flight. Although this defect was corrected in later flights, no ignition of the nose cone was obtained and the project was terminated.

The most extensive use of Loki rocket motors was to be in the synoptic meteorological program at Wallops in later years. Several versions of the Loki were to be constructed by several different manufacturers.

FIGURE 296. Cajun-Loki test vehicle for research in aerodynamic ignition of metallic cone. Vehicle is shown on mobile launcher, August 1, 1956.

DOUGLAS F5D-1 SKYLANCER AIRPLANE

The flight investigation at Wallops with models of the Douglas F4D-1 Skyray airplane has been discussed in Chapter 9. This investigation indicated that the drag could be reduced as much as 28 percent at transonic speeds by thinning the wing-root fillet and reducing the thickness of the wing and vertical tail. Equivalent bodies of revolution representing the modified airplane were flown in the Wallops Helium Gun. The Navy's BuAer was impressed with these results and authorized Douglas to apply them to the full-scale airplane in a version designated XF4D-2, which was later changed to F5D-1. On December 11, 1953, BuAer asked the NACA to test a scaled model of the F5D-1 airplane, and the NACA agreed to do so with the issuance of RA A73L127 on January 29, 1954.

Two scaled models were flown at Wallops—the first on December 13, 1955, with a double Deacon booster, as shown in figure 297. A maximum speed of Mach 1.64 was reached. The drag coefficient of the F5D-1 was shown to be a maximum of 0.025 at Mach 1.1, a reduction of about 33 percent from that of the original F4D-1 airplane, a somewhat larger improvement than had been predicted from the Helium Gun tests (ref. 17). The second model in the series was flown to determine the longitudinal trim change that resulted when rocket racks enclosed within the fuselage were extended in flight. Only a slight trim change was noted (ref. 18).

The full-scale airplane prototype was flown on April 21, 1956, and exceeded the speed of sound soon afterward. Only a small number were ordered, however, because of a lack of funds (ref. 19).

REPUBLIC F-105 AIRPLANE WING FLUTTER INVESTIGATION

The investigation of potential flutter possibilities at transonic speeds for the wings of such airplanes as the Convair F-102, North American F-100, and Chance Vought XF8U-1 have been discussed in earlier chapters. The D18 flutter vehicle was used in the tests. The use of a simpler vehicle, the D37, in flutter tests of the wing of the Grumman Rigel missile has been discussed in Chapter 10. At the request of the

FIGURE 297. Rocket model of Douglas F5D–1 airplane, shown on mobile launcher with double Deacon booster, December 13, 1956.

Air Force, three models of the wing of the Republic F-105 airplane were likewise tested with D37 types of vehicles.

The first test was made on October 20, 1954, and the second on December 20, 1954. A Cordite motor served as the fuselage of the test model as well as the sustainer, as shown in figure 298. A 3.25-inch rocket motor was used as the booster. In the interest of conservatism, the test wings had torsional stiffness 76 percent that of the scaled airplane value. When neither model indicated any flutter problem, a third model was constructed with only 50 percent of the scaled stiffness, to give a further indication of the margin of safety existing with the airplane. This model, flown on July 25, 1955, likewise showed no evidence of flutter for the airplane. Some high-frequency oscillations were noted in the flight records, but these were believed to be associated with a local weakness in the model construction and not to be indicative of the airplane's behavior (ref. 20).

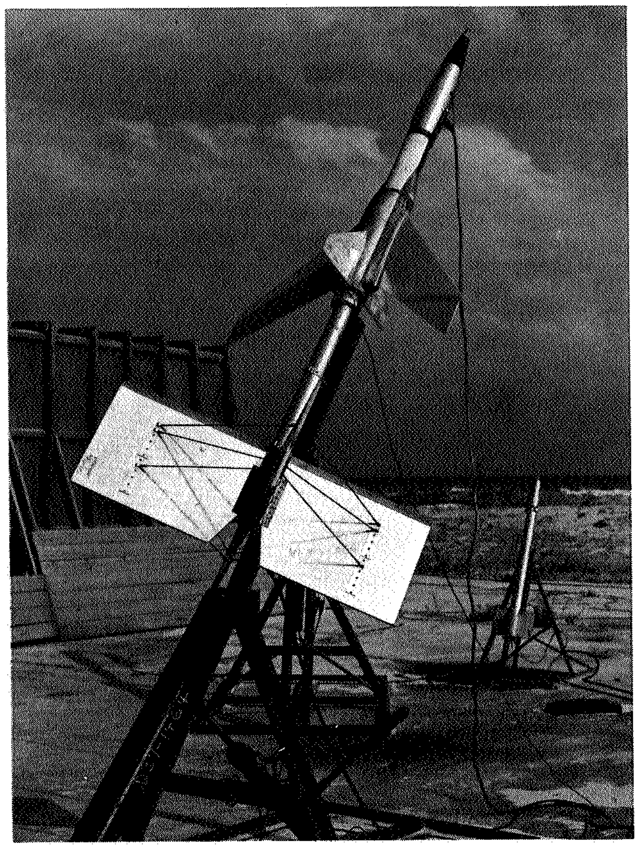


FIGURE 298. View of D37 simplified rocket model used on December 20, 1954, for flutter test of model of Republic F–105 airplane wing. A 3.25-inch test rocket may be seen in the background.

CANADIAN AVRO CF–105 ARROW AIRPLANE

In the spring of 1956, the NACA was called upon for assistance with a rocket model program underway at the Canadian Armament Research and Development Establishment (CARDE) range in Canada. As part of the program to obtain aerodynamic data for the AVRO CF-105 supersonic fighter airplane under development by A. V. Roe, Ltd., of Canada, for the Canadian Department of Defense, a series of scaled models was being flown at the CARDE range. The models were boosted by single-stage Nikes, whose motors were supplied by the USAF, who also had an interest in this airplane. The radar crew at CARDE were unable to pick up the model on their scope until several seconds after maximum speed had been reached, i.e., after Nike motor burnout. This was not acceptable to AVRO, and a visit was made to the NACA in April 1956. Upon learning from Krieger that the Wallops radar crew regularly "got on" a Nike booster before it burned out, the Canadians asked the NACA to let them launch two of their models from Wallops. Approval was given, and the two models were launched successfully on May 9 and 15, 1956.

The first model to be launched is shown in figure 299. The models flown at Wallops were zero-lift drag models, but later models were to be flown with pulsed controls in dynamic stability tests. All of the equipment, including the instrumented models, the booster, and telemeter receiver were brought to Wallops by the AVRO crew, which consisted of nine AVRO representatives and one CARDE range representative. Wallops provided radar tracking and photographic coverage.

The booster fin assembly used with the Nike motor was quite different from those used at Wallops before in that it was made of a riveted aluminum sheet, as in airplane construction. The model also had some riveted sections.

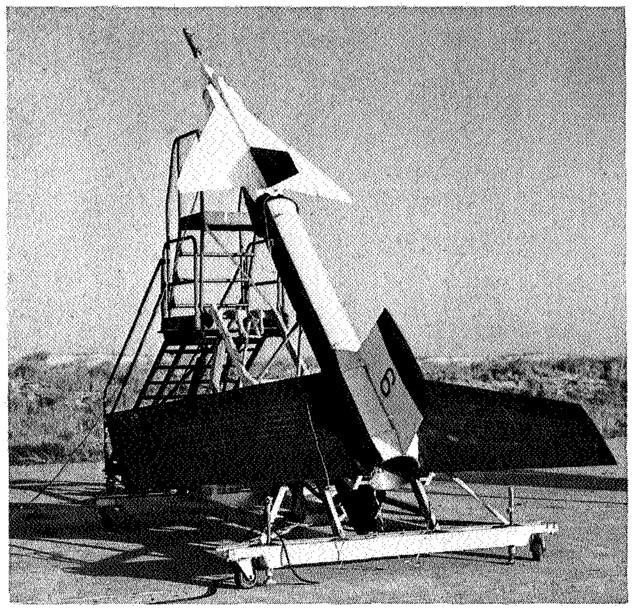


FIGURE 299. Rocket model of AVRO CF–105 Arrow airplane, shown with Nike booster on special launcher for test at Wallops, May 9, 1956.

In the two flights at Wallops, the radar operators were "on" the model well before booster burnout, and tracked the test model to splash. Needless to say, the Canadians were impressed. In fact, they asked if NACA men could help them at CARDE if they could not duplicate this tracking achievement (ref. 21). This proved to be unnecessary.

The telemeter records of the flights contained numerous oscillations in roll, sideslip, and pitch; and with later analysis stability characteristics were deduced from them. D. D. Ewart, AVRO aerodynamicist at Wallops for the test, later returned to Langley for assistance in analysis of these complicated motions. Little did he realize that 3 years later he was to return to Langley as an employee of the NASA Space Task Group on the Mercury Project and a member of the group of 25 Canadian and British engineers who emigrated to the United States and joined NASA after the CF-105 airplane had been canceled (ref. 22).

TRACKING OF ARMY GUN-LAUNCHED ROCKET PROJECTILES

Under a contract with the Army's Picatinny Arsenal, Armour Research Foundation of the Illinois Institute of Technology was assigned responsibility for developing a 70-mm rapid-fire, gun-launched rocket for high-altitude antiaircraft use. Armour furnished the rocket hardware, and Thiokol Chemical Corporation loaded the cases with propellant.

As a part of the development, Army Ordnance, on July 26, 1954, requested the NACA to track 15 rounds to be launched from a gun at Wallops. The NACA agreed to the request, and a gun was shipped to Wallops and set up on the launch pad with the Doppler radar to one side and an SCR-584 radar in a trailer about 50 feet to the rear. The firings at Wallops were made to provide data at high angles of elevation.

The rounds, various modifications of the T-231 70-mm HEAA projectiles, were spin-stabilized and were accelerated while in the gun barrel by a powder charge, as with normal projectiles. As the round left the gun, the internal rocket was ignited and provided additional velocity for the next 1.5 seconds.

The first 10 rounds were fired during October 1954 under the direction of Armour Institute, and the last 5 were fired on April 25, 1955, for Picatinny Arsenal directly. Several modifications to the rounds were represented in the different firings. Some of the rounds tumbled after they left the gun, because of insufficient stability; but the overall program was quite successful. The velocities and trajectories of all rounds were calculated from the radar data and were transmitted to Armour and Picatinny. In addition, the drag coefficients for some of the rounds were computed from the Doppler radar data. These data were helpful to the Army in development of this projectile and again demonstrated the versatility of the Wallops range (ref. 23).

PREFLIGHT JET DROP TESTS OF AVCO TEST VEHICLE

It has been mentioned earlier in this chapter that Avco Corporation was one of two contractors assigned to develop nose cones for the Atlas and Titan ICBM's. As part of this development, Avco subcontracted with Beech Aircraft Company to construct a flight test vehicle to be used to study the dynamic behavior of the nose cone in free flight at speeds up to Mach 2. The full-scale vehicle was 60 inches in diameter and 200 inches in length, and was essentially a fin-stabilized cylinder with a round nose.

The plan was to drop the vehicle at high altitude from within the bomb bay of a Boeing B-52 bomber. After clearing the airplane, the vehicle would be accelerated to Mach 2.0 by an internal rocket motor, after which the nose cone would be separated and its behavior recorded. The Air Force requested drop tests of a 1/30-scale model of this vehicle from a simulated B-52 bomb bay in the Wallops Preflight Jet.

The problem of releasing stores from within bomb bays at transonic and supersonic speeds and the development of methods for studying the problem with dynamic models have been discussed in Chapter 12. In the present tests, in which the vehicle was to be simply released rather than ejected, first-time use was made of the scheme of accelerating the parent airplane vertically to make up for lack of complete similitude when the light-model technique was employed. A few tests were also made with the heavy-model simulation, for comparison. Only a portion of the B-52 airplane was simulated, and it was attached to an overhead beam with a strut that could be accelerated upward by a pressure cylinder. The model was mounted with a positive angle of attack, and the lift on the wing contributed to the vertical acceleration required. The beam was attached to the top of the 27-inch nozzle of the Preflight Jet.

The tests in the Preflight Jet were made at Mach numbers of 0.64 and 0.93. Fourteen releases were made in July 1956. A disk containing a narrow slit was rotated in front of the camera to enable stroboscopic pictures of the test to be recorded on a single sheet of film. Lighting of the model was achieved by a series of flashbulbs timed to overlap and provide continuous illumination for about 100 milliseconds. Good pictures of the drops were obtained, and the vehicle was demonstrated to be safe to drop under the anticipated conditions. A lightly damped oscillation in pitch was noted after release (ref. 24).

That the technique was a good one was demonstrated when full-scale flight tests agreed well with the model tests. According to W. B. Stephenson, Avco Group Leader, "It appears that the PARD technique for store separation gives good predictions of what will happen to the full scale. Photos from wing pods showed the motion of the store after release to be in good qualitative agreement with the Fastax film from the model test."[4]

PROJECT HUGO: HURRICANE PHOTOGRAPHY BY NIKE-CAJUN SOUNDING ROCKET

Because of its location on the East Coast, Wallops was selected as the site for developmental firings of Nike-Cajun sounding rockets equipped with recoverable cameras for photographing hurricanes from high altitudes. Furthermore, Wallops at that time was the only range with experience in using the Nike-Cajun.

The U. S. Weather Bureau had been authorized to conduct research leading to improvement in the prediction of hurricanes and their location, movement, and intensity. During an Aerobee firing on October 5, 1954, a previously undetected hurricane was accidentally seen on a photograph taken from high altitude over White Sands Proving Ground. The hurricane was in the Gulf of Mexico off the coast of Texas and a short time later dumped six inches of rain on Brownsville, Texas.

4. Letter from W. B. Stephenson to Joseph Shortal, Aug. 17, 1956, regarding drop test vehicle.

This demonstrated ability of a sounding rocket to detect hurricanes led the Weather Bureau to ask the Office of Naval Research (ONR) to assist the Bureau in exploring this method further. The request led, in turn, to participation of the NACA in the program in response to a request from F. W. Reichelderfer, Chief of the Weather Bureau, on November 14, 1955.[5] Reichelderfer was a member of the NACA at that time and had been since 1939.

At ONR, Lieutenant Commander John E. Masterson of the Geophysics Branch was designated Project Officer and was the main Navy contact with Wallops during the program. The project was named Hugo. Preliminary plans were discussed at a meeting in his office on October 20, 1955, with the NACA represented by W. J. O'Sullivan, Jr., Naval Research Laboratory (NRL) representatives John W. Townsend, Jr., and Leslie H. Meredith were also present at the meeting ref. 25). Townsend and Meredith had been involved in the earth-photography project with the Aerobee at White Sands. ONR backed up the Weather Bureau's request to the NACA by one of their own on November 17, 1955.[6] Research Authorization O23L15, dated January 27, 1956, was subsequently issued under the cognizance of the Subcommittee on Meteorological Problems of the NACA Committee on Operating Problems.

The plan was to use Nike-Cajun sounding rockets fitted with fins and adapters of the type being procured by the University of Michigan for the Nike-Cajun vehicles in the IGY program, and to launch them from Wallops. Wallops was to assemble and launch the vehicles and, from radar tracking, notify the search airplane and recovery ship of the anticipated impact point of the nose cone. ONR contracted with New Mexico College of Agriculture and Mechanic Arts to develop the complete nose cone system containing a recoverable section housing motion picture cameras. A recovery parachute was to be used, plus tracking and location aids. New Mexico was given this assignment because of prior work of a similar nature at White Sands. New Mexico assigned R. Gilbert Moore as project engineer. NRL was assigned an advisory role on the instrumentation aspects. The Atlantic Fleet was assigned the task of recovering the nose cone containing the cameras. R. L. Krieger was designated as chief contact at Langley, and he in turn designated J. C. Palmer as the Wallops contact (ref. 26). The project at Wallops was given the designation B120.

Four launchings of Nike-Cajun sounding rockets were planned from Wallops during the period July–September 1956. The first two were to be clear-weather firings to uncover any defects in the system. The third firing was to be scheduled after passage of a cold front, and the fourth, after passage of a hurricane. A recovery exercise for the Navy forces was scheduled for May 1956, during which dummy packages dropped from an airplane would be located and recovered from the ocean off Wallops.

The first of the hurricane photography rockets was launched at Wallops on July 24, 1956, as planned. Figure 300 shows the rocket on the I-beam launcher. In the flight test, the rocket vehicle performed as planned, but something went wrong within the recovery package and it was not located. It was to be almost a year and a half before a second attempt was made.

It will be noticed that the vehicle in figure 300 closely resembles the Nike-Cajun flown by the University of Michigan. (See Figure 295.) The nose cone of the hurricane vehicle had the same cone angle (11 degrees), but was longer and tapered to a larger diameter. The maximum diameter was 9 inches and the overall length was about 63 inches. The weight of the nose cone was approximately 75 pounds for the hurricane rocket, as compared with 50 pounds for the University of Michigan nose cone. A description of the performance of this first hurricane rocket was included in the report on the basic Nike-Cajun system (ref. 27).

In the launch operation, the Nike booster rocket motor was ignited as usual and separated from the Cajun at burnout. A 13-second delay squib in the Cajun, energized at zero time, ignited the Cajun 10 seconds after the Nike burned out. After Cajun burnout, this stage, with the nose cone attached, coasted to an altitude of 406,000 feet. During the early part of the downward leg of the trajectory, the

5. Letter from F. W. Reichelderfer to H. L. Dryden, Director, NACA, Nov. 14, 1955, requesting assistance in Nike-Cajun firings at Wallops for development of hurricane photography technique.
6. Letter from ONR to Director, NACA, Nov. 17, 1955, requesting NACA assistance in Nike-Cajun launchings from Wallops Island.

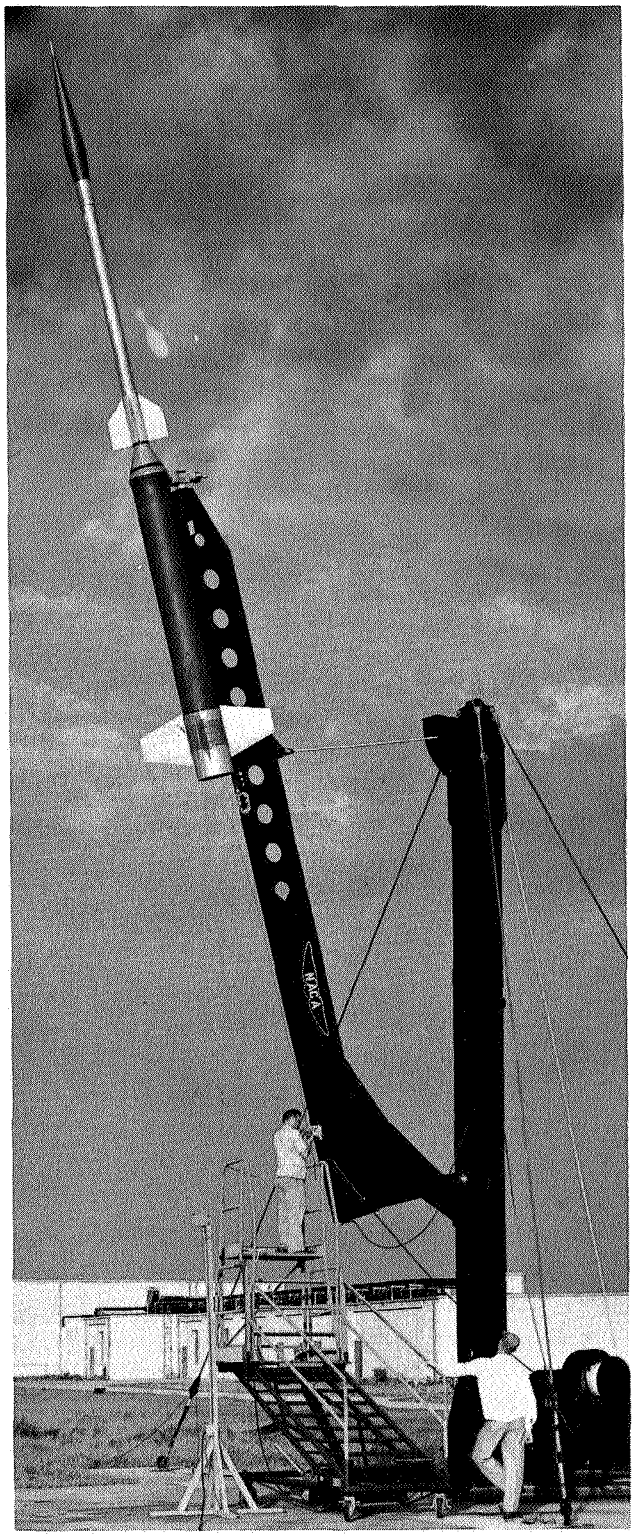


FIGURE 300. Technicians Harry Bloxom and Durwood Dereng adjust launcher elevation angle for first Nike-Cajun hurricane rocket, in preparation for launch at Wallops, July 24, 1956.

nose cone was separated from the rocket motor by an explosive bolt, and then the forward conical section was separated in a similar manner from the nose section, leaving a keg-shaped section 9 inches by 28 inches, containing the cameras to be recovered. A recovery parachute was opened at about 25,000 feet to slow the velocity to one safe for impact with the ocean. Two 16-mm aircraft gun cameras (GSAP type), as modified by NRL for the earlier Aerobee flights, were mounted side by side in the keg section, looking in opposite directions through holes in the sides of the nose cone. They began photographing at a rate of 8 frames per second when the nose cone was separated from the rocket motor case.

The recovery parachute was colored and metallized to aid visual and radar tracking during descent. Chaff was ejected from the nose cone for the same purpose, and dye markers were released upon impact with the water. A ruggedized version of a Rawinsonde transmitter, operating on a frequency of 1685 mc and a power of 10 watts, was carried on board. In addition, the package carried a SARAH (Search and Rescue and Homing) beacon developed by the British as an aid in rescuing airmen from the sea. This beacon operated on a frequency of 237.1 mc, with a power of 15 watts. The SARAH antenna, an erectable one similar to a flexible steel tape, popped open when the nose cone was separated.

Location and recovery of a dummy package was practiced by the Navy forces in May 1956. A destroyer was used as the recovery vessel, but since it was stationed 20 miles from the expected impact area, an airplane was used in addition, to aid in locating the package. In these practice trials, the package was dropped from a second airplane at an altitude of 18,000 feet. The destroyer was able to home on the SARAH signal from 14 miles away while the package was airborne, and from 8 miles after it was in the water. Homing antennas were also on the recovery airplane. Additional tests were made without an airplane but with the recovery package dropped overboard by a second destroyer. Seven nose keg drops like this were made to test the various components of the system.

In the first flight test, on July 24, 1956, the trajectory and calculated impact point were determined from tracking data available only from skin tracking by the SCR-584 radar. In this test, a range record was set for skin tracking of this size of target when the radar followed the vehicle to a range of 61,500 yards. From this track, the expected impact point was determined; but, as noted earlier, the recovery forces were unable to locate the package.

Krieger suspected that the trouble lay in the inability of the flexible SARAH antenna to survive the high aerodynamic loads it was exposed to at the time of ejection. A simulated test to confirm this theory was made in the 27-inch nozzle of the Preflight Jet, with operation at a velocity of 570 feet per second and a dynamic pressure of 387 pounds per square foot. The antenna was ejected into the airstream and photographed with a Fastax camera. "The antenna fluttered violently and broke into small pieces" (ref. 28).

After some modifications to the system, a second launching was attempted on December 23, 1957. In this test, the second stage broke apart. An intensive investigation of the design of the second stage, including the nose cone, was undertaken and a completely redesigned nose cone was adopted. The double cone shape was changed to that of a simple ogival nose on a cylindrical body having the same diameter as the Cajun motor shown in figure 301. With this change, the recovery package became a simple cylinder.

The final two launchings of the package with this design were made on December 5, 1958. For these two flights, a radar beacon was added to the nose cone. In the first attempt, the beacon went out and the nose cone could not be located, but in the second test everything worked as planned. By that time, the Reeves Mod II radar had been installed at Wallops, and it followed the beacon in the nose section for 90 percent of its trajectory, enabling an accurate determination of the impact point. The SCR-584 was used as a backup with skin tracking. When the Navy airplane was dispatched to this point, it reported a strong signal from a Mighty Mouse transmitter within the camera package. The airplane circled over the area until the destroyer arrived and picked up the camera package in good condition. There was a high wind on this day, and the launch vehicle was thrown somewhat off course. In addition, the camera package was blown along the surface of the ocean about 9 miles during the 2-hour period required for the ship to arrive in the area and retrieve it.

The Mighty Mouse beacon was the SARAH with a different antenna. After the structural weakness of the flexible, erectable, SARAH antenna had been demonstrated, it was replaced by a fixed exposed loop antenna, potted permanently in place in the nose cone.

The recovered film was processed by NRL and turned over to the Weather Bureau for analysis (ref. 29). Both cameras obtained good pictures of a circular area of the earth about 670 nautical miles in radius, centering near Wallops. This area included the east coast of the United States from Maine to Florida, the Great Lakes, and the Atlantic ocean. The nose cone was rolling about its long axis in flight and, in addition, was given a slight wobbling motion by the separation mechanism. Most of the pictures were of the clouds above the ocean, but as the wobble increased with time, more land area came into view. By matching consecutive pictures and analyzing the resulting mosaic, it was possible to identify the azimuth angle, altitude, and time for each picture. Weather data from ground stations over the entire area were obtained for corresponding times, to enable correlation with the photographs. Although there was no hurricane at the time of this flight, the considerable cloud cover with some clear space gave the meteorologists ample data for analysis and research. The experience gained and the photographic techniques developed with this one successful flight were to be of great benefit in the planning and execution of the first worldwide weather photographic satellite, *TIROS I*. It is also noteworthy that Wallops was to be the official receiving station for such pictures transmitted by satellites.

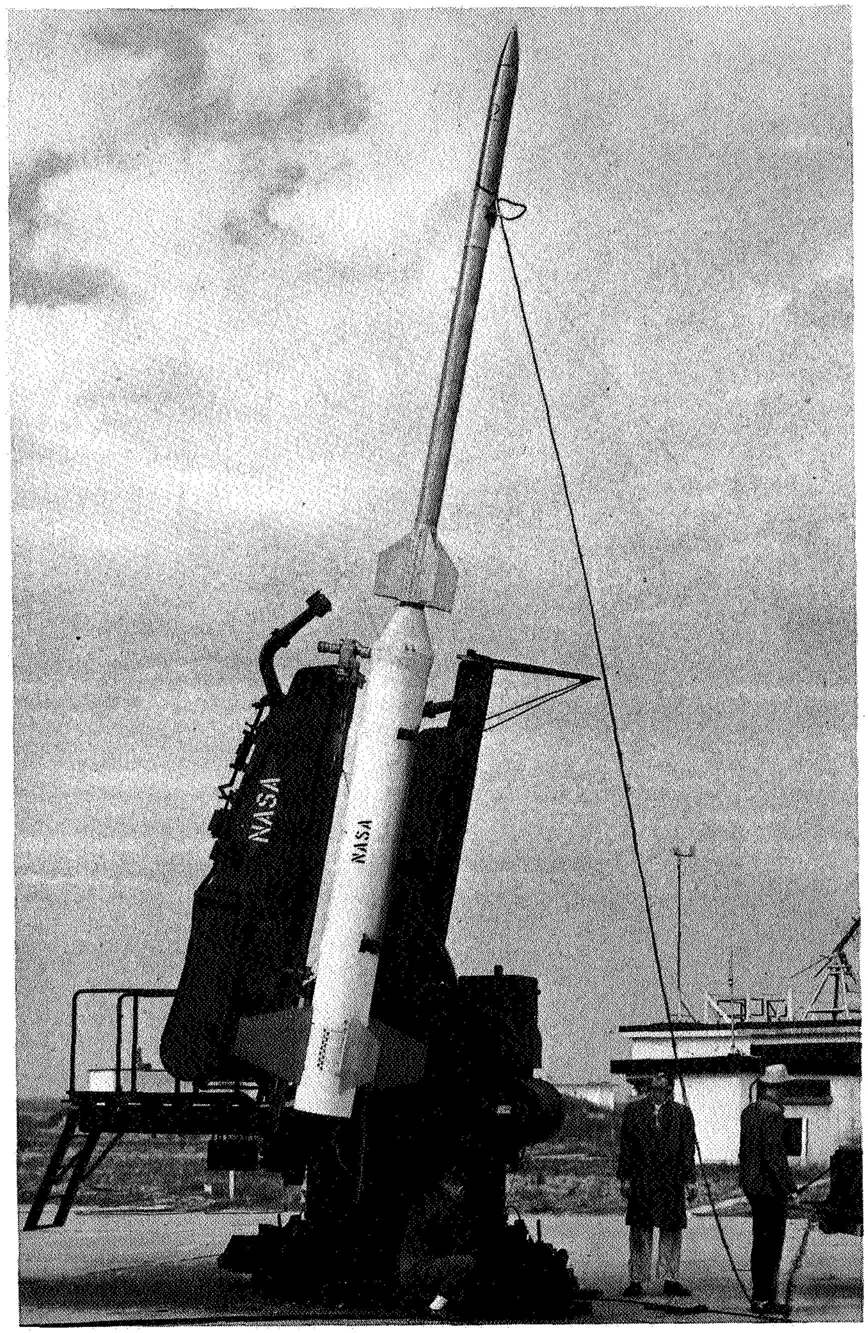


FIGURE 301. View of launch area at Wallops, December 5, 1958, as technicians G. Cutler, E. Collona, and D. Dereng (left to right) adjust Terrier launcher for test of redesigned Nike-Cajun hurricane rocket.

The difficulties with recovering the camera from the flights in 1956 and 1957 led Krieger to look into other recovery methods. Although the results of Krieger's research were not applied to the Hugo project, they were of general interest. Krieger's new approach was to eliminate the need for a parachute to lower the camera package safely to the ocean, and to do so by developing containers that could survive impact while descending at their terminal velocity.

The first design consisted of a simple, lightweight cylinder with a conical nose and a large-diameter stabilizing flare, as shown in figure 302. It was reasoned that this shape might survive a point-first water impact. A preliminary trial of this shape was made on July 28, 1958, with only a Cajun propulsive system. An NACA boat was stationed offshore from Wallops for recovery, and tracking was attempted by the Wallops Rawin equipment. In the test, the nose cone entered the water intact, and no evidence of any breakup was seen after it entered the water, but it was not recovered. It was conjectured that the pointed body buried itself in the soft bottom of the sea.

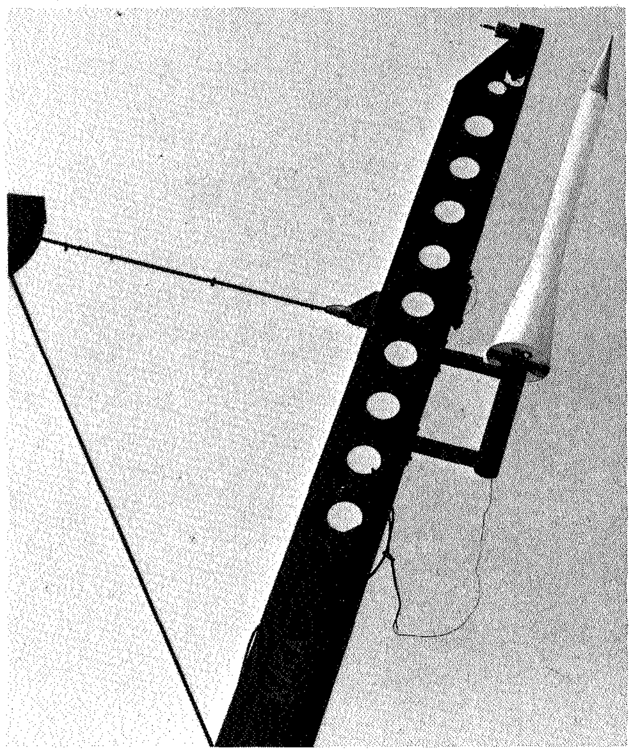


FIGURE 302. Rocket test model designed to survive water impact for recovery. Model is shown in mounted position at Wallops, July 28, 1958.

The second approach to a simple camera recovery package was to encase the camera in shock-absorbing material which would also provide buoyancy. Such a package was developed under contract by Experiment Inc., Richmond, Virginia, for the NACA. The experimental package was dropped from an airplane into the ocean near Wallops on September 12, 1958. Release was at a high enough altitude to ensure that terminal velocity was attained before impact. This method was demonstrated to be feasible but was not developed further because a successful recovery was made with the standard parachute recovery system a short time later.

COMPLETION OF GUST-LOADS RESEARCH: E39

The initiation of a gust-loads research program with rocket models at transonic speeds has been discussed in Chapter 10. This research was continued through 1957, with the launching of four additional models, all of which had cruciform wings. The initial intent of the cruciform arrangement was to allow testing of two different planforms in a single flight, but later the idea was used to obtain more data on a single shape. The first model in this series, launched on March 28, 1955, is shown in figure 303. The flight was successful, but the data were not suitable for analysis.

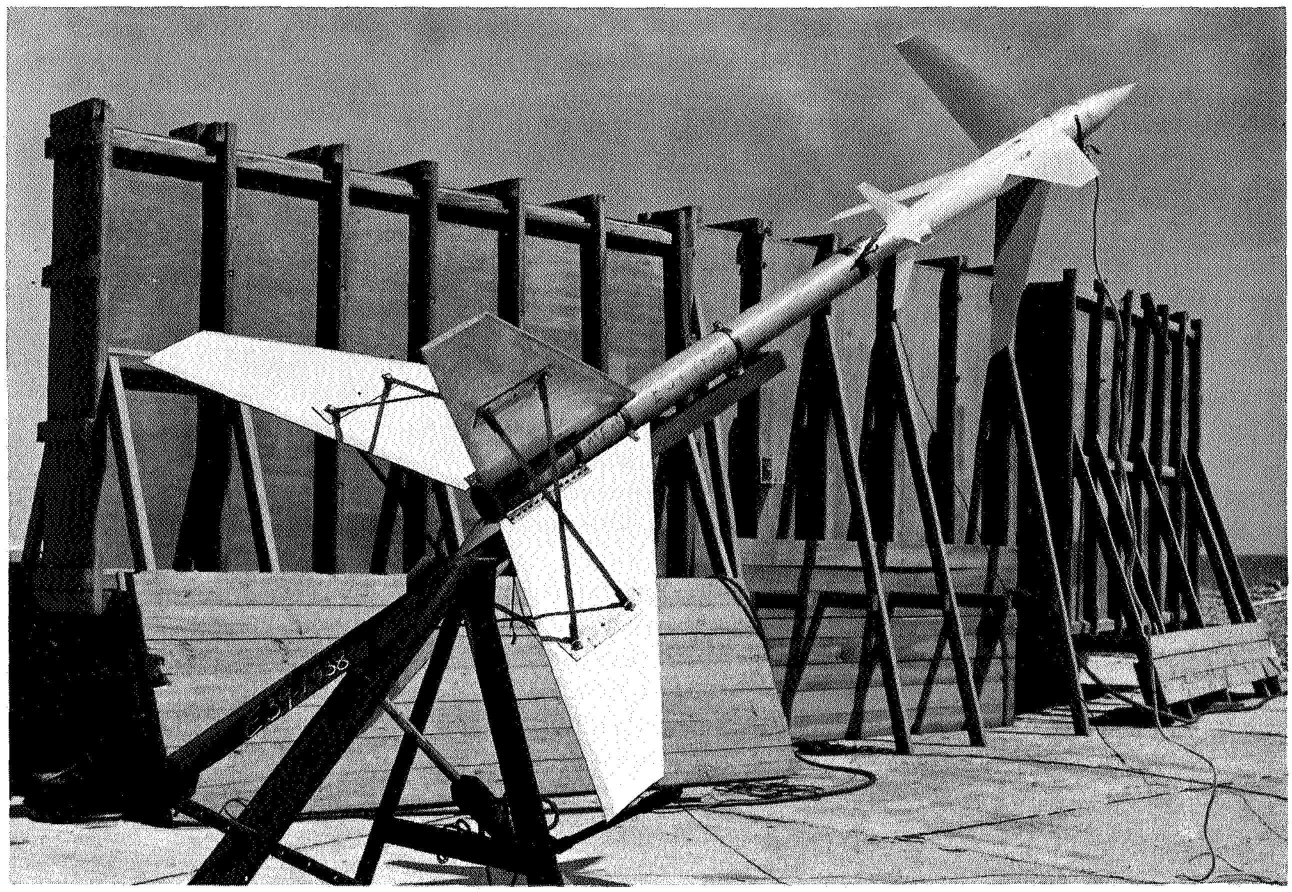


FIGURE 303. Gust loads research model with cruciform wings. View shows model with Deacon booster, ready for launch on March 28, 1955.

The second model had the same 60-degree delta wing arrangement as an earlier model (ref. 30) but was propelled by a double Deacon booster, without a sustainer, to a Mach number of 1.73. A power-spectral-density analysis of the acceleration data indicated that most of the loads due to gusts were concentrated at the natural frequency of the model in pitch. The amplification of the response was again found to be the greatest at transonic speeds, and was associated with a reduction in pitch damping for this planform. There was little effect of Mach number in the range from 1.02 to 1.67 (ref. 31).

Some additional insight into the response of rocket models to gusty air was provided by an analysis of acceleration data from 38 models flown at Wallops between 1952 and 1955. All of these models except two were flown in relatively clear air in research studies of such aerodynamic factors as drag, pitch damping, or buffeting. The two exceptions were two E39 models flown specifically to measure response to gusts, a consideration included for the purpose of comparison. In many tests in which damping or buffeting was of low magnitude, it appeared that response to atmospheric turbulence might be interfering with an accurate appraisal of the true aerodynamic factors. In search of some clue to such interference, the meteorological conditions existing at the time of each launching, as obtained by Rawinsonde balloons, were analyzed.

The important finding was that clear air was not an indication of lack of turbulence, but that atmospheric temperature lapse rate (the variation with altitude) was a determining factor. It was indicated that a lapse rate about halfway between that for dry air and that for saturated air could be considered a boundary between stable and unstable conditions, i.e., smooth and turbulent conditions. This finding explained some of the low-amplitude oscillations in buffeting and pitch-damping tests previously attributed to local aerodynamic effects, and provided an indicator that could be followed to ensure turbulence-free conditions for such aerodynamic tests (ref. 32).

LEADING-EDGE MISSILE LAUNCHER

The problems of high drag and separation difficulties with pylon-mounted guided missiles carried externally on aircraft led Paul R. Hill to propose that such missiles be carried and launched from a simple adapter extending forward from the leading edge of the wing of the aircraft. He proposed a plug-type adapter similar to those in use in rocket models at Wallops. In their design, the adapter fitted into the nozzle of the rocket motor of the stage ahead of it. Experience with successful ignition of thousands of rocket motors containing such a plug adapter convinced him that it was a feasible system. The adapters in use were designed to carry bending loads; so the only addition required for the proposed airplane application was a locking device to prevent accidental dislodgement of the missile.

Hill felt that experimentation was needed in regard to a major factor—determination of the extent of damage to a wing from a rocket blast. An actual test of launching such a missile from a wing was therefore required.

The demonstration was made at Wallops on February 1, 1955. A mockup of a section of the leading edge of an airplane wing containing the proposed missile adapter was mounted on the launching pad and several HVAR rocket motors were fired from it. The pressure inside the rocket motor during the early part of the launch period was recorded through a trailing wire attached to ground equipment. The tests indicated that the pressure at ignition rose more rapidly than in an unplugged nozzle, speeding up the get-away action. Only superficial damage was noted on the leading edge of the wing.

Next, four flight tests were made to evaluate the drag savings of such a system. A transonic airplane configuration with a sweptback wing was used. Two models had six scaled missiles at the leading edge of the wing, one model had six similar missiles hung from pylons beneath the wing, and the fourth model was flown without missiles, to provide comparison. A Mach number of 1.3 was obtained with a T42 rocket motor booster. The missiles mounted on the leading edge added less drag to the total configuration than did the six isolated missiles, whereas the pylon-mounted missiles added 50 percent more drag than that of the isolated missiles (ref. 33).

COMPLETION OF AIRPLANE WING AND BODY DRAG RESEARCH

From 1945, when Wallops' service as a test range began, to 1959, when such research was finally phased out, the rocket-model technique was used in a continuing general investigation of the drag of wings and bodies, as well as that of complete airplanes.

In the 1955–1959 period, discussed in this chapter, emphasis was placed on modifications to the area rule for supersonic application, not only for wings and bodies in combination but also for the treatment of such added items as canopies, stores, and nacelles. Finally, some basic drag data for general design use were obtained at speeds approaching Mach 4. The number of drag research models of all types flown fell drastically during the current period from the high value of 374 reached during 1953.

The effectiveness of the area rule in the design of pilots' canopies for aircraft was determined from a series of models, all having the basic F25 parabolic fuselage shape of fineness ratio 10. Five different canopy designs were tested without area-rule indentations, and with indentations corresponding to the Mach 1 area rule. The resulting longitudinal distribution of cross-sectional area for the indented models with canopies was the same as that for the basic fuselage. This was essentially the same procedure used earlier (described in Chapter 8), with an E2 body whose nose shape had been distorted to simulate the canopy of the X-3 research airplane. The canopies in the present tests were much larger, however, and the indentations were much more noticeable. (See figure 304.) All models had the standard two-stage propulsion system for F25 models, to cover a speed range of Mach numbers from 0.75 to 1.35.

The lowest drag was obtained with the canopy of highest fineness ratio located well forward on the body so as not to increase the maximum cross-sectional area. The drag increment for all of the canopies was practically eliminated at Mach 1 by the indentations used, but at higher Mach numbers little improvement was noted. The flat windshields were found to have as low a drag as a vee shape (ref. 34). This finding was in agreement with earlier tests in the Langley 8-foot and 4-foot tunnels, as presented in a paper at the NACA Conference on Aerodynamics of High Speed Aircraft, November 1–3, 1955 (ref. 35).

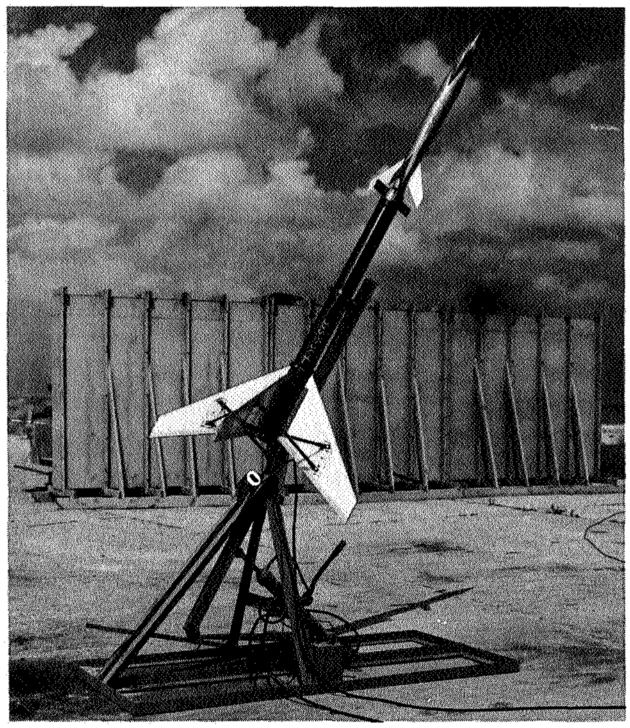


FIGURE 304. Rocket model with canopy and fuselage area-rule indentation on parabolic body. Model is shown in mounted position at Wallops, June 29, 1955.

There was general interest in application of the area rule to an airplane of the Convair B-58 type because of the many external components. One application was made by Sherwood Hoffman, who added a wing of the B-58 planform to the basic F25 fuselage. Two side-by-side or siamese nacelles were supported on pylons under each wing about midway between the fuselage and the wing tip. The fuselage had been contoured or indented to yield a total configuration longitudinal area development consistent with the supersonic area rule of R. T. Jones, applied at Mach 1.2. This model, shown in figure 305, was propelled to a Mach number of 1.35 by a single Deacon booster. The nacelles were open and the area of the stream tube was deducted from the total area in arriving at the amount of indentation. The results were compared with those from a similar model, flown earlier in the B-58 program, which had four staggered nacelles under the wing. The drag of the two models agreed at Mach 1.2, but the present model had much higher drag at transonic speeds than the earlier one. In fact, the drag of the present model was higher than that calculated from area-rule concepts, indicating the presence of additional interference effects (ref. 36).

The supersonic area rule was also applied to a model having an unswept, tapered wing with open nacelles located symmetrically on the wing at a station just inboard of the wing tips. For this case, indentations were made in both the fuselage and the nacelles to yield a smooth area distribution at a design Mach number of 1.41. This configuration gave the surprising result that the pressure drag was lower than that found previously for the same wing without the nacelles but with the fuselage indented in accordance with the same area rule (ref. 37). The total drag was higher because of additional friction drag on the nacelles. The explanation of the lower pressure drag was found to lie in the moment-of-area rule developed by B. S. Baldwin, Jr., and R. R. Dickey of Ames Laboratory (ref. 38).

M. A. Faget developed a method for contouring a fuselage or nacelle in the region of an intersection with a sweptback wing, to reduce the interference with the flow over the wing and realize more of the potential for drag reduction due to sweeping the wing. Numerous methods of achieving this goal had been proposed and, in fact, the area rule also accomplished this purpose. Faget's method was a geometrical procedure which he called a sine-cosine method. Modifications to a fuselage with a 45-degree sweptback wing were made on an F25 rocket model flown at Wallops in February 1956. The basic difference between this type of fuselage indentation and that of a Mach 1 area-rule design was that the sine-cosine method resulted in only one-third the reduction in fuselage volume. The transonic drag was somewhat lower with the area-rule indentation. When small stores were added to the wing

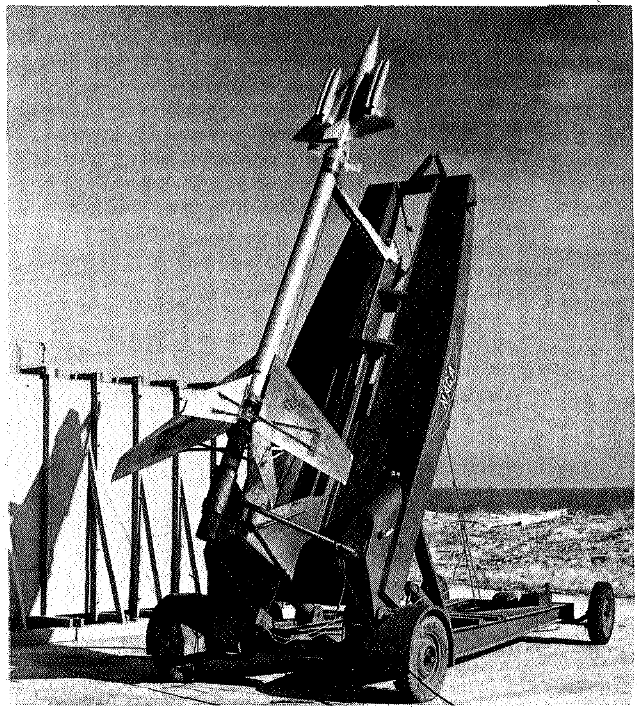


FIGURE 305. Rocket model with delta wing and twin-nacelle pods on fuselage indented in accordance with supersonic area rule. View shows model mounted with Deacon booster for flight test, February 1, 1956.

tips, however, to alleviate the flow discontinuity there, a considerable improvement over the area-rule design was achieved (ref. 39).

The application of the area rule to a tapered, sweptback wing for design Mach numbers of 1.0, 1.2, and 1.41 was investigated in another series of models in the F25 program. Although the indentations were most effective in reducing the drag at their respective design Mach numbers, the Mach number 1.2 indentation gave the lowest average drag for the Mach number range from 1.0 to 1.4 (ref. 40).

The drag penalties associated with adding external stores to wings and bodies have been discussed earlier in several chapters. The penalties for carrying rather large stores beneath indented fuselages having sweptback and delta wings now were determined in flight with several F25 models.

With the sweptback wing, a semisubmerged store was studied, (ref. 41), as well as a pylon-mounted store (ref. 42). Large interference effects were found for the pylon-mounted store in the presence of the indentation in the fuselage. The drag due to adding the cavity to the fuselage to house the semisubmerged store was small, but with the store in place the drag added was as much as twice that of a complete store tested as an isolated body.

With the delta-wing model, three different large stores of equal volume and of fineness ratios of 8, 10, and 12, respectively, were tested on short pylons beneath the indented fuselage. The drag increments from the store of fineness ratio 8 were about equal to those of the isolated store, and those for the store of fineness ratio 10 were slightly less than values for the isolated store, while those for the store of fineness ratio 12 were appreciably less than values for the isolated store, particularly at the higher Mach numbers. Agreement between experimental values for store drag and those calculated by supersonic-area-rule theory was generally poor, although the same theory showed excellent agreement with experiment for the model without stores, either with or without indentation (ref. 43).

An interesting concept in wing design was explored with two E25 drag models having unswept, tapered wings. The basic wing had a thickness ratio of 4.5 percent, and since thinner wings of cantilever construction were considered impractical, two externally braced wings of 1.78-percent thickness were investigated. One model had external braces from both the top and the bottom of the fuselage to a section of the wing about halfway to the tip. The second model had the wing located in a high-wing location, with some negative dihedral and external braces on only the lower surface. Theoretical calculations for Mach 1.1 indicated a possible reduction in total drag of the model from reduction in pressure drag of the wing associated with the reduced thickness. In the tests, the model with double braces had 15 percent less drag, while the model with braces on only the lower surface had 25 percent less drag (ref. 44). There was no evidence of flutter with either model.

One of the last series of rocket models in the drag-research program was designed to provide data on wing drag to a Mach number of 4.0. Research was under the direction of H. Herbert Jackson. All models contained an internal HPAG rocket motor and were boosted by either a quadruple Deacon, as shown in figure 306, or by a Nike booster, as shown in figure 307. The wings were mounted in a rearward location on an ogive-cylinder body of fineness ratio 19 with two small vertical fins. Two models without wings, but with four small fins, were also flown to enable an evaluation of wing drag. One of the wingless models was flown with a single Deacon-HPAG system to a Mach number of 3.5; the other reached Mach 4.0 with a double Deacon-HPAG system.

A series of five wing shapes was selected for these tests, as being representative of a Mach 4 airplane. The five included two highly sweptback wings of aspect ratio 3.0, having 5-percent hexagonal or 65A004 sections; a thin unswept wing of the same aspect ratio and 65A004.5 section; a 60-degree delta wing; and a diamond planform of the same aspect ratio as the delta wing, both with 65A003 sections.

The total drag coefficients of the configurations varied from about 0.020 for the thicker wings to 0.015 for the thin delta or diamond wings at Mach numbers approaching 4.0. The pressure drag of all wings at Mach 4.0 was determined by subtracting an estimated friction drag from the wing drag, which, in turn, had been determined by subtracting the drag of the body and fins from the total drag, allowing for the difference in number of fins. The pressure drag, so determined, agreed surprisingly well with that calculated by Newtonian impact theory (ref. 45).

COMPLETION OF INLET-RESEARCH FLIGHT PROGRAM

The general program of inlet research, discussed in Chapter 10, was completed in 1956 with a three-part effort: a study of nose inlets with bypass ducts, the extension of tests of conical-shock nose inlets to Mach 3, and the conduct of several flight tests of complete airplane configurations incorporating inlet and duct systems.

The inlet models in the bypass series were similar to the general F26 models flown earlier with single Deacon boosters. One problem with supersonic airplanes employing air-breathing engines had been to provide adequate airflow at both subsonic and supersonic speeds. An inlet designed for subsonic speeds was too large for the needs at supersonic speeds, and consequently, the excess air spilled around the inlet lip with excessive drag. One method of overcoming this difficulty was to use bypass ducts. The program at Wallops was an evaluation of a bypass system with fixed geometry that matched the flow requirements at Mach 2 and at subsonic speeds. Two bypass systems were tested: a 360-degree annular bypass, and twin bypass segments with slots. The models were tested in the Preflight Jet and in flight, and were compared with a conical-shock inlet without bypass. In the tests, it was found that the airflow requirements were adequately matched over the Mach number range; but, unfortunately, the overall drag at supersonic speeds was not improved. In fact, the inlet without a bypass had slightly lower drag throughout the speed range (ref. 46).

A series of four models with nose inlets and with different combinations of conical-shock and isentropic-compression center bodies was flight tested to Mach 3.0, as an extension of the earlier inlet research at Mach 2. The increased speed was obtained by using the four-deacon peelaway booster described in Chapter 11 and shown in figure 308. The inlets were designed for Mach 3, and the tests provided data on the behavior of such inlets over the Mach range from 1.5 to 3.0 (ref. 47).

The incorporation of an inlet and duct system into the design of a single-engine interceptor airplane was studied by Joseph H. Judd for two different engine arrangements, in an attempt to arrive at an improved airplane design. In one design, a half-conical spike inlet, located on the bottom of the fuselage beneath the wing, fed air to an engine located within the fuselage with a conventional tail exhaust. The inlet was separated from the bottom of the fuselage by a boundary-layer diverter and splitter plate. The second design consisted essentially of an engine nacelle with a conical spike, mounted

FIGURE 306. Technician Roy Hindle checks ignition wiring on Mach 4 wing-drag research model, shown with quadruple Deacon booster before launch on March 26, 1954.

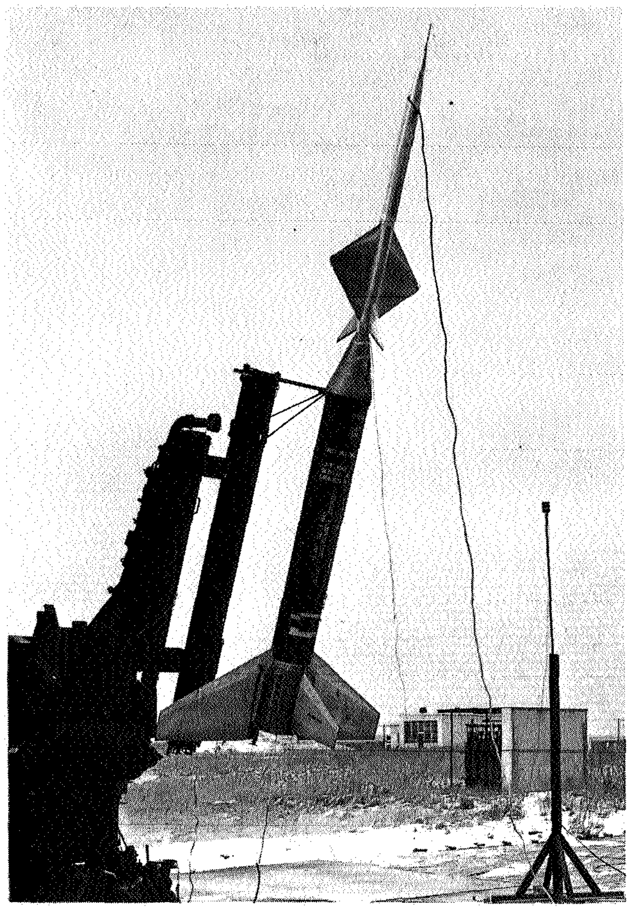


FIGURE 307. Mach 4 wing-drag research model with Nike booster, ready for flight test on January 12, 1955.

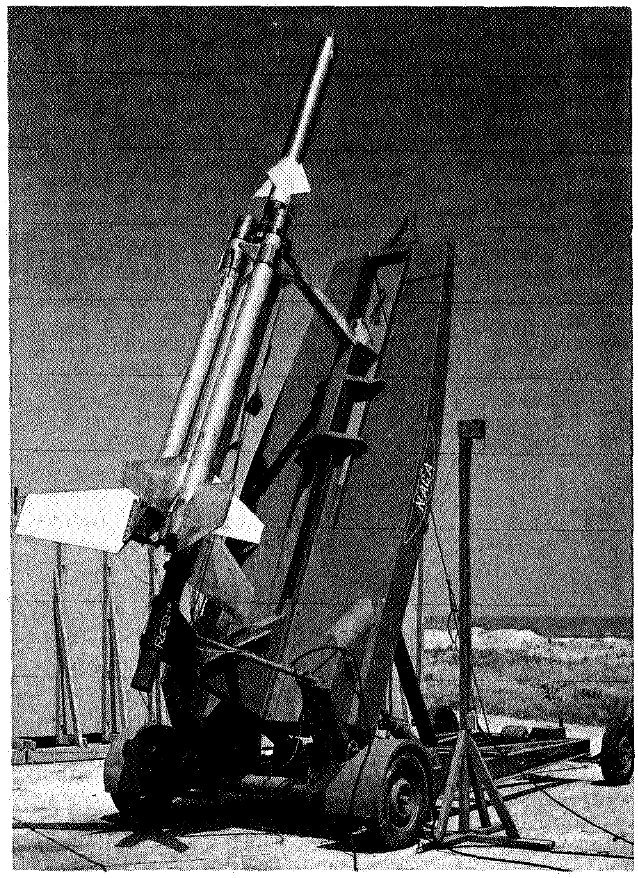


FIGURE 308. Conical-shock inlet model designed for Mach 3. Model is shown at Wallops with "peel-away" Deacon booster, June 22, 1956.

tangentially to the bottom of the fuselage without any boundary-layer splitter plate. Both models had tapered, sweptback wings, high-fineness-ratio fuselages, and conventional tail surfaces. Both models were boosted to Mach 1.9 by a single Deacon motor carried beneath the models as shown for the second model in figure 309. Both models showed about the same value of drag coefficient at supersonic speeds—0.025; but the inlet data indicated the existence of some flow separation in the circular inlet, and the need for some type of boundary layer control (ref. 48).

DRAG, STABILITY, AND CONTROL OF SHORT-SPAN MISSILES

The lateral control research program which began in 1945 with simple E5 models came to an end in 1956, with emphasis in the later years centered on controls for small air-to-air guided missiles, particularly controls having low actuating forces. The interest in short-span missiles stemmed from the necessity for internal stowage of missiles in supersonic aircraft to avoid the high drag penalty for carrying them externally. Interest in simplified controls was related to increased reliability as well as smaller size.

The drag and stability of a series of missiles having minimum span were determined from Helium Gun tests. Four combined lift and stabilizing surfaces were fitted to the rear half of either a regular parabolic body or one having its afterbody necked down to a small cylinder to expose more fin area. Some of the models had a fin span equal to the body diameter, with a planform referred to as a 90-degree delta wing. Wings of 80-degree and 85-degree delta shape were also tested. These tests showed a marked reduction in drag as the span was decreased. The delta-wing missiles were stable with

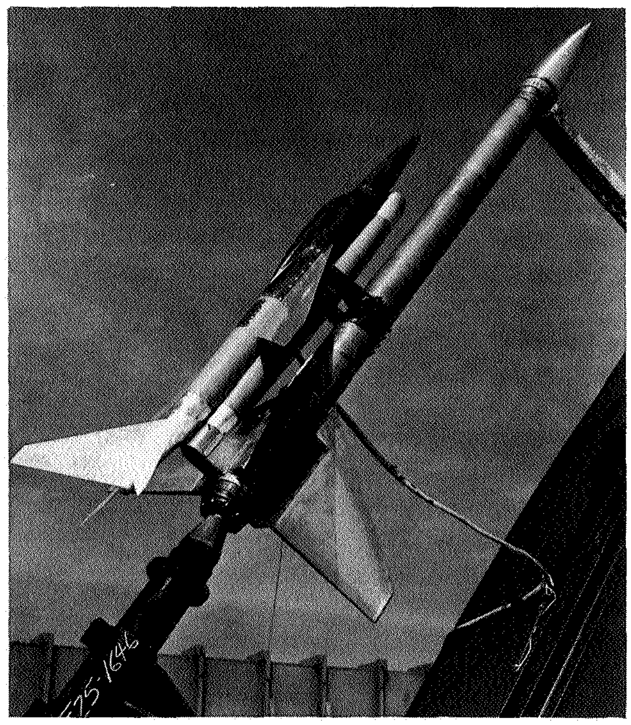


FIGURE 309. Research model of a complete airplane configuration with an underslung engine nacelle. View shows the model mounted piggyback on a Deacon booster, June 3, 1954.

the center of gravity at a point representing 52 percent of the body length, but the reduced-span missiles required a location farther forward, at a point equal to at least 43 percent of the length (ref. 49).

An extensive series of tests was made with rocket models having four 80-degree delta stabilizing surfaces. The tests were made to Mach 1.7 with the two-stage propulsion system. Trailing-edge flaps, spoilers, and air jets were investigated. The plain flaps were superior to the detached flaps. The best spoiler location was at the trailing edge of the wing. The air-jet control was one of the simplified systems investigated. Air was blown at right angles to the wing from a series of holes just ahead of the trailing edge. The air was obtained from a total-pressure tube located at the wing tip and ducted to the wing chamber containing the holes. Control resulted from direct reaction to the jet exhaust, and from the spoiler effect of the jet stream. In fact, the indirect effect was the predominant one, the total effect being of the order of 10 times the direct reaction at subsonic speeds and of 3 times the reaction at supersonic speeds (ref. 50).

The characteristics of the air-jet control were explored further in flight tests of an operating system with a movable control valve. The cruciform 80-degree delta wings were used as before, with air to the jets being supplied by a short tube with a normal-shock inlet at the wing tips. The controls were located on only two of the wing panels, both in the same plane. Because of the difficulties in obtaining linear flow by varying the opening of an orifice to the control jets, a scheme devised by Eugene D. Schult was used. The Schult plan employed a steady-flow system that exhausted air continually to both the upper and lower surfaces in proportion to the desired control sense. Rotation of a control rod in the wing at the jet location controlled the airflow from all jets to one surface or the other. In neutral, equal amounts flowed to the two surfaces. In the flight tests, the control rod was moved in a sinusoidal fashion from one full position to the other. A single Deacon booster accelerated the model to Mach 1.8.

The airjet control was found to be very linear with deflection of the control rod. As before, it was found that the wing and jet in combination magnified the thrust force of the isolated jet by a factor of 11 at subsonic speeds and 3 at supersonic speeds. The rolling effectiveness was superior to flap-type ailerons in that the control effectiveness did not fall off as rapidly at supersonic speeds (ref. 51).

The characteristics of a similar jet spoiler on a straight wing of low aspect ratio were determined in flight with two other models, one with the jet orifices near the leading edge, and the other with them near the trailing edge. The leading-edge location was entirely unsatisfactory because control was reversed over the transonic range. The trailing-edge location gave good control, with the induced effects ranging from 14 times the direct jet reaction at subsonic speeds to about 2.5 times the reaction at Mach 1.9 (ref. 52).

Another simple control device with low actuating forces was tested on a rocket model and in the Preflight Jet. The device consisted of two short vanes at right angles to each other on a common shaft extending through the wing near the trailing edge. The vanes were curved to force autorotation, but the vanes could be stopped in 90-degree positions by an escapement mechanism. For control, the vane on one surface could be stopped in a spanwise position while the vane on the other surface would be positioned chordwise. The device was simple and required quite small operating forces, but it had high drag and was of interest only on missiles for which drag was not important. The autorotation characteristics of a simulated system were obtained in the Preflight Jet at Mach numbers of 0.35, 0.80, 1.2, and 1.6. A curved shape was found to autorotate at all speeds and required about 0.01 second to rotate the required 90 degrees to reverse control. In the first flight tests, the vanes were simulated by fixed surfaces. The control developed by this rather short-span control was much lower at supersonic speeds than at subsonic speeds, but it was considered adequate for some installations. One possible use envisioned was on the D38 simple homing guided missile described in Chapter 10 (ref. 53).

The operation of a rotating-vane spoiler was also investigated in an E16 type of flight test. The two vanes were mounted on opposite ends of a rotating shaft passing through the wing normal to the chord plane. The vanes were oriented at right angles to each other and were shaped to provide autorotation. An escapement limited rotation to 90 degrees, which was sufficient to reverse the sense of the control. The only energy required was to actuate the escapement. The controls were on two of the panels of a cruciform arrangement of 80-degree delta wings. In flight, the escapement was moved at regular intervals to call for a series of right and left rolls in a square-wave pattern. A single Deacon booster provided speeds to Mach 1.8.

In the flight tests, the rotating vane provided satisfactory roll control except at speeds near Mach 1.2, where both the rolling effectiveness and vane-operating torque were marginally low. As expected, the vanes increased the drag of the model by about 50 percent (ref. 54).

Another control device that utilized air stream impact pressure for actuation was a bellows-actuated split flap developed by Eugene D. Schult. The trailing edge of a hinged split flap was connected to the trailing edge of the wing by a rubberized silk bellows that formed a sealed compartment. Air pressure fed to this compartment would move the flap for control. The device performed well in flight, with control deflections as high as 20 degrees being obtained (ref. 55).

In 1956, the Army's Picatinny Arsenal sponsored a symposium on finned ammunition. Picatinny had quite an active development program underway involving various finned projectiles. Upon the recommendation of Paul E. Purser, who was the NACA member of Picatinny's Aerodynamics Committee, Schult was invited to prepare a summary paper describing the many NACA-developed missile control devices that might find application for finned ammunition. Quite a comprehensive summary was prepared, not only of the special devices discussed in this chapter, but also of the more conventional ailerons and spoilers. The published version of the paper contained 51 references to other control-research papers (ref. 56).

The last control program to be discussed is one whose purpose was to provide flight information on a control for a guided missile having reaction controls, as well as aerodynamic controls, operating on the propulsion jet. Such a system could be used on a missile launched rearward from a bomber. During the initial phase, when the missile was actually traveling backward with respect to the airstream, the reaction control would be used until the missile had accelerated on its own, after which the aerodynamic control would take over. This flight program was a continuation of the jet-vane control research discussed in Chapter 8.

In the present program, identified as D21, three models were flown with flaps at the base of the missile, and with Cordite propulsion motors and a Deacon booster. The models were similar to the earlier D3 models with four 60-degree sweptback wing panels, except that the body behind the point of maximum diameter was developed into a square cross section for ease in mounting the controls. The aerodynamic controls were simple flaps attached to the rear of the flat-sided body. During the tests, the two opposing flaps were deflected, one away from the body—for aerodynamic control, and the other into the exhaust from the rocket motor—for reaction control. The three models differed in reaction-flap settings.

In flight, the models were propelled to a supersonic speed of Mach 1.7 with single Deacon boosters. After separation of its booster, the model was allowed to coast to a subsonic speed of 0.7, and the aerodynamic flap was under test. Then the internal Cordite was ignited, and the missile accelerated back to Mach 1.7. The jet reaction flaps were under test in this period. Following burnout of the Cordite motor, the aerodynamic flaps were again under test. The test results indicated that the body flap was quite effective in producing a trim change from either aerodynamic forces or jet reaction. Supplementary tests in the Langley 9-inch supersonic tunnel indicated that a spoiler in the same location as the flap could provide the same control without the high hinge moments of the flap (ref. 57).

GENERAL LATERAL STABILITY RESEARCH: E42

A technique for determining lateral stability derivatives from rocket-model flight tests was applied to a model of the Bell X-2 research airplane (as discussed in Chapter 7) and to a model of the Douglas X-3 research airplane (as discussed in Chapter 8). The same technique was used in a systematic general research program, identified as E42, to determine lateral stability of several additional configurations. The technique involved a time-vector analysis procedure wherein the value of some of the derivatives had to be assumed in order to find the value of the others.

A series of three models was flown with the configuration shown in figure 310. The three models were identical except that the wing was mounted first in a low-wing position, then in a high-wing position, and finally in a high-wing position with 10-degree negative dihedral. Lateral disturbances were induced by extending small vertical canard disturber vanes, preset at 10-degree deflection, at the forward end of the fuselage. Excellent results were obtained in all three tests, and data on lateral stability derivatives were provided over a speed range of Mach 0.7 to 1.3. The data agreed well with theoretical estimates. As predicted regarding rolling moment due to sideslip, the 10-degree negative dihedral reduced the rolling moment for the high-wing airplane to about the value for the low-wing airplane without dihedral (ref. 58).

Two E15 models were flown with pulsed controls to provide lateral stability data. These models had 45-degree sweptback wings and a low horizontal tail with negative dihedral, and were flown to a

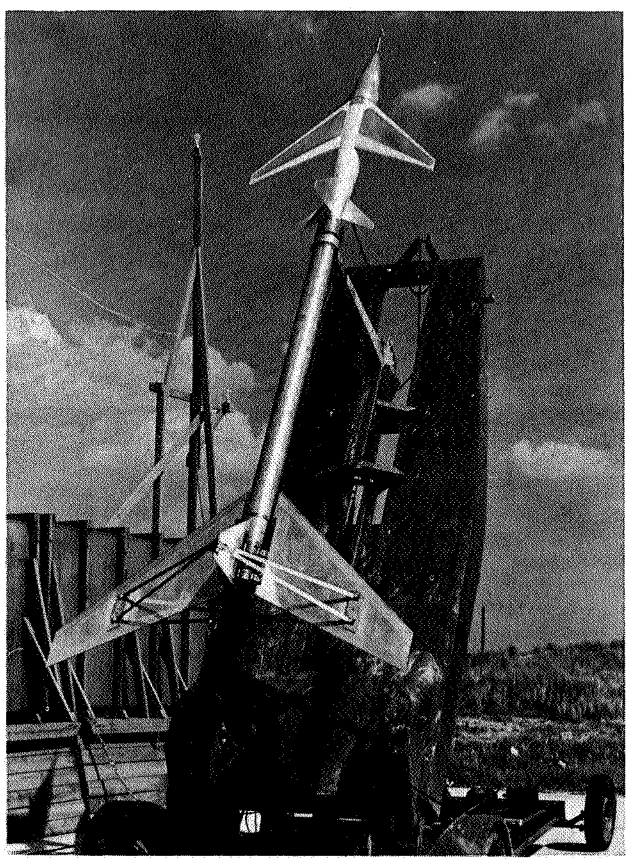


FIGURE 310. High-wing airplane model used in general lateral stability program. Model is shown with Deacon booster, February 21, 1956.

Mach number of 1.7 with a double Deacon booster. In one test, the rudder was pulsed to give disturbances in yaw, while in the other the two panels of the horizontal tail were pulsed differentially to provide a rolling disturbance. From the motions of the models following these disturbances, it was possible to evaluate some of the lateral stability derivatives (ref. 59).

The general research model with a 52-degree sweptback wing and with a tail boom and overhanging exhaust (discussed in Chapter 12) was flown in one test with a yaw disturbance by pulse rockets to yield lateral stability data, including power effects. Although no evidence of any effect of power was noted, extensive data on lateral stability were provided (ref. 60).

The aerodynamic and mass characteristics of the supersonic airplane of the type just described were such that damping of the lateral oscillations was low, and for the full-scale airplane some type of yaw damper was required. One rocket model was flown with a yaw damper that provided yawing moments in proportion to yawing velocity. An all-moving vertical tail provided these moments. Because of a dead spot in the operation of the damper system, it was possible to obtain lateral stability derivatives while the damper was essentially inoperative. The time-vector method was used in this case. Disturbances in yaw were induced by extending small vertical canard disturber vanes, preset at 10-degree deflection, at the forward end of the fuselage. The wing had 45-degree sweepback and an aspect ratio of 4.0. A double Deacon booster provided speeds to Mach 1.73. Although the yaw-rate damper had a rather large dead spot, the damping-in-yaw was appreciably improved for this model and the corresponding full-scale airplane (ref. 61).

COMPLETION OF LEWIS AIR-LAUNCHED ROCKET MODEL HEAT-TRANSFER PROGRAM

The initiation of the Lewis air-launched rocket model heat-transfer program at Wallops has been discussed in Chapter 11. In the initial phase, the models were constructed around a single-stage T40 rocket motor. When launched from a North American F-82 airplane at 36,000 feet (see figure 199, Chapter 10), such models reached a Mach number of about 5 as they plunged on a downward trajectory. These models were approximately 6.7 feet long and weighed about 208 pounds at launch. By May 1955, five such models had been launched over Wallops.

On November 2, 1955, the first of a new series of two-stage models having a T40 motor as a booster and a T55 motor within the model (see figure 311), was launched over Wallops from an altitude of 45,000 feet. Launching was now from a McDonnell F2H-2B airplane, shown in figure 312, and the Mach number reached was about 8. The gross weight at launch was about 236 pounds, and the last stage was 6 feet long. This system was used until July 1957, when the booster was changed to a Recruit rocket motor for an expected Mach number of about 10.

With the Recruit booster, the gross weight was approximately 469 pounds. The F2H airplane was used with this vehicle until July 1958, when a Martin B-57A airplane, shown in figure 313, was substituted for the remainder of the program, which ended in April 1960. In figure 314, a typical Recruit-T55 vehicle is shown being loaded on the B-57 airplane. A three-stage system was added to the program for even higher Mach numbers, but only a dummy flight was made before the entire program was phased out. The main emphasis of the Lewis program was on boundary-layer transition and heat transfer at high Reynolds numbers on highly polished, slender cones with either pointed or blunt tips.

The Lewis air-launched vehicles contained many of the elements of the Langley ground-launched systems at Wallops. The T40, T55, and Recruit rocket motors, as well as the delay ignition system, were obtained through Langley contacts. The Recruit motors were provided by the Air Force Ballistic Missile Division (BMD) as an adjunct to their X-17 heat-transfer program. The blowout diaphragm connecting the T40 and T55 motors, or the Recruit and T55 motors, were copies of the Langley device. The flared skirt at the base of these rockets, which served for stabilization and later as a high-altitude nozzle as well, was Langley-developed. The instrumentation, including the telemeter, was the Langley IRD design.

One basic difference between the air-launched and the ground-launched vehicles was that the air-launched vehicles, being carried externally on the airplane, were subjected to extremely low temperatures, and special heating blankets were required around the rocket motors and the telemeter.

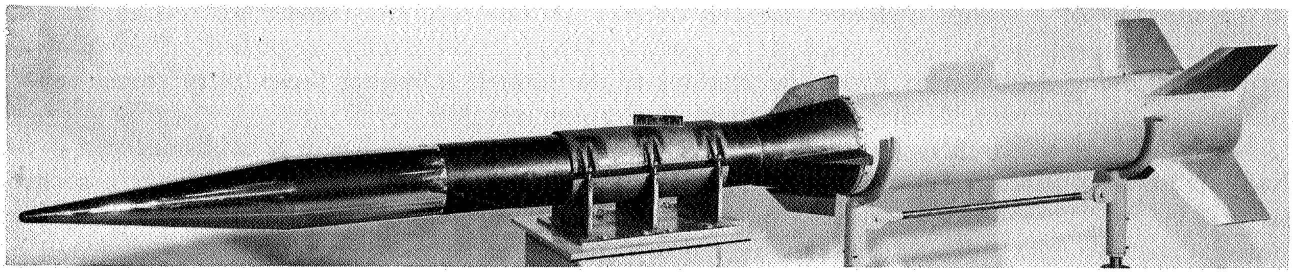


FIGURE 311. Lewis two-stage T40–T55 air-launched vehicle used in heat-transfer program, November 1955.

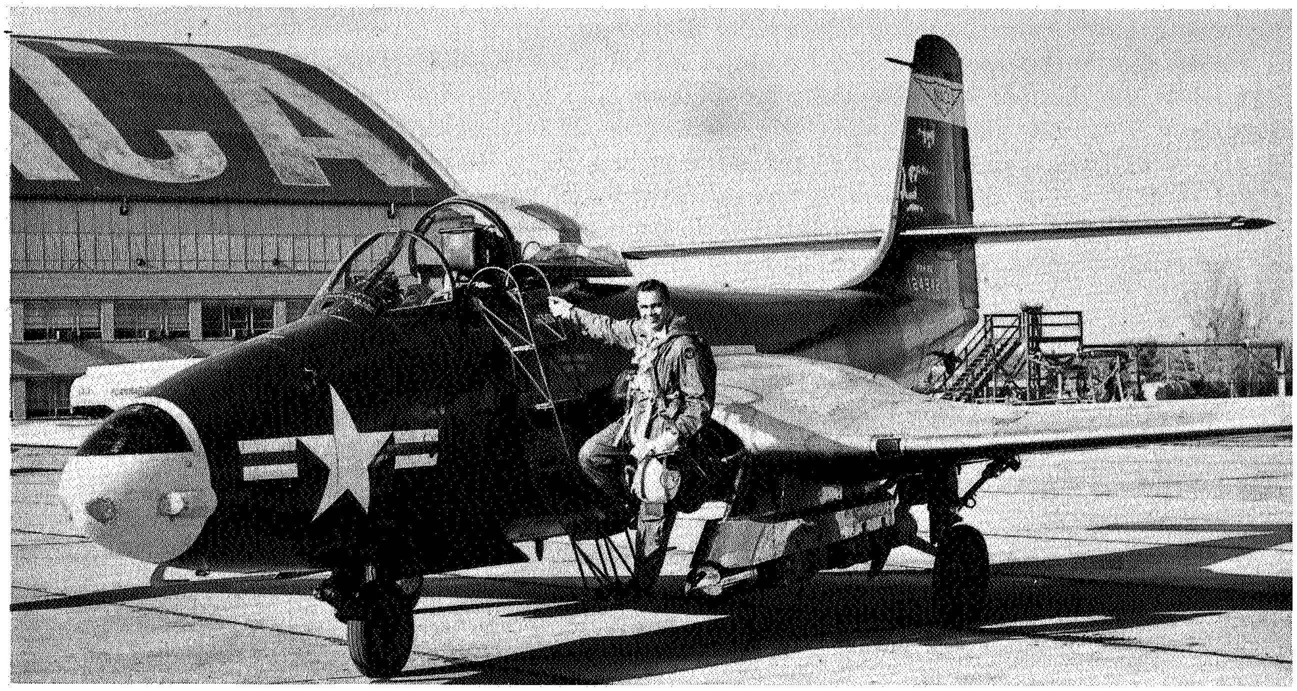


FIGURE 312. Pilot W. H. Swann with McDonnell F2H–2B airplane used in Lewis air-launched rocket-model program at Wallops, August 1955 to March 1958.

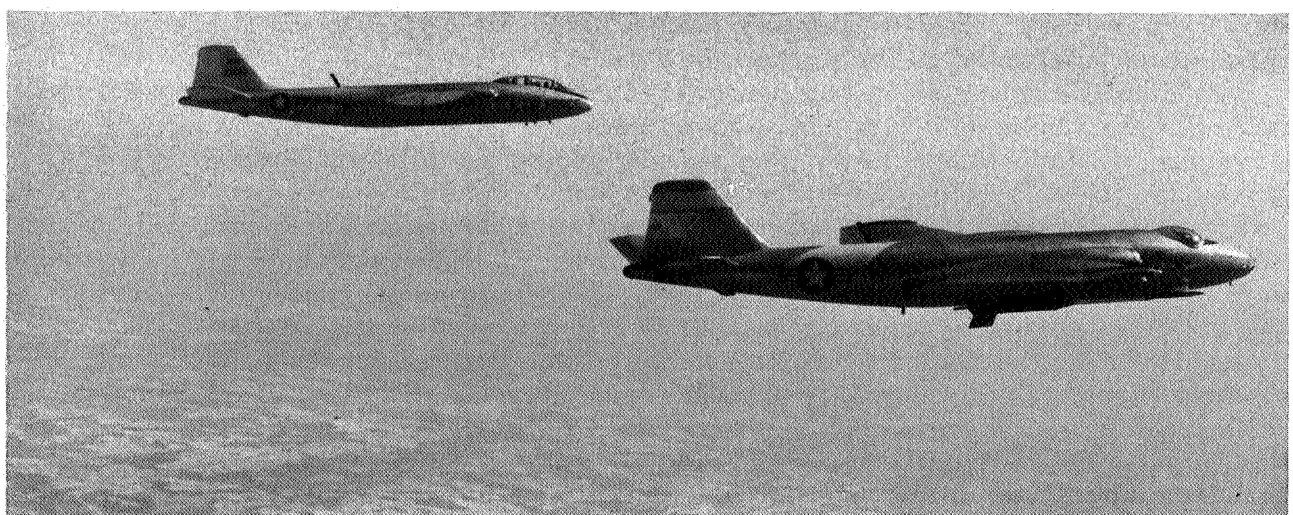


FIGURE 313. Martin B–57A photo and launch airplanes used in Lewis air-launched rocket-model program at Wallops, July 1958 to April 1960.

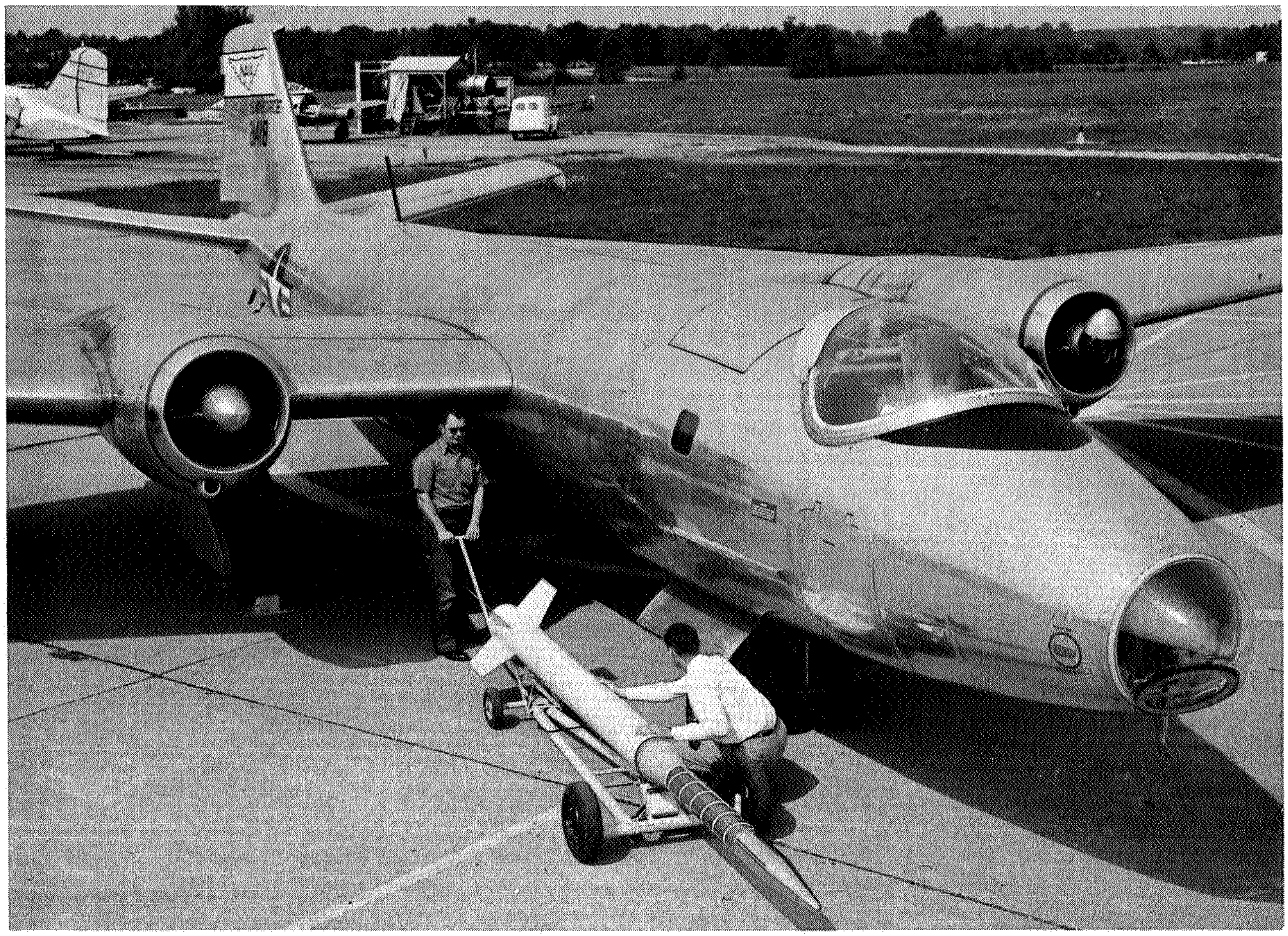


FIGURE 314. Lewis technician D. J. Raith and engineer E. Buller prepare to load Recruit-T55 rocket model on Martin B–57A airplane for air-launching over Wallops.

Any failures in flight were usually discussed with Langley personnel before any design changes were made. The close cooperation between Langley and Lewis in this program was a continuation of the system that began with the Lewis air-launched ramjet program. In that program, Langley—at first—constructed and installed the instrumentation. In fact, close cooperation had existed between the two facilities since establishment of the Lewis Laboratory in 1940 with a nucleus of personnel from Langley.

The five single-stage models with T40 rocket propulsion launched over Wallops in this program had 20-degree total-angle cones attached to cylindrical bodies with four stabilizing fins (see figure 244, Chapter 11). The main difference between the first four models was the ignition time after separation from the airplane at an altitude of 36,000 feet. For example, with one model, the delay was only 5.4 seconds, and a Mach number of 4.90 was reached at an altitude of 28,000 feet; with another, the delay was 19.8 seconds, and a Mach number of 4.42 was reached at 16,000 feet. The model with the longer delay plunged earthward along an approximately 55-degree trajectory and impacted the ocean about 11 seconds after ignition of its rocket, while the other model followed a more leisurely course and required about 50 seconds to impact. The differences in flight paths made it possible to obtain data at a given Mach number over a wide range of altitudes and Reynolds numbers.

Data on the flight performance of the T40 rocket motors in these four flights were combined with similar data from four air-launched ramjet flights in which T40 motors were used, in order to provide a single-source comparison of the behavior of T40 motors when they were ignited at altitudes between 29,000 and 35,000 feet. Of the eight firings, six performed as desired, but, for some unexplained reason, the remaining two motors did not ignite, although there was evidence that the igniter did perform in one case. For the four motors in the heat-transfer tests in which the motors exhausted directly into the atmosphere, an average impulse was 22,870 pound-seconds, which agreed well with earlier static tests. This was a significant finding, because one of the flight motors had been in storage for 24 months (ref. 62).

In these tests with the single-stage T40 motor, it was found that turbulent heat transfer to the cone agreed with the theory of Van Driest within 20 percent when the Reynolds number was based on the distance from the apex of the cone. Transition from laminar to turbulent flow was indicated at a local Reynolds number of 8 million, at a Mach number of 2.5 (ref. 63).

The fifth model in this series differed from the others in the surface finish. In an attempt to obtain very high Reynolds numbers at transition to turbulent flow, the skin was given a high polish by the use of progressively finer grades of diamond polishing compound. The finish was about 2 microinches, as determined by a Brush surface analyzer.

The 20-degree cone had a sharp-pointed nose and thermocouples along its length back to a distance of 25.8 inches. Launch on May 6, 1955, was made from an F2H airplane at 35,340 feet. During burning of the rocket motor, the flight path was inclined downward about 24 degrees. A maximum Mach number of 5 was reached at an altitude of 27,000 feet.

The state of the boundary layer was determined from the temperature measurements and the deduced heating rates. The flow was turbulent at first but became laminar simultaneously all along the cone during rocket burning at a local Mach number of 2.7. The wall-to-local temperature ratio was 1.2, well within the region of theoretical stability of the laminar layer (ref. 64). The flow changed to turbulent when the temperature ratio started to rise at local Mach numbers between 3.5 and 3.9. The conditions still corresponded to those for infinite stability, which led the researchers to question some of the assumptions of the theory. Nevertheless, laminar flow was noted at a local Reynolds number of 32 million. Data on turbulent heat transfer were obtained at local Reynolds numbers to 50 million.

A comparison of the flight transition data with wind-tunnel results indicated that decreasing the roughness from 16 to 2 microinches had no effect, and Mach number had no effect, at least up to a value of about 4.0. A strong dependence on temperature ratio was found, however, with a ratio of just under 1.2 appearing to be an asymptote, as shown in figure 315 (ref. 65). The picture was confused by the finding that the transition Reynolds number was also a function of actual distance along the cone. The value of 32 million was obtained at the rearmost station, whereas at the foremost station the transition Reynolds number was only 17 million.

The first two-stage vehicle with the T40-T55 rocket motor combination was successfully air-launched over Wallops on November 2, 1955, from a McDonnell F2H airplane at 47,500 feet. A Mach number of 8.17 was reached at an altitude of 37,500 feet. The model was a 15-degree cone followed by a cylindrical section to which was attached a 10-degree half-angle stabilizing flare or skirt, plus four

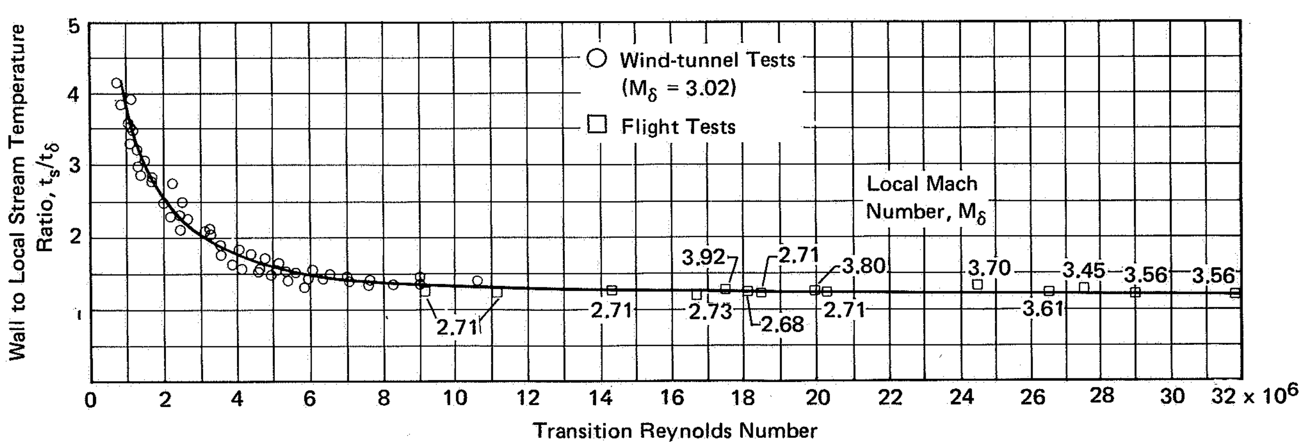


FIGURE 315. Graph showing dependence of transition Reynolds number upon ratio of wall temperature to stream temperature for a 20-degree cone, as determined from Lewis air-launched rocket models and wind-tunnel tests.

small wedge-shaped fins, as shown in figure 311. The tip of the nose was rounded to a radius of 7/16 inch. The T40 stage had regular fins as before. The nose and instrumented part of the cylinder were highly polished to a surface finish of 2 microinches.

In the test, it was found that laminar flow was maintained over the instrumented area up to the maximum Mach number. The maximum measured local Reynolds number on the cone, based on assumption of a sharp tip, was 48.5 million. The small amount of rounding of the nose and the highly polished surface, plus the fact that the model was at a low temperature ratio, all contributed to this high Reynolds number with laminar flow. The favorable effect of blunting the tip was explained by an analysis of W. E. Moeckel of Lewis, which showed that the local Mach and Reynolds numbers at the surface are reduced because of the detached shock wave. The extent of this local effect depends upon the amount of blunting. Moeckel calculated that this effect would increase the extent of laminar flow over a surface by factors ranging from 2 at Mach 3 to 30 at Mach 15 (ref. 66). Turbulent flow over the flight model was not obtained until after the model had decelerated to Mach 3.45 and had reached a temperature ratio of 1.92. This point was reached on the cylinder at a local Reynolds number of 27.5 million (ref. 67).

The second two-stage model was launched on May 24, 1956, and was identical to the first; but it descended on a somewhat steeper trajectory. The maximum Mach number reached was 6.75 at 28,000 feet. Laminar flow was maintained on the highly polished cone to a local Reynolds number of 50.2 million. Heat transfer under turbulent flow conditions was measured on the flare at a Reynolds number of 116 million and a Mach number of 6.7 (ref. 68).

The effect of surface roughness on transition of the laminar boundary layer was investigated in flight with three T40-T55 models otherwise similar to the two just described. On one model, the skin of the cone was made of inconel and polished with diamond paste to an average roughness of 2 microinches, as measured with an interference microscope. On the second model, the skin, made of nickel, was vapor-blasted to a roughness of 100 microinches and then polished to a final finish of 50 microinches. The third model, also made of nickel, was polished to a 2-microinch finish and then vapor-blasted to the final finish of 20 microinches.

These three models were launched between March 4 and May 2, 1957. The model with the 2-microinch finish reached a Mach number of 7.2 in flight; the one with the 50-microinch finish reached Mach 7.6; and the model with the 20-microinch finish reached only Mach 5.1 because of a failure in flight, apparently due to a loss of stability. The results for the smooth model agreed with previous results on a similar body and evidenced laminar flow to a local Reynolds number of 46.3 million, calculated from sharp cone considerations. Transition from laminar to turbulent flow occurred at a much lower Reynolds number as the temperature ratio increased to about 1.50. Surprisingly, the model with the 20-microinch finish had a lower transition Reynolds number than the one with the 50-microinch surface. Apparently the type of roughness was as important as the degree. Transition to turbulent flow occurred with the rough models at temperature ratios where a stable laminar flow was predicted.

This result was considered a verification of the "transition reversal" phenomenon noted in earlier wind-tunnel tests by Jack, Wisniewski, and Diaconis (ref. 69). It was conjectured that roughness counteracted the beneficial effects of cooling. The measured heat-transfer values agreed well with Van Driest's theory when the theory was corrected for the favorable effects of nose bluntness (ref. 70).

The heat transfer to blunt bodies became of increasing interest as Mach number increased. Extremely blunt bodies were of interest for the reentry nose cones of long-range ballistic missiles. The heating rates on hemispherical noses depended greatly upon whether the boundary layer was laminar or turbulent. In some tests, the transition to turbulent flow was not delayed to a high Reynolds number as it had been with only slightly blunted cones. Extensive flight research on the transition phenomenon on herispherical noses was, therefore, conducted by many techniques, including the PARD rocket models (to be discussed in the following chapter), the Lockheed X-17 vehicle, and the Aerophysics HTV vehicle, as well as the Lewis air-launched system.

The measurement of heat transfer to a basic hemisphere-cylinder was made in a Lewis air-launched test in which the new Recruit rocket motor was used in the program for the first time. It was launched on November 6, 1956, as a single-stage vehicle with four stabilizing fins, and reached a Mach number of 5.6 at an altitude of 14,000 feet. The cylinder was 9 inches in diameter and 122.6 inches in length. The gross weight of the vehicle at launching was 409 pounds. In figure 312, it is shown under the wing of the F2H launch airplane.

Temperatures were measured at many points around the hemispherical nose and at several points on the cylinder back to about 16 inches. Pressures also were measured at four locations. The instrumented surface, made of nickel, was highly polished with diamond paste to a mirror finish with a value of roughness of less than 5 microinches, and was protected from surface erosion prior to launch by a soft paper skullcap which was removed at launch by a string connecting it to the airplane.

The pressure measurements on the hemisphere agreed well with Newtonian theory and verified the sonic point as being the 45-degree station. The heat-transfer data indicated laminar flow at the stagnation point, with transition to turbulent flow occurring before the 11.5-degree station. The measurements agreed with laminar theory at the stagnation point, and with turbulent theory over the hemisphere and cylinder at all measurement stations (ref. 71). Transition at such a forward location was unexpected, but it was shown by Wisniewski to correlate very well with other data (ref. 72). This correlation will be discussed in more detail in the following chapter.

In order to explore the beneficial effects of nose bluntness on a smooth cone in the maintenance of laminar flow, three models with increasing amounts of bluntness were air-launched from a McDonnell F2H airplane during the period between August 7, 1957, and January 31, 1958. In figure 316, a model of this type is shown being loaded on the launch airplane. The Recruit-T55 propulsion system was used. The nose radii of the three models were 1 inch, 1.5 inches, and 2 inches, respectively, on a basic 15-degree cone. All models were polished to a 2-microinch finish.

The model with the greatest bluntness reached a Mach number of 8.5, while failures limited the other two to Mach 6.5. Both laminar and turbulent heat-transfer data were found to be in good agreement with theory when the effects of the nose bluntness were considered. The flow over the cone and cylinder at all measurement stations was laminar on the model with the least bluntness (1.0-inch radius). The free stream Mach number and Reynolds number were about the same as those for the earlier model with less bluntness (0.44-inch radius) although the local Reynolds number, which included the effect of the blunt nose, was considerably lower. With the 1.5-inch nose radius, transition from laminar to turbulent flow apparently occurred simultaneously all over the cone, triggered by a condition ahead on the hemispherical nose. With the 2-inch nose radius, transition occurred ahead of the 45-degree station on the nose. The transition results fitted the correlation parameter of Wisniewski (ref. 73).

Two air-launches were made with highly polished 15-degree cones having rather flat noses instead of hemispheres. The first model was launched from a McDonnell F2H airplane on March 28, 1958; but because of a failure of the T55 stage, it did not reach its design Mach number. The second model, however, which was launched from a Martin B-57A airplane on July 24, 1958, performed very well and reached a Mach number of 9.7. Laminar flow was maintained at this speed to a Reynolds number of 26.3 million (ref. 74).

A highly polished 15-degree cone-cylinder-flare model was launched from a B-57A airplane over Wallops on July 15, 1958. This model had a blunt nose with a 1-inch radius and was designed expressly for the longest possible laminar run. It was propelled to a Mach number of 8.92 by its two-stage Recruit-T55 rocket system. Laminar flow was maintained to a Reynolds number of about 70 million, an unusually high value.

The chairman of the NACA, General James H. Doolittle, accompanied by J. F. Victory, NACA Executive Secretary, visited Lewis in May 1958 on a fact-finding tour, in anticipation of the NACA's being given the space program responsibility. One of his stops was the air-launch rocket project. He is shown in figure 317 as he receives a briefing on this flight program. One of the Recruit-T55 models is shown on its transport dolly, actually the door of the bomb bay of the B-57A airplane, along with one of the simple practice bombs to be dropped just prior to the actual launch.

The Recruit-T55 model shown to Doolittle on his visit to Lewis was launched successfully from a B-57A airplane over Wallops on September 12, 1958. It reached a Mach number of 8.5 at 39,000 feet. The model was a highly polished, 15-degree cone-cylinder and, as can be seen in figure 317, a collar approximately one-half inch high was fitted around the cylinder about a foot behind the cone-cylinder juncture. This formed what was known as a "forward-facing step." The purpose of the test was to measure heat transfer in the region of turbulent, separated flow ahead of this collar or step. To ensure

FIGURE 316. Lewis engineer Scott Simpkinson (right foreground) elevates Recruit-T55 air-launched rocket model into position on pylon of McDonnell F2H–2B airplane, for a Wallops test on August 7, 1957. He is assisted by Frank Bechtel (left) and Frank Maruna.

FIGURE 317. NACA Chairman James H. Doolittle receives briefing on Lewis air-launched rocket-model program, June 24, 1958. Left to right: E. Buller, G. M. Preston, J. H. Doolittle, J. F. Victory, E. Manganiello, F. C. Thompson, E. R. Sharp, W. H. Hunter, and J. H. Disher.

that the flow in this region would be turbulent, a knurled ring was located at the cone-cylinder juncture, and the cylinder back to the collar was vapor-blasted to a 60-microinch roughness. The tip of the conical nose had a hemispherical radius of 0.44 inch.

The test results indicated a pronounced effect of the blunt nose on local conditions, as evidenced by the heat-transfer measurements on the surface of the cone. Below a Mach number of about 6, the heating corresponded to that computed for blunt-tip conditions for laminar flow. Above this Mach number, the heating increased to as much as three times the degree indicated by theory. Calculations of the thickness of the boundary layer indicated that it was thicker than the calculated, reduced Mach number layer, thus exposing the boundary layer to flow corresponding to sharp-tip conditions. This effect was verified by the agreement obtained between measured heat transfer and calculations based on sharp-tip conditions. The flow over the cylinder was turbulent, as planned. The heating within the separated area, as expected, was roughly 40 percent less than that predicted for attached flow to a frustrum of a cone having a base diameter the same as that of the collar (ref. 75).

The last model flown in the heat-transfer program had a conical nose with a large hemispherical radius. It was a dummy model (no rocket motors), flown to check out the launch behavior of a three-stage rocket vehicle designed for higher speeds. The three-stage vehicle consisted of a cluster of three Recruits, a single Recruit, and then a T55 in the last stage. It was, in effect, the Recruit-T55 system, plus a cluster of three Recruits added as an additional stage. In figure 318, the complete model is shown in position on its launch airplane, the Martin B-57A. It was attached to the outside of the door of the bomb bay. The launch of this dummy, on January 28, 1958, was successful.

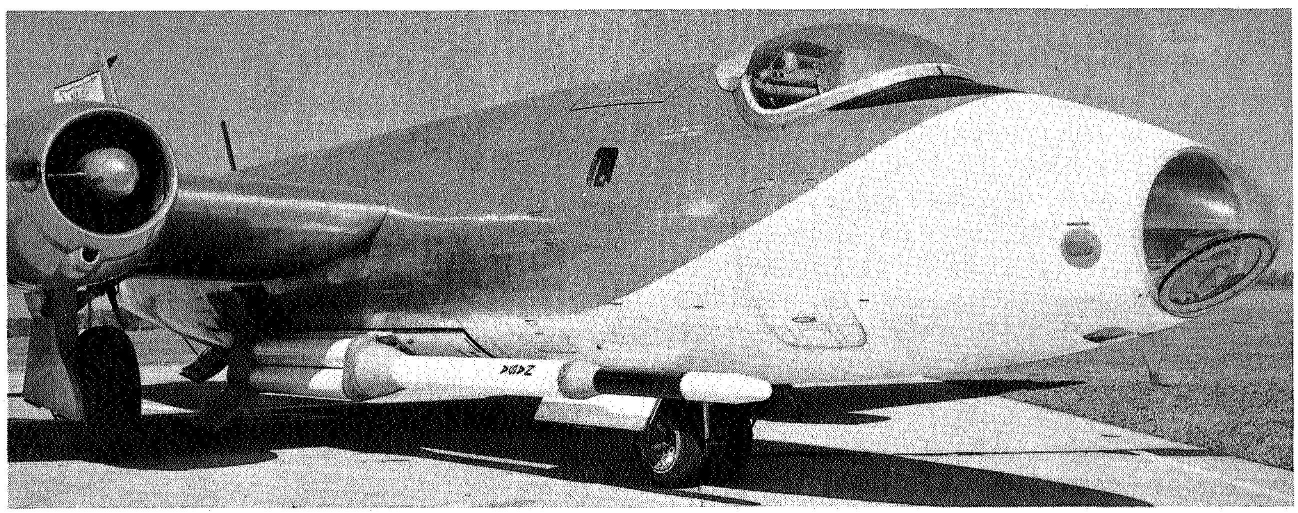


FIGURE 318. View of Lewis three-stage air-launched rocket model with a blunt conical nose. Model is shown in place on Martin B–57A airplane for test at Wallops, January 28, 1958.

On March 19, 1958, an attempt was made to launch the actual test article, but difficulty with the release mechanism while the B-57A was over Wallops forced the airplane to return to the Lewis Laboratory at Cleveland, Ohio. The vehicle would not release, and the mechanism could not be relocked. The landing at Cleveland with the vehicle still attached was not looked forward to, but there appeared to be no alternative. There were anxious hours as the airplane was flown back to Cleveland, because an accidental drop of this three-stage rocket vehicle into a populated area might create havoc. W. V. Gough, Jr., at Lewis, on radio contact with pilot W. H. Swann, cautioned Swann not to increase his speed because that might force the vehicle loose. Swann wanted to know how he was going to get down from his 40,000-foot altitude without doing so. By using his brake flaps and delaying his descent until he was near home, he managed to hold onto the potential missile until he was over Lake Erie. As the air speed and air forces built up during the final descent, the vehicle did indeed work loose, but it dropped harmlessly into the lake.[7]

7. Telephone conversation between W. V. Gough, Jr., and J. A. Shortal, Mar. 13, 1970.

While the pilot was overjoyed at having gotten rid of this monster at his door, the loss to the project was a sad one for no additional vehicles were on hand, and a live launch was never made by the NACA.

Staff members of the Air Force Special Weapons Center (AFSWC), who had worked sucessfully with PARD and Wallops personnel in the JASON project (see Chapter 15), were impressed with the possibilities of adapting the Lewis three-stage vehicle to use as a sounding rocket, which they named "Jaguar." They particularly liked the air-launch feature, which would give them almost unlimited operational capability.

The Jaguar development followed the Lewis design very closely, even to the extent of using the same launch airplane and carrying position. One change made was to replace the T55 rocket motor in the last stage with a JPL Baby Sergeant motor, which was about the same size but had higher performance. The plan was to launch the Jaguar vehicle from the Martin B-57 airplane during a near-vertical-climb maneuver, as developed in the toss-bombing technique. The vehicle was about 26 feet long and weighed about 1,600 pounds.

Six dummy launches and two tests with live rocket motors were made. A maximum altitude of 595 nautical miles was calculated for a nominal payload weight of 25 pounds (ref. 76). The first firing was made early in 1960. The intended use of the Jaguar was to measure Northern Light discharges and the behavior of trapped radiation. Preliminary tests were made at White Sands Missile Range by AFSWC of ARDC (ref. 77). The Jaguar never went beyond the development stage, and its intended function was taken over by other sounding rockets or by satellites.

The last two air-launches by Lewis at Wallops were for boundary-layer noise research. Both models were propelled by single-stage Recruit rocket motors, but difficulty with the instrumentation in flight interfered with the project. The last flight was made on April 29, 1960.

In summary, the Lewis air-launched rocket-model program was quite succesful and contributed to a better understanding of heat transfer and boundary layers up to Mach 10. It was found that laminar flow could be maintained on a smooth, slender body to a Reynolds number of 70 million at a Mach number of 9.0. A low value of wall-to-stream temperature ratio was helpful in maintaining a long laminar run unless the surface was rough, in which case a further lowering of the temperature ratio caused transition to turbulent flow. Blunting the tip of a cone was found to have a favorable effect on delaying transition and in reducing heat transfer to the cone. If the Reynolds number on the tip itself was too high, however, transition occurred there and practically the entire body was subjected to turbulent flow (ref. 78).

PARD HEAT-TRANSFER RESEARCH ON SLENDER BODIES

Since the major problem of aircraft at hypersonic speeds was survival of the structure at high temperatures due to aerodynamic heating, it was logical that the first research programs with the new PARD multistage rocket systems were related to aerodynamic heat transfer. The early heat-transfer research at Wallops with ground-launched rockets propelled to Mach 4.0 was discussed in Chapter 8 and extension of this research to Mach 10 was covered in Chapter 11. With the new vehicle systems, the research was now extended to Mach 15. Continued emphasis was placed on slender shapes, such as the RM-10, or on slender cones, with either pointed or slightly rounded noses.

As has been discussed earlier in this chapter, the successful flight of the four-stage Nike-Nike-T40-T55 vehicle in October 1954 was followed by a number of additional flights with the same boost system. Also, as mentioned earlier, the launch technique was changed to an "over-the-top" trajectory to keep reentry within the range of Wallops.

One of the models flown was a duplicate of the first, except that it was instrumented for measurement of pressures over the nose and flare of the test model. There was need for experimental pressure data in order that the heat-transfer data could be correlated on the basis of measured local flow conditions.

This model, shown in figure 319, was launched on June 7, 1956, and the over-the-top firing schedule was followed, except that the last two stages fired too soon. The premature firings gave such a

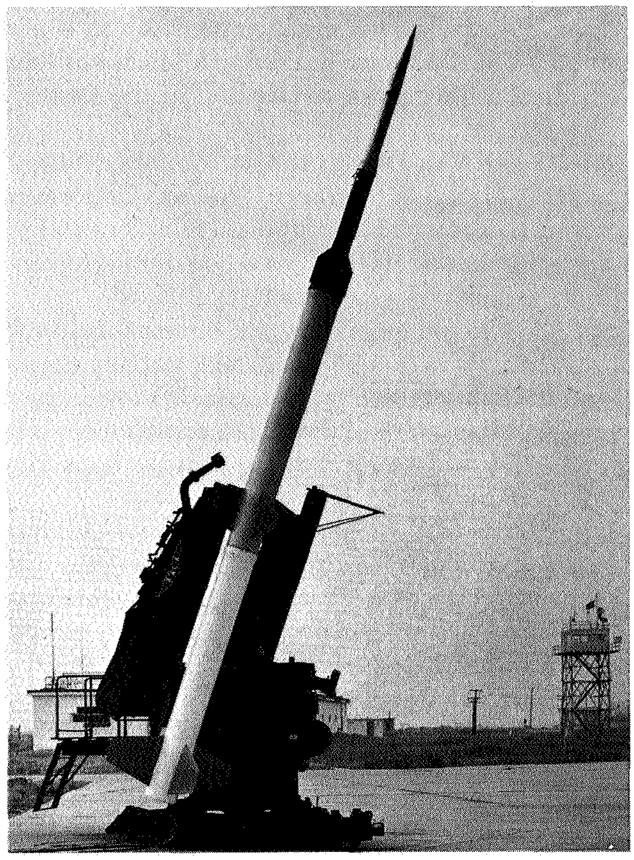


FIGURE 319. Four-stage launch vehicle with test model instrumented for pressure distribution. Vehicle and model are shown mounted on launcher for test, June 7, 1956.

high trajectory that the pressures were too low to be measured accurately with the pressure range of the instruments used. Although the model reached a maximum Mach number of 8.4, usable pressure data were obtained only to Mach 4.3, at the end of second-stage burning. The measured pressures agreed well with theory, although there was some indication of flow separation on the flare (ref. 79).

In the flight test of a 1/6-scale RM-10 model mounted on a sting ahead of a Deacon motor (discussed in Chapter 8), there was some evidence of transition from turbulent to laminar flow. In order to allow further exploration of this phenomenon, a second model was flown to Mach 4.2 with thermocouples located at several stations along the length of the model. The somewhat higher speed in this test was obtained by using a triple Deacon booster in addition to the Deacon in the last stage. Measurement of temperatures at several stations was made possible by development of a system of commutating the readings from the different stations and using in-flight calibration, which consisted of the transmission of the readings of three reference voltages equal to zero, one-half, and full-scale readings.

In this test, the presence of laminar flow was indicated twice during the flight. The first time was for just a brief moment when a "burst" of laminar flow was noted at a Mach number of 2.9 and a local Reynolds number of 13.3 million. An explanation was found after calculations of flow and skin temperatures indicated that the Van Driest region of infinite stability of the laminar boundary layer for two-dimensional flow had been penetrated (ref. 80). After the model coasted to higher altitudes and had passed the peak Mach number, laminar flow was again noted, but by this time the local Reynolds numbers were down between 3 and 4 million (ref. 81). By this time, the use of thin inconel for the skin of heat-transfer models was customary for high-speed tests. The characteristics of inconel, including emissivity, over the operation range of temperatures was determined especially for such use by the National Bureau of Standards for the NACA (ref. 82).

The first flight tests with Nike-Deacon and Nike-Nike-Deacon systems have been described in Chapter 11. In these tests, a sharp 10-degree cone was used, and temperatures were measured at a single station. The next Nike-Nike-Deacon flown had the same conical nose but was instrumented with thermocouples at six stations along the length of the cone. Otherwise, the arrangement of this flight vehicle was the same as before. (See figure 239, Chapter 11.) The data were limited to a Mach number of 5.9 instead of the expected Mach 7 because of a structural failure prior to burnout of the Deacon motor.

The turbulent heat-transfer measurements agreed well with Van Driest's theory for cones; but of greater interest were the indications of laminar flow at high Reynolds numbers. This was important because the heat-transfer rate for laminar flow was only about 1/7 the value for turbulent flow. Transition from turbulent to laminar flow was noted at a local Reynolds number of 19.4 million when the flight conditions were such as to lie well within the region of infinite stability of a laminar layer (ref. 83).

By this time, the stability calculations of Van Driest had been extended to three-dimensional flow by Dunn and Lin, and although for such a case infinite stability was no longer predicted, stability of the laminar flow to very high Reynolds numbers was indicated for temperature ratios somewhat lower than those of Van Driest (ref. 84). It was of interest that, at a given station, the flow would apparently shift from turbulent to laminar and back to turbulent in about one second, indicating that perhaps the transition point was oscillating rapidly with time.

In an effort to obtain more information on the significance of the region of stability of laminar flow, a large 10-degree cone, constructed of copper, was flown. The cone, 100 inches in length, was mounted on the front of a Nike rocket motor, as shown in figure 320. The point of the cone was rounded to a radius of about 1/16 inch. Although it was known that this single-stage rocket would provide a Mach number of only 3.5, a maximum Reynolds number of 160 million was expected. Such a large value was planned to allow a determination of transition to quite a high value, if it developed.

In the test, however, turbulent flow existed over most of the cone, with the result that the skin heated much faster than expected. This, in turn, made the temperature ratio higher than expected, with the result that the model did not explore the stability region as far as planned. Nevertheless, temperature ratios near 1.2 were obtained for local Mach numbers up to 3.5. As the model decelerated from Mach 3.5, the temperature ratio increased, and the model was no longer in the stable region. Unexpectedly, the highest transition Reynolds number, 33.1 million, was obtained as the temperature ratio was rising. In fact, the model had almost emerged from the stable region.

The copper surface of the model had been polished to a mean value of roughness of 10 to 16 microinches, as measured with a profilometer. However, postflight measurements made with an interference microscope on a sample sheet of copper, polished in the same manner, indicated readings about 10 times as great as those of the profilometer. It was concluded that the present model probably had a roughness of between 100 and 150 microinches. This amount of roughness was believed to have contributed to the somewhat lower than expected transition Reynolds number. The heat-transfer measurements under either laminar or turbulent flow conditions agreed reasonably well with theory. Turbulent heat-transfer data were provided to a Reynolds number of 154 million at a Mach number of 3.6 (ref. 85).

An attempt was made to extend the heat-transfer data on a 10-degree cone to much higher Mach and Reynolds numbers. A cone, 103 inches long, was made with an inconel skin and was equipped with an internal T40 rocket motor and an Honest John-Nike booster. This three-stage vehicle was flown to a Mach number of 9 at an altitude of 87,000 feet in a semi-over-the-top trajectory. The second stage was allowed to coast to an altitude of 50,000 feet before ignition, after which the trajectory was a climb of approximately 45 degrees. The vehicle is shown in figure 321. Unfortunately, a failure in the telemeter during burning of the second stage limited the heat-transfer data to Mach 2.

The forward surface of the cone was polished to a mirror finish by diamond-dust abrasive and had a mean roughness of 2 microinches as measured by an interference microscope. During handling, the polished surface was protected by a sprayed strippable coating of plastic that was peeled off just before launch. While the cone was on the launcher, the surface was protected by a paper wrapper that was torn off by the air forces after launch.

The temperature measurements indicated turbulent flow over the entire cone even when the Reynolds number was only 1.6 million at the most forward measurement station. For the temperature and Mach number, the model was always outside the region of theoretical stability of the boundary layer, but some useful information was salvaged from the flight. Static stability and damping of the cone

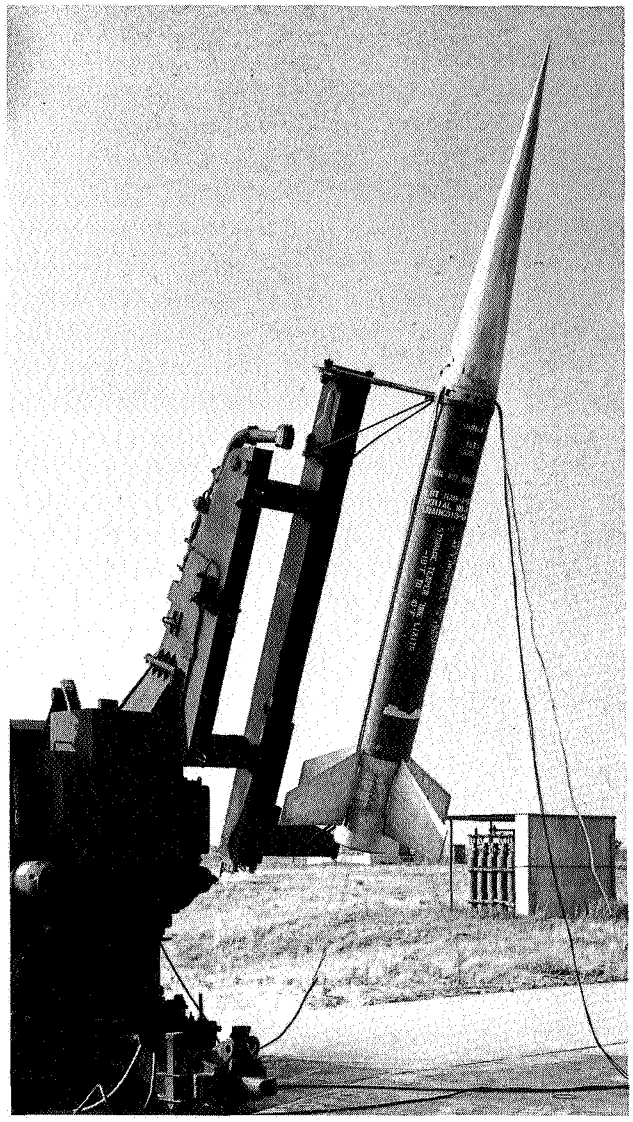


FIGURE 320. Large 10-degree conical body model mounted on Nike booster for heat-transfer investigation, May 26, 1955.

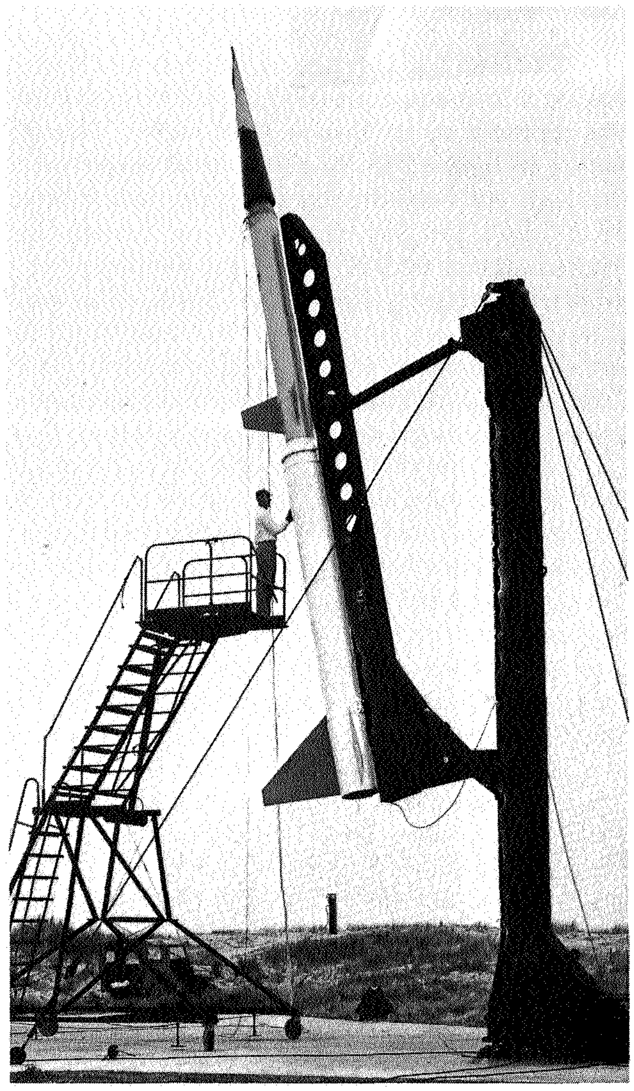


FIGURE 321. Technician Durwood Dereng measures elevation angle of Honest John-Nike-T40 launch vehicle used in heat-transfer test of 10-degree cone to a Mach number of 9. Launching took place on July 5, 1956.

were determined at Mach 5.2, following an oscillation while in power-on flight; and drag was determined near Mach 9 after burnout of the third-stage motor. The drag data indicated the possibility that the flow had changed to laminar over half the length by that time. The Reynolds number for that distance at Mach 9 was abut 3 million (ref. 86).

The launching of the Nike-Nike-T40 vehicle at Wallops on the same day as the first four-stage model (October 14, 1954) has been discussed in Chapter 11. The vehicle was equipped with a 15-degree cone 31 inches long, attached to a cylindrical body and stabilizing flare. The cone was sharp pointed and had thermocouples along its length, starting at station 6.5. The three stages fired in succession as planned, and a maximum Mach number of 7.3 was reached; but the temperature portion of the data was not transmitted after a Mach number of 5.2 was reached, during burning of the third stage. The inconel surface of the cone was polished to a roughness of about 10 microinches, as measured by a profilometer. In the tests, the flow varied from laminar to turbulent along the length of the cone, with a maximum local transition Reynolds number of 30.3 million at a local Mach number of 3.0. The transition Reynolds number did not appear to be as sensitive to temperature ratio as it did to local Mach number. The heat-transfer data agreed well with theory, using a Reynolds number based on length from the tip (ref. 87). The data from this flight, along with the data from the four-stage model that reached Mach 10.4, were presented at a Conference on Aircraft Loads, Flutter, and Structures in March 1955 (ref. 88).

The heat transfer to a slightly blunted 25-degree cone was determined in flight with a rocket model having a four-stage propulsion system similar to the one just described, escept that the first Nike stage was replaced by an Honest John motor. This system has been described earlier in this chapter and is shown in figure 288. In this test, all stages performed as expected, and a Mach number of 9.89 was reached. An over-the-top trajectory was followed, with the third stage being fired at an altitude of 99,000 feet, just past the apogee on a downward flight path angle of about 7 degrees. The last stage burned out at 90,000 feet. Skin temperatures and pressures were measured along the nose cone, cylinder, and flare. The complete skin of the model was oxidized in a furnace prior to assembly. A large amount of data were obtained from the flight (ref. 89), but, unfortunately, during the burning of the last stage the model was at an angle of attack, and direct comparisons with earlier data were not possible. The data did indicate transition Reynolds numbers of about the same magnitude, less than 10 million, as had been found on the earlier 15-degree cone with an oxidized surface (ref. 90).

During March 1957, the effect of angle of yaw on heat transfer to a 20-degree cone was determined from tests in the 27-inch nozzle of the Preflight Jet at a Mach number of 1.98. The cone had a rounded tip with a radius of 0.50 inch, and a base with a maximum diameter of 7 inches. Thermocouples and pressure orifices were located along the length of the cone, with two thermocouples on the nose, one at the stagnation point, and one at the 45-degree station. The tests covered an angle range from 0 to 9 degrees. The Reynolds number was about 12 million per foot of length. The data indicated turbulent flow at the 45-degree station on the nose as well as at all rearward stations. The heat transfer at the stagnation point was slightly lower than that to be achieved according to the theory of Sibulkin (ref. 91). At angles of yaw, the heat transfer increased on the windward surface and decreased on the leeward, both in accordance with existing theories (ref. 92).

The heat transfer to a blunted cone at Mach numbers to 15.5 was determined with one of the Honest John five-stage vehicles described earlier in this chapter. The cone had an included angle of 29 degrees and a hemispherical tip with a radius of 0.62 inch. The tip and conical surfaces were polished to a roughness of about 5 microinches, as measured with an interference microscope. An asbestos insulating liner was placed on the inner surface of the cone. The liner, in turn, was covered by a radiation shield to protect the internal instrumentation from the extremely high temperatures expected on the skin.

The complete vehicle was flown on an over-the-top trajectory, with the third stage being ignited at an altitude of 96,000 feet while the vehicle was in a climbing trajectory of about 3 degrees. Suddenly, 8.2 seconds later, the telemeter went out during burning of the last stage. The model was traveling at a Mach number of 15.5 at an altitude of 98,200 feet. The T55 rocket motor still had 0.5 second to go at this time, and the longitudinal acceleration was 590 feet per second. Failure of the telemeter was believed to have resulted from structural failure, for the actual temperature measured on the inner surface of the skin was 2,470° F and the rate of change of temperature was 5,293° F per second. With a calculated temperature difference between the inner and outer surfaces of the skin of several hundred degrees, a failure was not surprising, in view of the fact that the melting temperature of inconel is 2,500° F. In fact, the nose probably burned up. The heat-transfer rate reached a maximum of 1,650 Btu per square foot per second. The calculated stagnation temperature was 20,081° F at the end of the measurement period.

The heat-transfer results for the most forward station agreed well with theoretical values for laminar, equilibrium, dissociated flow; but at more rearward stations the results were higher than those indicated by laminar theory, and transition to turbulent flow was indicated even though the Reynolds number was quite low, being less than 1.0 million (ref. 93).

HEAT TRANSFER TO AIRCRAFT COMPONENTS

The heat-transfer research discussed so far was on fairly simple bodies and was applicable to either airplanes or missiles. The other components of aircraft, such as wings and tail surfaces, were likewise subject to aerodynamic heating effects, and the general research programs were broadened to include them. Some of the preliminary results were presented at a conference on High-Speed Aircraft, held at

Langley in November 1955 (ref. 94). Chapter 10 has discussed some effects of aerodynamic heating on wings, including flutter resulting from heating in the Preflight Jet. A follow-up program, involving flight tests as well as additional heating tests, will be discussed in Chapter 14.

The Preflight Jet was a particularly useful facility for testing wings because angle-of-attack effects could be determined. One such test was made of a 60-degree delta wing at Mach 2. The semispan wing panel is shown in figure 322. The wing was restrained by a hinged arm during the rough flow conditions at the start of the test. The wing had an NACA 65A005 profile and was of built-up construction. The main skin was 0.050-inch thick and was insulated from the supporting structure to minimize heat losses from conduction. The skin, as well as the leading and trailing edges, was made of Invar steel, which has a low coefficient of thermal expansion and was used to minimize stresses and distortions caused by the hot surface during the tests.

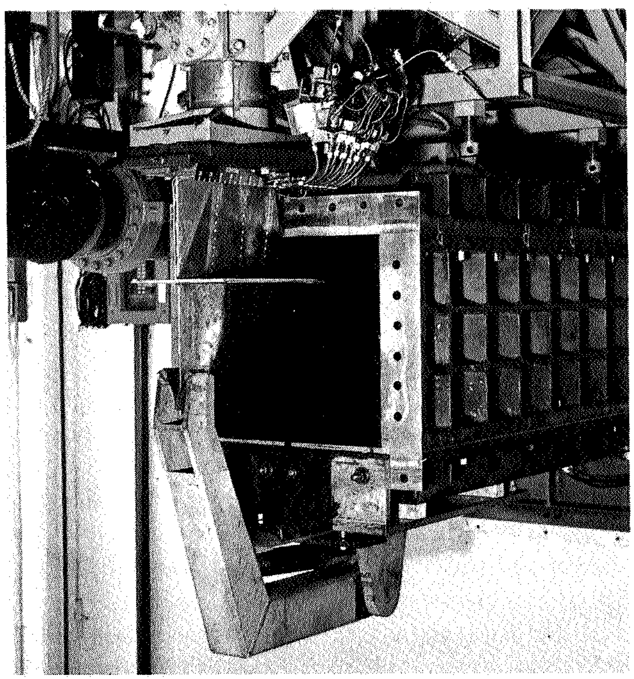


FIGURE 322. Model of 60-degree delta wing in Preflight Jet for aerodynamic heating research, July 1955. The large clamp at the wing tip was removed after steady airflow had been established.

Temperatures were measured on one surface of the wing, and pressures at opposite stations on the other surface along the chord, for three spanwise locations. Tests were made at positive and negative angles of attack from 0 degrees to 9 degrees. The Mach number was 1.98, and the Reynolds number, based on the mean aerodynamic chord, was 22 million. The flow was found to be turbulent at all measurement stations. The heat transfer increased on the lower surface as the angle of attack was increased. The Stanton numbers, however, which take into account local flow conditions, were nearly constant on the lower surface, in agreement with theory. On the upper surface, however, the experimental Stanton numbers were as much as 30 percent less than those of theory. The importance of pressure gradients and crossflows and, possibly, shock formations was thereby demonstrated (ref. 95).

Heat transfer to a wing having a hexagonal section was determined in flight, as a supplementary part of the investigation of the heating of a large 10-degree cone (shown earlier in figure 320). The wing under test was actually one of the stabilizing fins on the vehicle. The maximum Mach number was 3.64, with a maximum Reynolds number, based on mean aerodynamic chord, of 31.9 million. The wing had a 30-degree sweptback leading edge and an unswept trailing edge. The skin was made of two pieces of sheet magnesium welded together at the leading and trailing edges, and then welded to two spanwise spars. Temperatures for three spanwise stations were measured at the center of the leading edge and at other chordwise locations back to 88 percent of the chord. The highest temperature was obtained at the leading edge but the instrumentation was not adequate for correlation with theory. Laminar flow was indicated over the forward 5 percent of the wing, with turbulent flow over the remainder. Satisfactory agreement with the theory of Van Driest was indicated (ref. 96).

The measurement of heat transfer to the leading edges of wings was explored more extensively with two special models. The models were propelled by a three-stage Nike-T40-T55 system, the first of which is shown in figure 323. The vehicle was expected to reach a Mach number of 7.5 at an altitude of 47,500 feet in a straightaway firing, but because of a structural failure at the end of first-stage burning, a Mach number of only 3.0 was reached, in the first test on September 10, 1956. The second model launched on December 13, 1957, reached a Mach number of 7.5 as planned, but instability of the last stage after separation rendered the data invalid after burnout of the second stage at Mach 4.0. Each model consisted of an ogive-cylinder-flare body with a length of 76.6 inches. The body was similar to the slender heat-transfer models tested earlier, but had, in addition, four wing segments located about 3 feet back from the nose of each model. Each segment represented the inboard, leading-edge portions of a rather large wing. The segments were hollow and had inconel skins with thermocouples and pressure orifices attached to the inside surface, from the stagnation point of the leading edge rearward.

The first model had segments of wings of 0-degree and 75-degree sweepback, with a nose radius of 3/8 inch. Each segment extended outward from the fuselage about 2 inches. The tests indicated that turbulent flow existed from the leading edge rearward on all wing segments, a condition believed to be due to the influence of the turbulent boundary layer over the main body at this location. The data indicated that the sweptback leading edge had about one-half the heating rate of the one that was unswept. Although this simulation of a wing by such a short segment did not provide the laminar flow conditions expected at the leading edge, it did indicate a potential problem created by boundary-layer effects in producing increased heating at a wing-body juncture (ref. 97).

On the second model, the wing segments were doubled in length to about 4 inches from the surface of the body to try to get outside the influence of the body and its turbulent boundary layer. Three of the segments had 45-degree sweepback and leading-edge diameters of ¼, ½, and ¾ inch, respectively. The fourth segment had 36.75-degree sweepback and a leading-edge diameter of ½ inch. Instrumentation was concentrated on the problem of heat transfer along the leading-edge stagnation line. Thermocouples were installed at the leading edge at four spanwise stations and at several other points back of this line. The heat transfer at the stagnation point was found to be much higher than that corresponding to laminar flow. It was not determined whether this was the result of body interference as before, or whether it was a natural result of sweepback's inducing a turbulent layer (ref. 98).

A unique method for the flight measurement of heat transfer to a wing-body combination at an angle of attack was to mount two small models in front of the last stage of an Honest John-Nike launch vehicle, as shown in figure 324. This combination was called the "two-headed monster." One model had a wing with 39-degree sweepback, and the other, a wing with 75-degree sweepback. Both were set at an angle of attack of 7 degrees, and the areas were adjusted to provide equal lift for symmetry. Although both wings were only segments of a complete wing, each panel extended from the surface of the body about the width of one diameter (4 inches). A 10-channel telemeter was used to transmit skin temperatures, pressures, and accelerations. Fifty-one thermocouples were installed, and their readings were divided between three of the channels, which were commutated to provide readings from each station every 0.25 second.

A maximum Mach number of 4.86 was reached in the test at an altitude of 26,000 feet. The accelerometer indicated that the vehicle was at an angle of attack of 1 degree or less. Temperature data were obtained on both models for 29 seconds, at which time the Mach number had decreased to 2.5 (ref. 99). The temperature data were converted to heating rates, which were then compared with similar rates computed from theory. Turbulent flow was indicated at all stations except at the tip of the nose and the leading edge. The nose had a radius of 0.125 inch, and the leading edge, a radius of 0.05 inch. The heating rates on the windward side of the body were about twice those on the leeward side. Theory underestimated the heating on the windward side and slightly overestimated the heating on the leeward side. The presence of the wings increased the heating somewhat on the windward side of the body. The heating on the wing surfaces was in fair agreement with turbulent theory, with the windward surfaces again having about twice the heating rate as that of the leeward surfaces (ref. 100).

In consideration of tests in Langley wind tunnels as well as at Wallops, an overall assessment of heat transfer to wings at angles of attack was presented in a paper at the NACA Conference on Aircraft Loads, Structures, and Flutter in March 1957 (ref. 101).

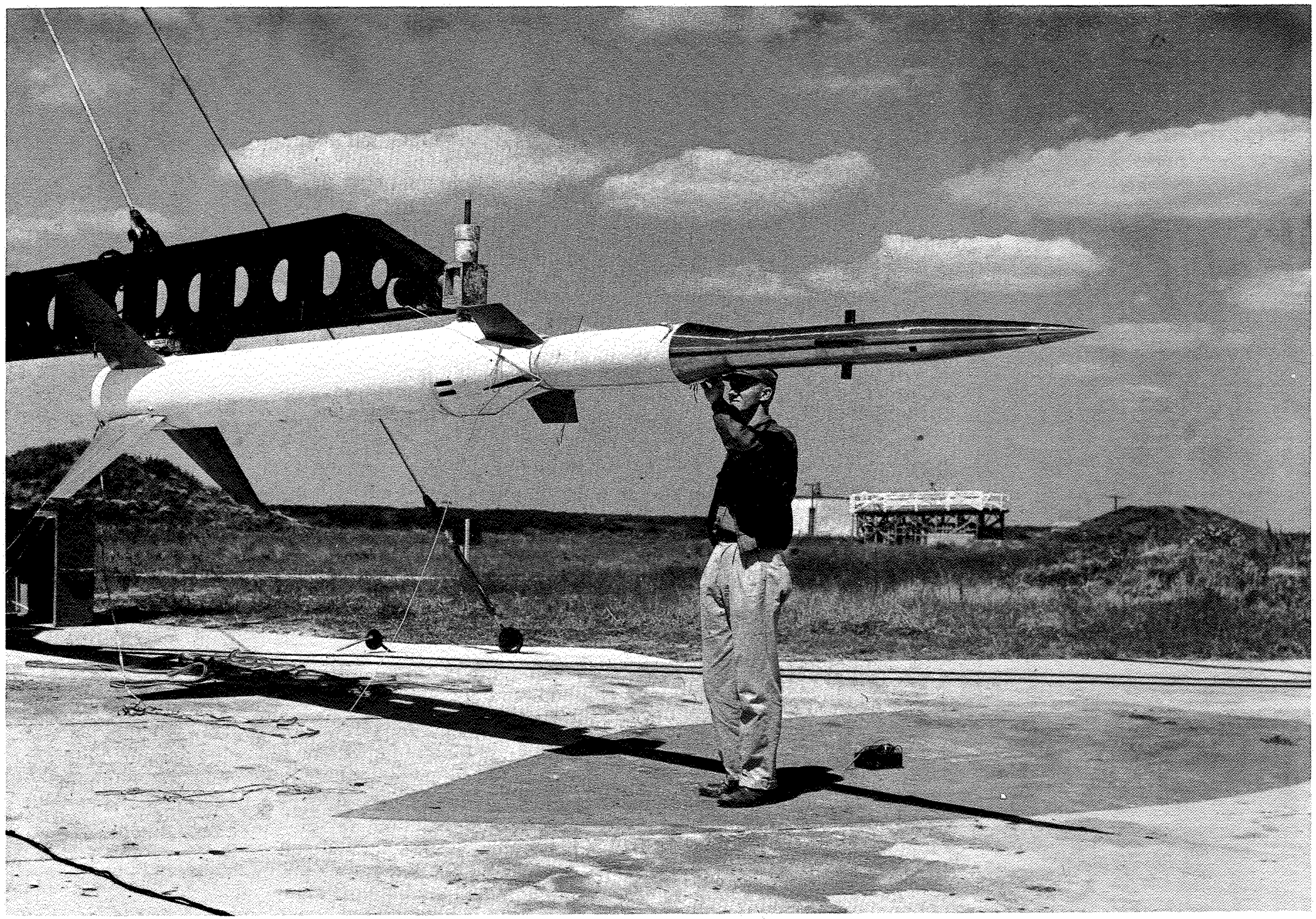


FIGURE 323. Technician Durwood Dereng examines three-stage Nike-T40-T55 rocket model used in wing leading edge heat-transfer test, September 10, 1956. Four stub wings are positioned on the last stage.

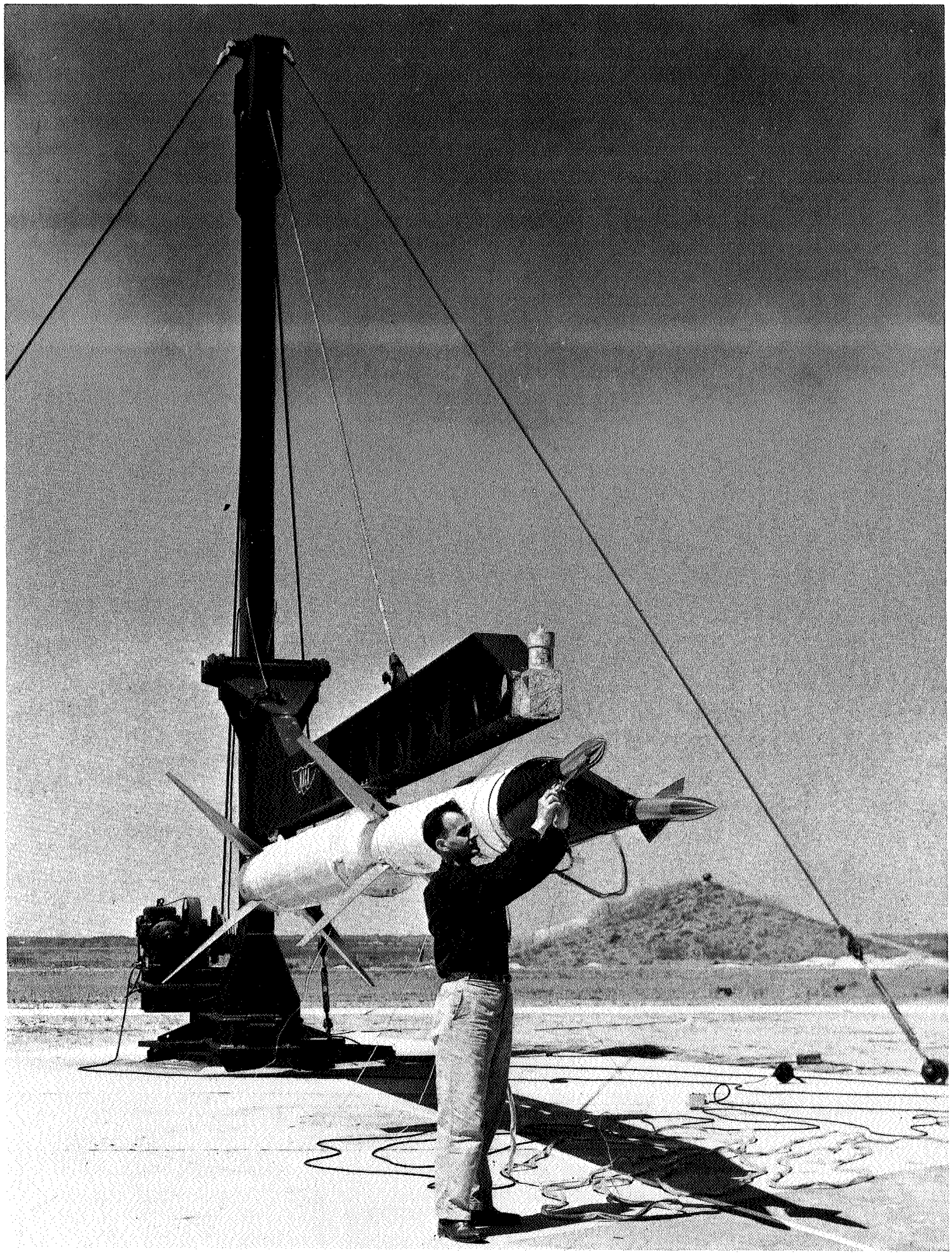


FIGURE 324. Engineer L. T. Chauvin examines "two-headed monster" on an Honest John-Nike launch vehicle, April 10, 1957.

Another aircraft component given attention in the heat-transfer program was a deflected trailing-edge flap or aileron. A 60-degree clipped-delta wing was equipped with a full-span 14.4-percent mean chord flap and was instrumented for heat-transfer measurements. Four wing panels were employed as stabilizing fins on a long ogive-cylinder body. Two panels had flaps deflected 10-degrees; the other two were deflected 20 degrees. The model contained a Deacon rocket motor and a double Deacon booster, which together provided a Mach number of 2.6. Structural failure of the fins occurred after the peak Mach number. The Reynolds number varied from 11 million to 18 million, on the basis of a mean chord of 1.48 feet. The heat transfer to the windward side of the deflected flap was about 2.5 times that to the fin directly ahead of the flap, while the heat transfer to the leeward side of the flap was only one-third of that to the fin. Theory for turbulent flow on a flat plate was in good agreement with the measurements when the theory was based on local flow conditions and length from the leading edge of the fin to the measurement station (ref. 102).

One aerodynamic heating problem of interest was the heating occurring at the point of shock impingement. Some tests of materials in high-temperature air jets suggested that there might be an intensification of heating at such points. In order to determine this effect under free-flight conditions, a special model was designed in the shape of a cross, and was made from two intersecting cylinders. The cylinder in the line of flight had a diameter of 0.88 inch and a hemispherical nose, and was attached directly ahead of the second stage of a rocket vehicle. The intersecting cylinder had a diameter of 0.75 inch and was located behind the nose at a distance equal to two diameters. The intersecting cylinder had a total span of five diameters. The transverse cylinder was equipped with thermocouples along its leading edge. A Nike-Recruit two-stage propulsion system was used. A maximum Mach number of 7.4 was reached at an altitude of 16,000 feet, but no data were obtained after mach 5.91 because of structural failure possibly from excessive temperatures. The thermocouple readings were commutated at a high rate to provide data at each station every 0.10 second. The flow pattern around the test cylinder was determined from schlieren photographs taken in separate tests in the Preflight Jet and in the Langley Unitary Wind Tunnel, from which the shock-impingement locations were determined. The test results did not show the expected accelerated heating rate, but rather showed a fairly uniform heating along the span of the transverse cylinder. The magnitude of the heating did not vary consistently with Mach number, being about one-half the theoretical laminar rate below Mach 3 and about twice that of theory, above Mach 4 (ref. 103).

The heat transfer in separated flow on an 8-degree cone was determined in the 12-inch Mach 1.8 nozzle of the Preflight Jet, during June 1956. Separation on the cone was forced by adding to the nose several different blunt objects such as large spheres, hemispheres, flat plates, and blunt cones. Temperatures were measured along the cone behind these objects. The tests indicated that heat transfer in the separated region was reduced to about one-half the theoretical turbulent value; but after flow reattachment, the heat transfer equaled the theoretical turbulent value. No local hot spots at the point of reattachment were noted (ref. 104).

References

1. Piland, R. O., Memorandum for Assistant Director, June 4, 1954, giving justification for procurement of Honest John rocket motors.
2. Wallops Daily Log, Sept. 15, 1955.
3. Allen, H. Julian; and Eggers, A. J., Jr.: *A Study of the Motion and Aerodynamic Heating of Missiles Entering the Earth's Atmosphere at High Supersonic Speeds.* NACA RM A53D28. Reissued as NACA TN 4047, 1957.
4. Faget, M. A., Memorandum for Associate Director, Jan. 11, 1955, proposing a reentry test vehicle.
5. Shortal, Joseph A.; and Swanson, Andrew G.: "NACA Hypersonic Flight Testing With Multistage Rockets." Paper presented at IAS National Midwestern Guided Missile Meeting, St. Louis, Mo., May 12–14, 1958.
6. Bland, William M., Jr.; and Bressette, Walter E.: *Some Effects of Heat Transfer at Mach Number 2.0 at Stagnation Temperatures Between 2,310° and 3,500° R on a Magnesium Fin With Several Leading-Edge Modifications.* NACA RM L57C14.
7. English, Roland D.; Spinak, Abraham; and Helton, Elred H.: *Physical Characteristics and Test Conditions of an Ethylene-Heated High-Temperature Jet.* NACA TN 4182, Jan. 1958.
8. Bland, William M., Jr.: *Effectiveness of Various Protective Coverings on Magnesium Fins at Mach Number 2.0 and Stagnation Temperatures Up to 3,600° R.* NACA RM L57J17.
9. Bland, William M., Jr.: *Some Effects of Fin Leading-Edge Shape on Aerodynamic Heating at Mach Number 2.0 at a Stagnation Temperature of About 2,600° R.* NACA RM L57K12.
10. Thibodaux, J. G., Jr., Memorandum for Associate Director, Apr. 13, 1954, regarding visit to Elkton Division of Thiokol Chemical Corporation on Feb. 10, 1954.

11. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Space and Technology in the Exploration of Space, 1915–1960.* NASA, 1961, p. 82.
12. Lee, Dorothy B.: *Flight Performance of a 2.8 KS 8100 Cajun Solid-Propellant Rocket Motor.* NACA RM L56K01.
13. Royall, John F., Jr.; and Garland, Benjamin J.: *Characteristics of the Nike-Cajun (CAN) Rocket System and Flight Investigation of its Performance.* NACA RM L57D26.
14. Corliss, William H.: *History of Sounding Rockets,* NASA, 1969.
15. Thibodaux, J. G., Jr., Memorandum for Associate Director, Mar. 8, 1955, regarding visit of D. E. Shonard of Aerophysics Development Corporation to PARD on Jan. 27, 1955, to discuss hypersonic flight tests.
16. Hill, P. R., Memorandum for Associate Director, Nov. 15, 1955, regarding visit of R. J. Magnus and D. Bitondo of Aerophysics Development Corporation on Nov. 4, 1956, to discuss their Hypersonic Test Vehicle.
17. Hastings, Earl C., Jr.; and Mitcham, Grady L.: *Comparison of the Minimum Drag of Two Versions of a Modified Delta-Wing Fighter as Obtained From Flight Tests of Rocket-Boosted Models and Equivalent Bodies Between Mach Numbers of 0.80 and 1.64* NACA RM L56E04.
18. Hastings, Earl C., Jr.; and Dickens, Waldo L.: *Effects of Inlet Modification and Rocket-Rack Extension on the Longitudinal Trim and Low-Lift Drag of the Douglas F5D–1 Airplane as Obtained With a 0.125-Scale Rocket-Boosted Model Between Mach Numbers of 0.81 and 1.64.* NACA RM SL57D30.
19. *Jane's All the World's Aircraft,* 1957–1958, p. 284.
20. O'Kelly, Burke R.: *Free-Flight Tests of 1/10-Scale Republic F–105 Airplane Wings in the Subsonic to Low Supersonic Range to Investigate the Possibility of Flutter.* NACA RM SL56B13.
21. Shortal, Joseph A., Memorandum for Associate Director, May 21, 1956, regarding Wallops assistance to Canadian Department of Defense with the AVRO CF–105 airplane.
22. Swenson, Loyd S., Jr.; Grimwood James M.; and Alexander, Charles C.: *This New Ocean, A History of Project Mercury.* NASA, Washington, D.C., 1966, p. 153.
23. Lanford, Wade E.: *Flight Tests of Fifteen T–231 Gun-Launched Rocket Projectiles.* NACA RM SL56F27.
24. Lee, John B.: *An Investigation of the Release Characteristics of a 1/30 Dynamically Scaled AVCO Boosted Vehicle From the Simulated Bomb Bay of the B–52 Airplane.* NACA RM SL56I18a.
25. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Oct. 26, 1955, regarding meeting with ONR concerning development of hurricane photography rocket.
26. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Mar. 12, 1956, regarding meeting at Langley, Feb. 20–21, 1956, to discuss hurricane photographic rocket tests at Wallops Island.
27. Bland, William M., Jr.: op. cit.
28. Wallops Daily Log, Aug. 17, 1956.
29. Hubert, Lester F.: *Analysis of Project Hugo Test Firing December 5, 1958.* MSL Report No. 2, Aug. 1960, Weather Bureau, U.S. Dept of Commerce. Included in appendix to hearings before the committee on Science and Astronautics, U.S. House of Representatives, 87th Congress, July 25–27, 1961.
30. Vitale, A. James: and Mitchell, Jesse L.: *Experimental Results From a Test in Rough Air at High Subsonic Speeds of a Tailless Rocket Model Having Cruciform Triangular Wings, and a Note on the Calculation of Mean Square Loads of Aircraft in Continuous Rough Air.* NACA RM L55L28.
31. Vitale, A. James: *Results From an Investigation in Rough Air at Mach Numbers From 0.84 to 1.67 of a Tailless Rocket Model Having 60° Triangular Wings.* NACA RM L56F07a.
32. Mason, Homer P.; and Gardner, William N.: *A Limited Correlation of Atmospheric Sounding Data and Turbulence Experienced by Rocket-Powered Models.* NACA TN 3953, Apr. 1957.
33. Hill, P. R.; and Hoffman, S.: *Preliminary Evaluation of the Wing Leading Edge as a Missile-Mounting Location.* NACA RM L56J12.
34. Kouyoumjian, Walter L.; and Hoffman, Sherwood: *Free-Flight Investigation to Determine the Drag of Flat- and Vee-Windshield Canopies on a Parabolic Fuselage With and Without Transonic Indentation Between Mach Numbers of 0.75 and 1.35.* NACA TN 4405, Sept. 1958.
35. Hoffman, Sherwood; and Robins, A. Warner: "Drag of Canopies at Transonic Speeds." Paper presented at NACA Conference on Aerodynamics of High-Speed Aircraft, Langley Field, Nov. 1–3, 1955. Reissued as NACA RM L55L23.
36. Hoffman, Sherwood: *Free-Flight Investigation of the Drag of a Model of a 60° Delta-Wing Bomber With Strut-Mounted Siamese Nacelles and Indented Fuselage at Mach Numbers From 0.80 to 1.35.* NACA RM L57G29.
37. Hoffman, Sherwood: *Supersonic-Area-Rule Design and Rocket-Propelled Flight Investigation of a Zero-Lift Straight-Wing-Body-Nacelle Configuration Between Mach Numbers 0.8 and 1.53.* NACA RM L56B27.
38. Baldwin, Barrett S., Jr.; and Dickey, Robert R.: *Application of Wing-Body Theory to Drag Reduction at Low Supersonic Speeds.* NACA RM A54J19.
39. Faget, Maxime A.: *The Sine-Cosine Method For Reducing the Interference Pressure Drag of Sweptback Wings.* NACA RM L57D24.
40. Blanchard, Willard S., Jr.; and Hoffman, Sherwood: *A Flight Investigation to Determine the Effectiveness of Mach Number 1.0, 1.2, and 1.41 Fuselage Indentations For Reducing the Pressure Drag of a 45° Sweptback Wing Configuration at Transonic and Low Supersonic Speeds.* NACA RM L57B27.
41. Hoffman, Sherwood: *Zero-Lift Drag of a Large Fuselage Cavity and a Partially Submerged Store on a 52.5° Sweptback-Wing-Body Configuration as Determined From Free-Flight Tests at Mach Numbers of 0.7 to 1.53.* NACA RM L56L21.
42. Hoffman, Sherwood: *Free-Flight Investigation at Mach Numbers From 0.8 to 1.5 of the Effect of a Fuselage Indentation on the Zero-Lift Drag of a 52.5° Sweptback-Wing-Body Configuration With Symmetrically Mounted Stores on the Fuselage.* NACA RM L57L04.

43. Hoffman, Sherwood: *Free-Flight Investigation of the Drag of a 60° Delta-Wing Configuration With Large Stores Mounted Below the Indented Fuselage at Mach Numbers Between 0.8 and 1.6.* NASA Memo 10–9–58L.
44. Dickens, Waldo L.; and Hastings, Earl C., Jr.: *Comparison of Low-Lift Drag at Mach Numbers From 0.74 to 1.37 of Rocket-Boosted Models Having Externally Braced Wings and Cantilever Wings.* NACA RM L57G10.
45. Jackson, H. Herbert: *Free-Flight Measurements of the Zero-Lift Drag of Several Wings at Mach Numbers From 1.4 to 3.8.* NACA RM L56C13. Reissued as NASA TN D–395, June 1960.
46. Leiss, Abraham; and Kouyoumjian, Walter L.: *Investigation of Fixed-Geometry Supersonic Inlets With Bypass Ducts For Matching Torbojet-Engine Air-Flow Requirements Over a Range of Transonic and Supersonic Speeds.* NACA RM L57K14.
47. Kouyoumjian, Walter L.: *Free-Flight Investigation to Determine the Inlet External Drag of Four Inlet Models at Mach Numbers From 1.50 to 3.00.* NACA RM L58B04.
48. Judd, Joseph H.: *A Free-Flight Investigation of the Drag Coefficients of Two Single-Engine Supersonic Interceptor Configurations From Mach Number 0.8 to 1.90 to Determine the Effect of Inlet and Engine Locations.* NACA RM L55G05a.
49. Hall, James Rudyard: *Preliminary Free-Flight Study of the Drag and Stability of a Series of Short-Span Missiles.* NACA RM L55J13.
50. Schult, Eugene D.: *Free-Flight Investigation at Mach Numbers Between 0.5 and 1.7 of the Zero-Lift Rolling Effectiveness and Drag of Various Surface, Spoiler, and Jet Controls on an 80° Delta-Wing Missile.* NACA RM L56H29. Reissued as NASA TN D–205, Feb. 1960.
51. Schult, Eugene D.: *Free-Flight Roll Performance of a Steady-Flow Jet-Spoiler Control on an 80° Delta-Wing Missile Between Mach Numbers of 0.6 and 1.8.* NACA RN L57J28.
52. Kehlet, Alan B.: *Free-Flight Investigation of Comparative Zero-Lift Rolling Effectiveness of a Leading-Edge and a Trailing-Edge Air-Jet Spoiler on an Unswept Wing.* NACA RM L5710.
53. Schult, Eugene D.: *A Free-Flight Investigation at High Subsonic and Low Supersonic Speeds of the Rolling Effectiveness and Drag of Three Spoiler Controls Having Potentially Low Actuating-Force Requirements.* NACA RM L55G11a.
54. Schult, Eugene D.: *Free-Flight Performance of a Rotating-Vane-Spoiler Roll Control System With Low Actuating Forces.* NACA RM L57C21.
55. Schult, Eugene D.: *Free-Flight Measurements of the Rolling Effectiveness and Operating Characteristics of a Bellows-Actuated Split-Flap Aileron on a 60° Delta Wing at Mach Numbers Between 0.8 and 1.8.* NACA RM L54H17.
56. Schult, Eugene D.: "Some Characteristics of Roll-Controls Having Possible Application to Fin-Stabilized Ammunition." Paper presented at Symposium on Fin-Stabilized Ammunition, Picatinny Arsenal, Dover, N.J., Oct. 17, 1956. Published as NACA RM L57A04. Reissued as NASA TR R–197, Apr. 1964.
57. Henning, Allen B.; Wineman, Andrew R.; and Rainey, Robert W.: *Some Data on Body and Jet Reaction Controls.* NACA RM L56L17.
58. Gillis, Clarence L.; and Chapman, Rowe, Jr.: *Effect of Wing Height and Dihedral on the Lateral Stability Characteristics at Low Lift of a 45° Swept-Wing Airplane Configuration as Obtained From Time-Vector Analyses of Rocket-Propelled-Model Flights at Mach Numbers From 0.7 to 1.3.* NACA RM L56E17.
59. McFall, John C., Jr.; Mitchell, Jesse L.; and Vitale, A. James: *Lateral Stability Investigation at Mach Numbers From 0.8 to 1.7 of Two Rocket-Boosted Models of an Airplane Configuration With a 45° Swept Wing and a Low Horizontal Tail.* NACA RM L57G25.
60. Curry, T. Bradley, Jr.; and Crabill, Norman L.: *Rocket-Model Investigation of Lateral Stability Characteristics and Power Effects of a Jet-Engine Airplane Configuration With Tail Boom at Mach Numbers From 1.15 to 1.37.* NASA TN D–638. Jan. 1961.
61. D'Aiutolo, Charles T.; Willoughby, William W.; and Coltrane, Lucille C.: *Free-Flight Experience of the Lateral Stability Characteristics at Low Lift of a 45° Swept-Wing Rocket-Propelled Model Equipped With a Nonlinear Yaw-Rate Damper System at Mach Numbers From 0.76 to 1.73.* NACA RM L56L18.
62. Disher, J. H.: *Performance of Air-Launched T–40 Rocket Motors With Two Types of Igniter.* NACA RM SE54J12.
63. Rabb, Leonard; and Simpkinson, Scott H.: *Free-Flight Heat-Transfer Measurements on Two 20°-Cone-Cylinders at Mach Numbers From 1.3 to 4.9.* NACA RM E55F27.
64. Van Driest, E. R.: "Calculation of the Stability of the Laminar Boundary Layer in a Compressible Fluid on a Flat Plate With Heat Transfer." *Jour. Aero. Sci.*, vol. 19, no. 12, Dec. 1952, pp. 801–812.
65. Rabb, Leonard; and Disher, John H.: *Boundary-Layer Transition at High Reynolds Numbers as Obtained in Flight of a 20° Cone-Cylinder With Wall to Local Stream Temperature Ratios Near 1.0.* NACA RM E55I15.
66. Moeckel, W. E.: *Some Effects of Bluntness on Boundary-Layer Transition and Heat Transfer at Supersonic Speeds.* NACA TN 3653, Mar. 1956. Reissued as NACA TR 1312, 1957.
67. Disher, John H.; and Rabb, Leonard: *Observations of Laminar Flow on a Blunted 15° Cone-Cylinder in Free Flight at High Reynolds Numbers and Free-Stream Mach Numbers to 8.17.* NACA RM E56G23.
68. Rabb, Leonard; and Krasnican, Milan J.: *Observations of Laminar Flow on an Air-Launched 15° Cone-Cylinder at Local Reynolds Numbers to 50 $\times$ 10⁶ at Peak Mach Number of 6.75.* NACA RM E56L03.
69. Jack, John R.; Wisniewski, Richard J.; and Diaconis, N. S.: "Effects of Extreme Surface Cooling on Boundary-Layer Transition." Paper presented at Symposium on High-Speed Aerodynamics and Structures, Gainesville, Fla., Jan. 22–24, 1957. Reissued as NACA TN 4094, Oct. 1957.
70. Rabb, Leonard; and Krasnican, Milan J.: *Effects of Surface Roughness and Extreme Cooling on Boundary-Layer Transition For 15° Cone-Cylinder in Free-Flight at Mach Numbers to Mach 7.6.* NACA RM E57K19.
71. Krasnican, M. J.; and Wisniewski, R. J.: *Free-Flight Determination of Boundary-Layer Transition and Heat Transfer For a Hemisphere-Cylinder at Mach Numbers to 5.6.* NACA RM E57F10.
72. Wisniewski, Richard J.: *Note on a Correlation of Boundary-Layer Transition Results on Highly Cooled Blunt Bodies.* NASA Memo 10–8–58E.

73. Krasnican, M. J.; and Rabb, L.: *Effects of Nose Radius and Extreme Cooling on Boundary-Layer Transition For Three Smooth 15°-Cone-Cylinders In Free Flight at Mach Numbers to 8.50.* NASA Memo 3–4–59E.
74. Weston, Kenneth C.; and Lumney, Glynn S.: *Heat-Transfer Measurements on an Air-Launched, Blunted Cone-Cylinder Rocket Vehicle to Mach 9.7.* NASA TM X–84, Sept. 1959.
75. McConnell, Dudley George: *Free-Flight Observation of a Separated Turbulent Flow Including Heat Transfer Up to Mach 8.5.* NASA TN D–278, Oct. 1961.
76. *Performance Summary For the Jaguar Sounding Rocket Vehicle.* Chance Vought Corp., Report AST/E1R–13329, Apr. 18, 1961.
77. *Jane's All The World's Aircraft,* 1960–1961, p. 473.
78. Disher, John H., Memorandum to USAF, "Review of NACA Lewis Air Launch Free-Flight Program Using B–57A Airplane," Aug. 1958.
79. Bland, William M., Jr.; and Kolenkiewiez, Roland: *Free-Flight Pressure Measurements Over a Flare-Stabilized Rocket Model With a Modified von Karman Nose For Mach Numbers Up to 4.3.* NACA RM L57J24.
80. Van Driest, E. R.: "Calculation of the Stability of the Laminar Boundary Layer in a Compressible Fluid on a Flat Plate With Heat Transfer." *Jour. Aero. Sci.,* vol. 19, no. 12, Dec. 1952, pp. 801–812.
81. Piland, Robert O.; Collie, Katherine A.; and Stoney, William E.: *Turbulent and Laminar Heat-Transfer Measurements on a 1/6-Scale NACA RM–10 Missile in Free Flight to a Mach Number of 4.2 and to a Wall Temperature of 1400° R.* NACA RM L56C05.
82. Ginnings, Defoe C.; and Thomas, Eugenia: *The Electrical Resistance and Total Radiant Emittance of Inconel in the Range 0° to 1000° C.* NBS Rep. 4111 (NACA Contract S54–22), Nat. Bur. Standards, May 1955.
83. Rumsey, Charles B.; and Lee, Dorothy B.: *Measurements of Aerodynamic Heat Transfer and Boundary-Layer Transition on a 10° Cone in Free Flight at Supersonic Mach Numbers up to 5.9.* NACA RM L56B07. Reissued as NASA TN D–745, May 1961.
84. Dunn, D. W.; and Lin, C. C.: "On the Stability of the Laminar Boundary Layer in a Compressible Fluid." *Jour. Aero. Sci.,* vol. 22, no. 7, July 1955, pp. 455–477.
85. Merlet, Charles F.; and Rumsey, Charles B.: *Supersonic Free-Flight Measurements of Heat Transfer and Transition on a 10° Cone Having a Low Temperature Ratio.* NACA RM L56L10. Reissued as NASA TN D–951, Aug. 1961.
86. Hall, James R.; and Speegle, Katherine C.: *Limited Heat-Transfer, Drag, and Stability Results From an Investigation at Mach Numbers Up to 9 of a Large Rocket-Propelled 10° Cone.* NACA RM L57E08.
87. Rumsey, Charles B.; and Lee, Dorothy B.: *Measurements of Aerodynamic Heat Transfer and Boundary-Layer Transition on a 15° Cone in Free Flight at Supersonic Mach Numbers Up to 5.2.* NACA RM L56F26.
88. Piland, Robert O.; and Collie, Katherine A.: "Aerodynamic Heating of Rocket-Powered Research Vehicles at Hypersonic Speeds." Paper presented at NACA Conference on Aircraft Loads, Flutter, and Structures, March 2–4, 1955, Langley Field, Va. Reissued as NACA RM L55E10c.
89. Bond, Aleck C.; and Rumsey, Charles B.: *Free-Flight Skin Temperature and Pressure Measurements on a Slightly Blunted 25° Cone-Cylinder-Flare Configuration to a Mach Number of 9.89.* NACA RM L57B18.
90. Lee, Dorothy B.; Rumsey, Charles B.; and Bond, Aleck C.: *Heat Transfer Measured in Free Flight on a Slightly Blunted 25° Cone-Cylinder-Flare Configuration at Mach Numbers Up to 9.89.* NACA RM L58G21.
91. Sibulkin, M.: "Heat Transfer Near The Forward Stagnation Point of a Body of Revolution." *Jour. Aero. Sci.* (Readers Forum), vol. 19, no. 8, Aug. 1952, pp. 570–571.
92. English, Roland D.: *Effects of Yaw on the Heat Transfer to a Blunt Cone-Cylinder Configuration at a Mach Number of 1.98.* NASA Memo 10–8–58L.
93. Bland, William M., Jr.; Rumsey, Charles B.; Lee, Dorothy B.; and Kolenkiewicz, Ronald: *Free-Flight Aerodynamic-Heating Data to a Mach Number of 15.5 on a Blunted Conical Nose With a Total Angle of 29°.* NACA RM L57F28.
94. Chauvin, Leo T.: "Aerodynamic Heating of Aircraft Components." Paper presented at NACA Conference on Aerodynamics of High-Speed Aircraft, Langley Field, Va., November 1–3, 1955. Reissued as NACA RM L55L19b.
95. Carter, Howard S.: *Heat Transfer on the Lifting Surfaces of a 60° Delta Wing at Angle of Attack For Mach Number 1.98.* NACA RM L56C23.
96. Swanson, Andrew G.; and Rumsey, Charles B.: *Aerodynamic Heating of a Wing as Determined From a Free-Flight Rocket-Model Test to Mach Number 3.64.* NACA RM L56F11e.
97. O'Neal, Robert L.; and Bond, Aleck C.: *Heat Transfer to 0° and 75° Swept Blunt Leading Edges in Free Flight at Mach Numbers From 1.90 to 3.07.* NACA RM L58A13. Reissued as NASA TN D–1256, Apr. 1962.
98. O'Neal, Robert L.: *Heat Transfer to 36.75° and 45° Swept Blunt Leading Edges in Free Flight at Mach Numbers From 1.70 to 2.99 and From 2.50 to 4.05.* NASA TM X–208, Mar. 1960.
99. Chauvin, Leo T.: *Temperature Measurements From a Flight Test of Two Wing-Body Combinations at 7° Angle of Attack For Mach Numbers to 4.86 and Reynolds Numbers to 19.2 × 10⁶.* NACA RM L57F27.
100. Speegle, Katherine C.: *Heat-Transfer Measurements of Two Wing-Body Combinations at 8° Angle of Attack From a Flight Test For Mach Numbers to 4.86 and Reynolds Numbers to 19.2 × 10⁶.* NASA Memo 10–25–58L.
101. Bond, Aleck C.; Feller, William V.; and Bland, William M., Jr.: "Aerodynamic Heat Transfer to Wing Surfaces and Wing Leading Edges." Paper presented at NACA Conference on Aircraft Loads, Structures, and Flutter, Langley Field, Mar. 5–7, 1957. Reissued as NACA RM L57D22c.
102. Chauvin, Leo T.; and Buglia, James J.: *Measurement of Aerodynamic Heat Transfer to a Deflected Trailing-Edge Flap on a Delta Fin in Free Flight at Mach Numbers From 1.5 to 2.6.* NACA RM L57B20. Reissued as NASA TN D–250, June 1960.
103. Carter, Howard S.; and Carr, Robert E.: *Flight Investigation of Heat Transfer to an Unswept Cylinder Subjected to an Incident Shock and Flow Interference From an Upstream Body at Mach Numbers Up to 5.50.* NASA TN D–988, Oct. 1961.
104. Garland, Benjamine J.; and Hall, James R.: *Measurements of Aerodynamic Heat Transfer in Turbulent Separated Regions at a Mach number of 1.8.* NACA RM L57L09.

CHAPTER 14

BALLISTIC MISSILE NOSE CONE RESEARCH: 1957

NEW FACILITIES AND DREDGING

Addition of the large Nike and Honest John rocket motors to the Wallops inventory, necessitated by the emphasis on increased flight speeds in the hypersonic research program, overtaxed the existing Propellant Magazine (see figure 86, Chapter 7). As a result, construction of a second magazine was requested and approved as a C&E item of $90,000 in the budget for fiscal year 1956. On August 23, 1955, delivery of a 77,000-pound shipment of 3.25-inch rocket motors, obtained at no charge from Navy surplus, made the problem more acute.

A request for approval of the general plans for the new storage building was sent to NACA Headquarters on September 1, 1955, and was granted on September 16, 1955, as Project 1640. Detail plans and specifications were prepared and bids received early in 1956. The first bids exceeded the allotment, but after some changes the second bids were only slightly above the estimate. On August 29, 1956, an additional sum of $4,500 was transferred from a Langley C&E road project with the approval of NACA Headquarters, bringing the total available funding to $94,500. Contract NA1-2859 was awarded to Sullivan Engineering Company, and the project was officially completed in February 1958, at a total cost of $94,045.

The new facility was named Fuel Magazine, Building Number 5030. It was constructed of concrete on wood piling and was covered with earth on three sides out to a distance of 29 feet. Inside dimensions included a 30-foot width, a 50-foot length, and a 15-foot ceiling height. A single door and loading platform were provided on one end. As shown in figure 325, the building was located about 350 feet beyond the existing rocket magazine and about 250 feet from the road. The access road and fence were extended to include the new magazine within the restricted area. Pending completion of the building, use had been made of the Navy facilities at Chincoteague.

The hypersonic research program also necessitated construction of an additional launcher. The multistage launcher (see figure 285, Chapter 13) constructed in 1955 for vehicles having Honest John motors as the first stage, would not handle a multi-stage vehicle having a Sergeant motor as the first stage. A launcher of larger capacity (20,000 pounds) was designed along the same lines as the existing equipment, except that the mast was now to be braced by rigid tubing instead of cables. In addition, two hoists were to be attached to the boom for raising the rocket vehicles into position.

A request for approval, dated August 13, 1956, was granted by NACA Headquarters on September 5, 1956, as Project 1808 with authorization for a total expenditure of $48,000 from GOE funds. Contracts were let for the construction of a foundation and for the fabrication of the main components of the launcher. In April 1957, the design was revised to include a third suspension point

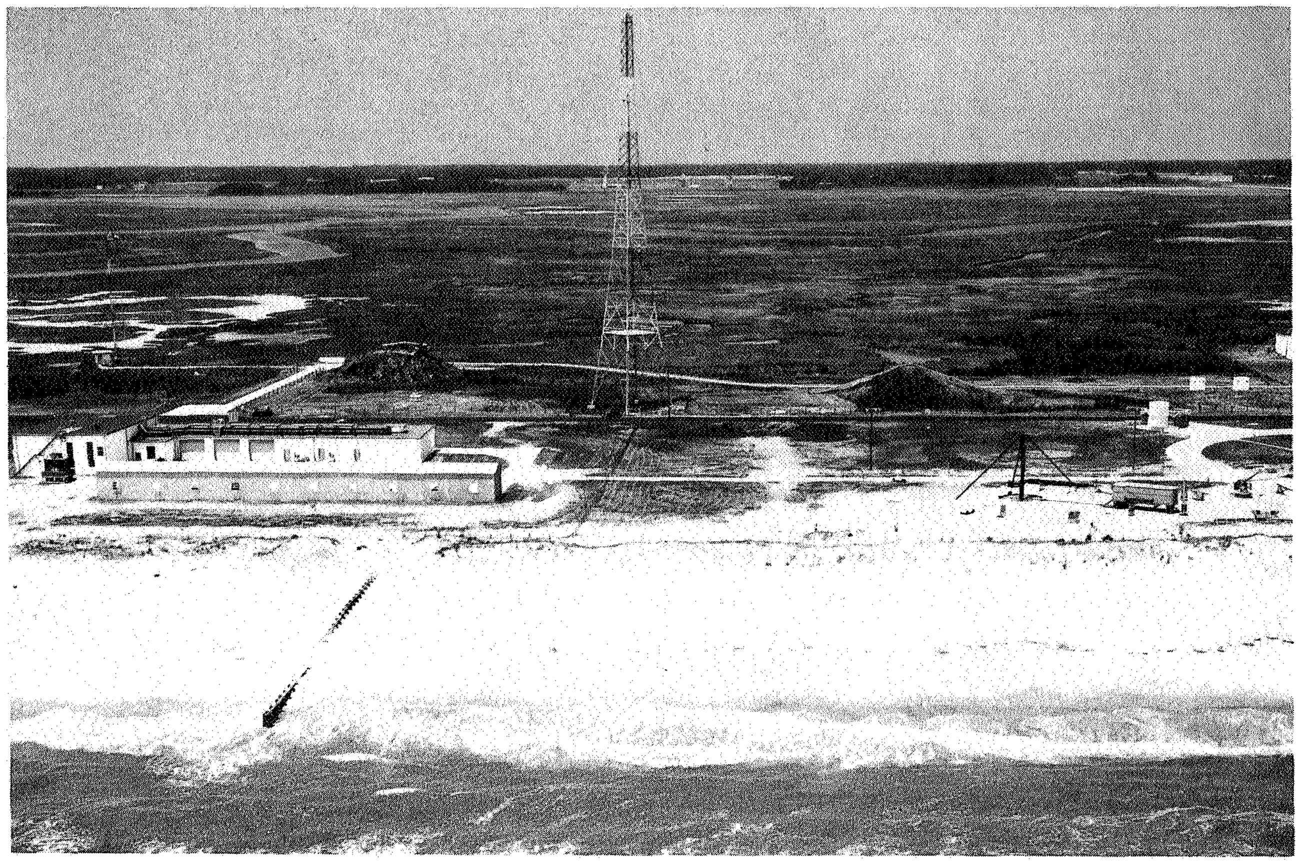


FIGURE 325. Aerial view of Wallops Island, February 1958, showing new propellant magazine in enclosed area across the road from the Assembly Shop.

forward of the original end of the boom, which necessitated a 10-foot extension to the boom. Because of difficulties in locating a fabricator to erect the launcher at Wallops, the work was done by NACA personnel. At the same time, they made the extension to the boom. Approval of this revised plan was given by NACA Headquarters on May 1, 1957. The total funding remained at $48,000 but the total for contractual services was reduced to $32,000. The launcher was completed on September 30, 1957, at a total cost of $41,442, of which $31,428 was for contracted services.

This tubular launcher was located at Launching Area 1 beside the smaller multistage launcher. The new launcher was used for the first time on April 24, 1958. (See figure 385, Chapter 15.) The first Sergeant vehicle was launched from it on June 27, 1958, as a part of the high-Mach-number heat-transfer program to be discussed later.

These two launchers were both quite satisfactory and became the standard launchers at Wallops for multistage solid rockets. Two additional tubular launchers were to be constructed at Wallops later as part of the expansion of facilities under NASA. Many requests for drawings of these launchers were received from other ranges and interested companies, among them Sandia Corporation, in May 1958; Eglin Air Force Base, in June 1958; Marquardt Corporation, in July 1958; Cook Research Laboratories, in July 1958; and the Pacific Missile Range, in October 1958.

Some additional paving in the launch area was completed in June 1957. The paving was in three sections, approved by NACA Headquarters on February 24, 1956, and designated as Project 1749. The total cost was $15,160. Part of the paving was delayed until the Fuel Magazine had been completed. This section provided a direct paved road from the Magazine to the main road. The second section of the paving provided a direct road from the Assembly Shop to Launching Area 1, and some additional paving at the rear of the Assembly shop. The third section provided a concrete sidewalk to replace a 1945-vintage landing-mat walkway from the launch area to the Control Tower.

The ferry channel between the Wallops Island dock and the Mainland Dock had a continuing problem of silting and required redredging every few years. Approval was obtained from NACA

Headquarters for such redredging on November 29, 1955, to be performed as Project 1726, with the use of GOE funds. By this time, the ferry sometimes struck bottom in certain places at low tide.

The project also included dredging a small boat basin next to the ferry slip at the island end of the channel. It was planned to abandon the old boat dock farther downstream.

Permission to place dredged material on private property was obtained from the property owners on October 26, 1955, and the customary permit was obtained from the Army Corps of Engineers on March 2, 1956. After the bids had been received it was necessary to obtain approval for an increase in cost above the estimate. Approval was given on April 4, 1956, and the work was started thereafter. Another change, approved June 5, 1956, involved enlarging the area to be used for the small boat basin. The final cost for the redredging contract was $50,715. Work was completed on June 30, 1957.

After the small boat basin had been created, a pier and float extending 125 feet from the ferry dock were constructed. The installation is shown in figure 326, which also shows a bad icing situation (to be discusssed in a later chapter). The pier was 4 feet wide, and the float was 8 feet by 20 feet. A hinged ramp connected the two. The work was approved on December 4, 1956, as Project 1869, and was completed on August 31, 1957, at a contract cost of $6,300.

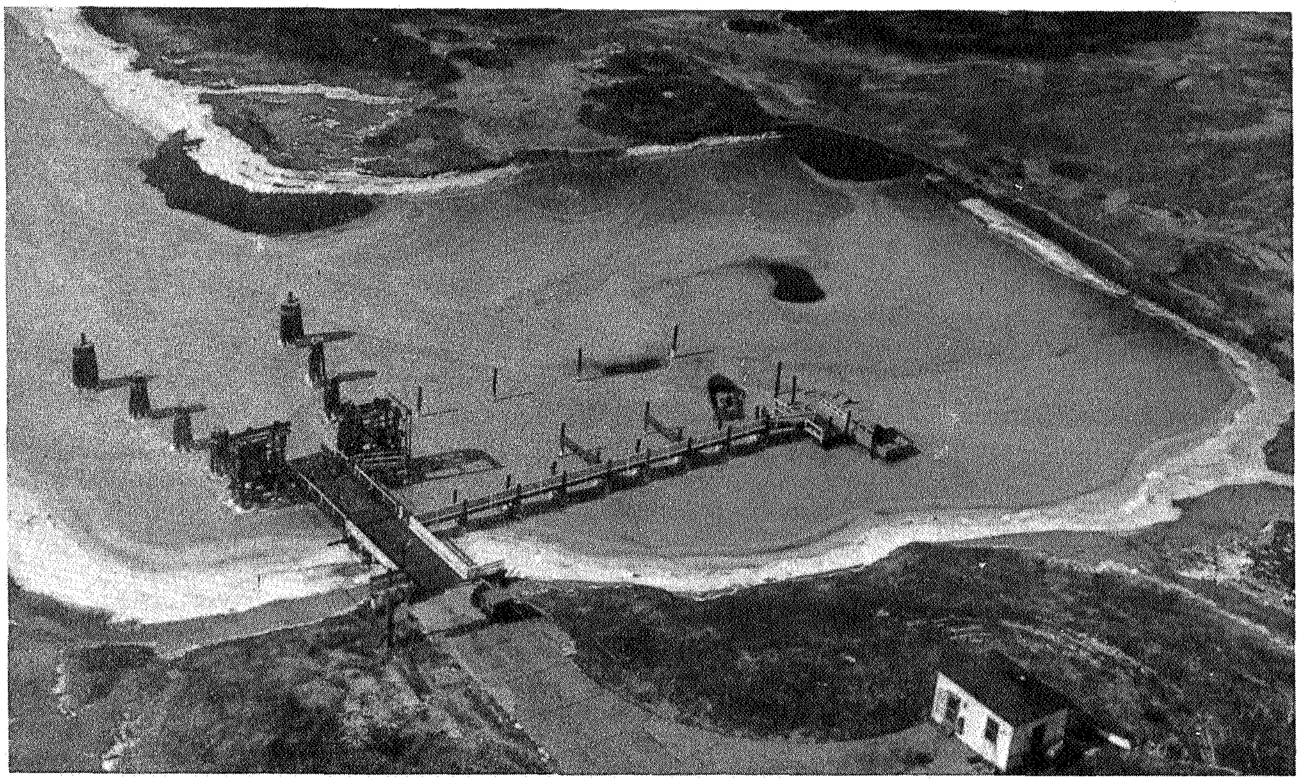


FIGURE 326. Aerial view of Wallops Island Dock, showing ferry landing, pier for small boats, and turning basin added in 1957.

The construction of a permanent building to house the SCR-584 radar has been discussed in Chapter 10. The radar was removed from its van and placed inside the building, and its antenna was anchored to the roof. This 584 radar had an 8-foot antenna and was the radar containing the long-range modification made by NACA personnel. The building (Station 3) had three main rooms. The SCR-584 occupied the north room, and the plotboard was located in the center room. The south room was reserved for a new modified version of the 584 radar called the Reeves Mod II.

The Mod II was a special development for the Atlantic Missile Range, and one was procured for Wallops at a cost of $240,000. It had a 10-foot antenna, also located on the roof of the permanent building, and its range was about twice that of the earlier 584 radar. Most important of all was the fact that while in use, it could be switched readily from skin tracking to homing on a beacon within a model. This was important in case of failure of a beacon in the early stages of a flight—at least some data could be obtained by skin tracking. The Mod II was an S-band radar with a peak power of 350 kilowatts. It was installed during 1957 and received its final acceptance test on March 6, 1958. It was a definite asset to the Wallops range and was the prime radar until equipment with an even greater range was procured.

MCDONNELL F4H-1 PHANTOM AIRPLANE

As a continuation of the plan of Navy BuAer to have all of its new supersonic aircraft investigated by the rocket-model technique at Wallops, a request was made to the NACA on January 7, 1955, for flight tests of four models of the McDonnell F4H-1 Phantom airplane, to determine drag and stability characteristics. A Nike booster was used, as shown in figure 327.

FIGURE 327. Rocket model of McDonnell F4H-1 airplane on Terrier launcher with Nike booster, June 17, 1957.

The first two models, flown on May 15, and October 2, 1956, respectively, failed structurally before burnout of the booster motor. The attachment between the model and the Nike motor was found to be critical as to alignment as well as rigidity. The third and fourth models, launched on June 19, 1957, and March 24, 1958, respectively, were both successful and provided data to Mach 2.0 (ref. 1).

The McDonnell F4H-1, later to be designated F4 and used extensively by the Air Force as well as the Navy, was a supersonic, all-weather interceptor and attack bomber. It was powered with two General Electric J79 turbojet engines and reached a Mach number of 2.6 in one flight. It was the successor to the F3H-1 Demon, and made its first flight on May 27, 1958. It weighed 40,000 pounds and carried six Sparrow air-to-air guided missiles. An altitude record of 98,557 feet was set by the F4H-1 on December 6, 1959, and many speed records were set over a period of time (ref. 2). It was to remain one of the military's superior aircraft for many years.

In the rocket-model tests, the all-movable horizontal tail was pulsed to provide data on control effectiveness as well as lift, drag, and stability. The results indicated no difficulty with the airplane and the data were transmitted to the Navy and to McDonnell.

EJECTION TESTS OF GENIE ROCKET FROM CONVAIR F–106 AIRPLANE MODEL

Rocket-model flight tests in support of the Convair F-102A airplane, forerunner of the F-106, have been discussed in Chapter 11. Studies of the ejection of stores from the bomb bay of a Republic F-105 airplane model in the Preflight Jet have been discussed in Chapter 12. In the F-105 program, the stores were ejected from the airplane at velocities up to 30 feet per second, to ensure safe separation. Similar tests were desired to study the ejection of Douglas Genie rockets from a model of the F-106 airplane. Preliminary arrangements were discussed during a visit of Convair representative H. A. Mitchell to PARD on February 2, 1956. On May 1, 1956, the Air Force officially requested the tests, and the NACA gave approval on June 28, 1956.

During its development, the Genie was called by various names including "Dingdong," "Bird Dog," and "High Card." It was an unguided, rocket-powered, air-to-air missile carrying a nuclear warhead. It was 17 inches in diameter and 9 feet 7 inches in length, and was carried internally in the bomb bay of the Convair F-106 interceptor airplane, along with four Hughes Falcon missiles. It had a maximum speed capability of Mach 3 (refs. 3 and 4).

The ejection tests at Wallops were made in the 27-inch nozzle of the Preflight Jet at Mach numbers of 0.86, 1.39, 1.59, and 1.98 at different simulated altitudes up to 29,450 feet. The tests were run in three phases, October 1956 (ref. 5), February 1957, (ref. 6), and May 1958, (ref. 7). The "light-model" method was used.

In the tests, sequence pictures of the rocket as it left the bomb bay were made, as shown in figure 328. It was desired that the rocket be in level flight when its motor was ignited. The tips of the fins were retracted when stowed in the bomb bay and were to be extended at the time of ignition of the rocket motor. In the Preflight Jet tests, it was found that with the proper application of ejection velocity and nose-down pitching moment, a safe ejection could be made, but it was found desirable to extend the fins as soon as possible. The results of the tests were transmitted to the Air Force and to Convair.

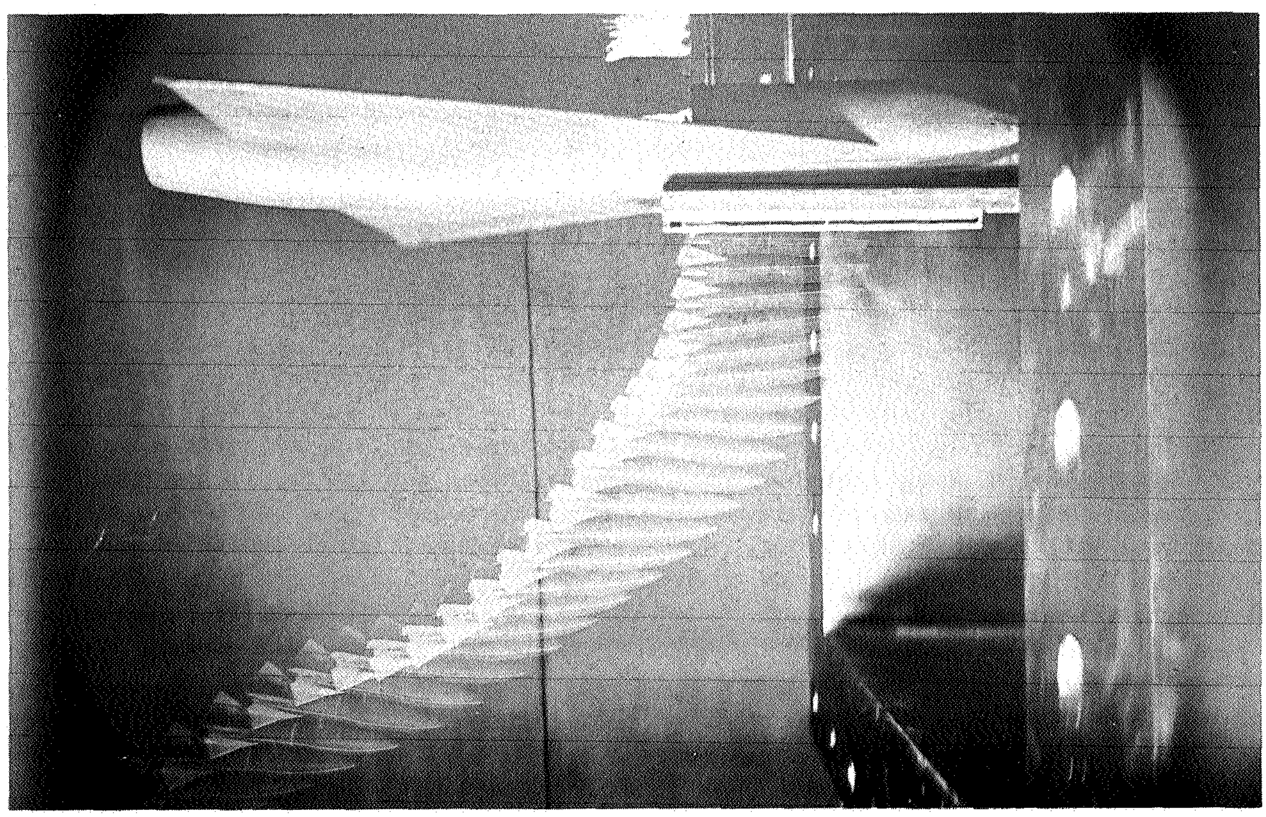


FIGURE 328. Successful ejection of Genie rocket from bomb bay of F–106 airplane model in Preflight Jet, February 1957.

MARTIN TITAN ICBM AERODYNAMIC HEAT TRANSFER

When the Western Development Division of the Air Force ARDC awarded a contract to the Glenn L. Martin Company for the Titan missile as a second approach to the ICBM problem, one of the requirements was that a stiffened cylinder be used for the fuel tanks, as opposed to the pressurized tank design used by Convair on the Atlas. One proposal by Martin consisted of external, circumferential stiffeners around the tanks. It was believed that the additional drag of these rings would be tolerable because the highest velocity of the missile would be reached at extreme altitudes where drag was of little consequence. The aerodynamic heating of such exposed structures was a different matter, and because of separation of flow behind the stiffeners, the heating was not amenable to calculations. Consequently, the Air Force, at the instigation of Martin, asked the NACA to measure the heat transfer to such a simulated structural panel in the 27-inch nozzle of the Preflight Jet at Wallops.[1]

Three different arrangements of external stiffeners and a flat plate, for comparison, were tested in the 27-inch nozzle during August and September, 1956, at Mach numbers of 0.77, 1.39, and 1.98. The models were furnished by the Martin Company. The plates were 50 inches in length and the stiffeners were at right angles to the airstream. Two heights of stiffeners were tested, 0.4 inch and 1.0 inch. The stiffeners were hat-shaped in cross section, with spacing varied on successive models. The external skin and stiffeners were made of 0.062-inch inconel to serve as a calorimeter, and were insulated from the supporting structure by a sheet of asbestos. Thermocouples and pressure orifices were installed on the stiffeners and adjacent skin. The free-stream total temperature for all tests was 935°R.

The test showed a rise in pressure upstream of each stiffener, reaching a maximum on the upstream face of the stiffener. The pressure decreased rapidly downstream of each maximum-pressure point. The aerodynamic heat transfer to the smooth plate was in good agreement with the turbulent theory of Van Driest at all Mach numbers. The heat transfer to the stiffened plates was non-uniform, as would be expected, and the level varied greatly with Mach number, registering a sharp increase in heating on the forward face of each stiffener. At the subsonic speed, the overall heating was greatly increased over that to the flat plate. At low supersonic speeds, the heating increase was only that added to the stiffeners, while at the highest speed (M 1.98) the heating between the stiffeners was equal or slightly below that on a flat plate. The overall effect was an increase in heating (ref. 8).

By the time the tests of the externally stiffened panels were being conducted, the plan for using them on the full-scale Titan missile had been abandoned, but heat transfer data were still desired on the smooth shape. The data obtained in the Preflight Jet with the smooth plate were applicable but data were needed at higher Mach numbers. In addition, the transition sections at the nose and between the first and second stages made calculations of heating questionable. The effects of the actual nose of the missile on the heating downstream was also of interest.

On August 1, 1956, the Air Force requested the NACA to conduct a rocket-model flight program to measure aerodynamic heating on the external skin of 1/18-scale models of the Titan, at speeds to Mach 4.0.[2] The NACA approved the request on October 29, 1956. Three models, all supplied by Martin, were successfully flown at Wallops between July and November 1957. A single Cajun rocket motor provided the desired speed near Mach 4 at an altitude of 4,000 feet. The Reynolds numbers of the 1/18-scale models closely approximated the value for the full-scale missile at its expected altitude. Pressures as well as temperatures were measured to provide information on local flow conditions in order that heat transfer could be calculated for comparison with measured values.

Design for the first and third models included a spherical nose. Laminar flow was observed on the front part of the nose, with transition to turbulent flow occurring near the sonic station. The second model had a flatter nose, and transition occurred close to the stagnation point. In all cases, heat transfer was in fair agreement with theory when the flow was either fully laminar or fully turbulent (refs. 9, 10, and 11). The data were transmitted to Martin and BMD for use in design of the Titan.

1. Letter from Air Force BMD to NACA Headquarters, Aug. 1, 1956, requesting tests of WS-107A-2 panels in Wallops Preflight Jet.
2. Letter from AF WADC to the NACA, Aug. 1, 1956, requesting rocket model tests of Titan WS-107A-2 missile.

GENERAL ELECTRIC NOSE CONE FOR CONVAIR ATLAS ICBM

The missile activities of General Electric Company took on new life after the award of a contract to develop a nose cone for the Atlas ICBM. This work was concentrated at the Missile and Space Division, Philadelphia, Pennsylvania, and many flight test programs were conducted at Wallops for the Air Force under the direction of GE. These programs were generated, in part, through the activities of four PARD engineers who had resigned from the NACA between October 1955 and May 1956 for employment by GE: Rowe Chapman, Jr., Robert F. Peck, Herbert H. Jackson, and A. James Vitale.

The first of the several GE nose-cone programs was a rather ambitious one in which scaled models of the blunt nose cone were to be propelled to about Mach 4 and then separated from their boosters. Following separation, static and dynamic stability were to be determined along with measurements of pressures and temperatures over the sharply coverging afterbody. After consultation with PARD, a 3-stage Honest John-Nike-Nike rocket system was selected and a series of six models was planned. An official request for assistance was made by the Air Force on May 8, 1957, and approved by the NACA on May 28, 1957. General Electric was to construct the nose cone models, the Air Force was to provide the rocket motors, and the NACA was to instrument the models, conduct the flight tests at Wallops, and analyze the results. On August 1, 1957, the original bowl-shaped nose cone was replaced by a short, blunt cone corresponding to an advanced design. Emphasis was now on pressures and aerodynamic heating.

The first model, shown in figure 329, was launched on October 25, 1957. Separation of the model from the last stage was to be accomplished by opening a cowling or drag flap at the front of the motor case after burnout of the motor. In the test, the high pressures on the front of the nose reached the cowling inadvertently and caused separation prematurely at burnout of the second stage. The Mach number was too low to obtain meaningful data. On the second model, the design was changed to take advantage of the high total pressure by bleeding it to the area between the rear of the model and the front of the motor case. In this test, on February 28, 1958, the rockets fired as planned and the cowling opened as desired, but the model did not separate from the booster. It was conjectured that part of the

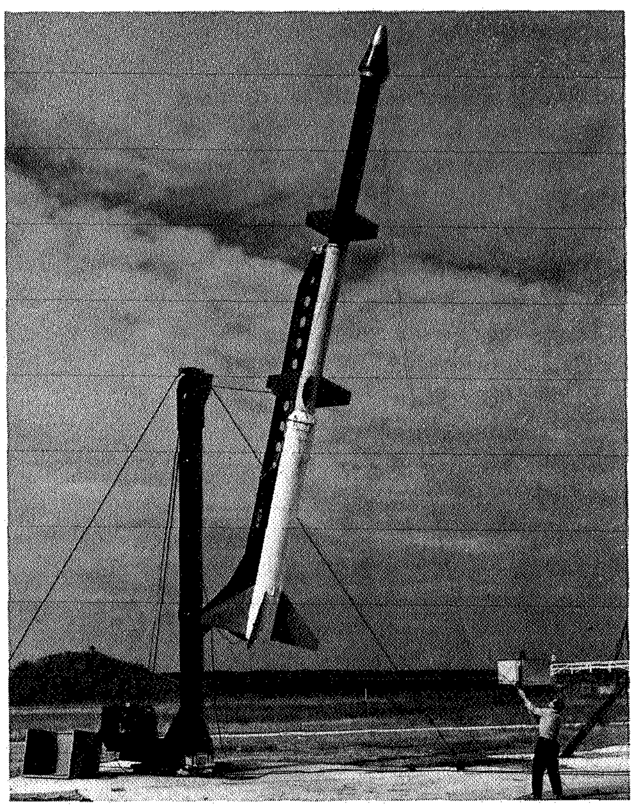


FIGURE 329. Photographer Don Foster checks external-power leads to GE nose cone on Honest John-Nike-Nike test vehicle, October 25, 1957.

cowling was in a region of separated flow and did not receive full pressure. Successful separation appeared hopeless at this point without a complete redesign, and the remaining tests were canceled. This flight program had the PARD designation "F123."

NOL INSTRUMENT ROCKET DEVELOPMENT

Chapter 12 has discussed the successful development of smoke rockets for the Naval Ordnance Laboratory (NOL) for use during the nuclear tests at Bikini Island. On February 19, 1957, during a visit to Wallops, Peter Hanlon and H. B. Benefiel of NOL expressed a desire to obtain the same type of assistance in development firings of another special rocket vehicle for use in later nuclear tests. The same group had participated in the smoke-rocket development and were pleased with the success of the earlier project. The new project consisted of a parachute-supported instrument package to be sent aloft and ejected from the nose cone of a rocket vehicle. Wallops was to provide launch and tracking facilities plus photographic coverage. A series of five firings was planned (ref. 12).

NACA Headquarters received the official request for assistance from NOL on February 26, 1957, and approved the program on March 8, 1957. The components were constructed by American Machine and Foundry Company. One of the rockets, ready for launch, is shown in figure 330. The project was given the designation "B124," and responsibility for the program at PARD was assigned to C. A. Brown, Jr.

The tests began on March 21, 1957, and continued through March 21, 1958. Because of difficulties with the ejection mechanism and with the parachute, 23 firings were required to develop a satisfactory system. The final records from the tests were sent to NOL on March 24, 1958.

UNIVERSITY OF MARYLAND TERRAPIN SOUNDING ROCKET

The Terrapin sounding rocket was developed by Republic Aviation Corporation for the University of Maryland, for the use of Dr. S. F. Singer and his associates there in a cosmic ray experiment at altitudes to 400,000 feet. Singer was interested in a small sounding rocket that could carry payloads of around 6 pounds to that altitude. His program of six firings was financed by the National Security Agency.

After contacting NACA Headquarters in May 1955, Singer visited PARD on June 6, 1955, to discuss problems one would likely encounter in designing and flying a small two-stage sounding rocket (ref. 13). Following this visit, he invited bids on the design and construction of six such systems with general specifications based on information obtained at PARD. Republic Aviation was awarded a contract, and on July 8, 1955, M. S. Roth of Republic visited PARD and discussed a proposed design with J. A. Shortal and J. G. Thibodaux (ref. 14). Roth proposed a two-stage vehicle having a Thiokol T47 motor as the first stage and a Loki II motor as the second. Roth was informed that the stubby T47 motor would require rather large fins, and that large fins would probably also be required on the Loki II. On December 1, 1955, E. A. Eddy of Republic visited PARD and described a somewhat larger system found necessary to achieve the required performance. This was a modified Deacon motor for the first stage and a T55 motor for the second. This was the system to be adopted.

The Deacon modification consisted of increasing the burning time from 3 to 6 seconds, with no change in total impulse but with a small reduction in weight. The payload compartment ahead of the T55 motor was a 2-foot-long 10-degree cone with a hemispherical nose of 0.97-inch radius. The total weight at launch was estimated to be 229 pounds. Eddy estimated that the first stage would provide a Mach number of 3, and that the second stage would then take the payload to a Mach number of 6 after a 26-second coast period. A maximum altitude for a vertical launch was estimated to be 500,000 feet with an 8-pound payload. PARD personnel felt that the drag assumed for the vehicle was too low, and recommended that the nose of the cone be made less blunt for better performance. Several other suggestions were given Eddy, such as a description of the frangible-diaphragm connector used on T55 nozzles, a description of delay squibs and ignition concepts, and a recommendation that he consider using the higher performance Cajun motor instead of the Deacon (ref. 15).

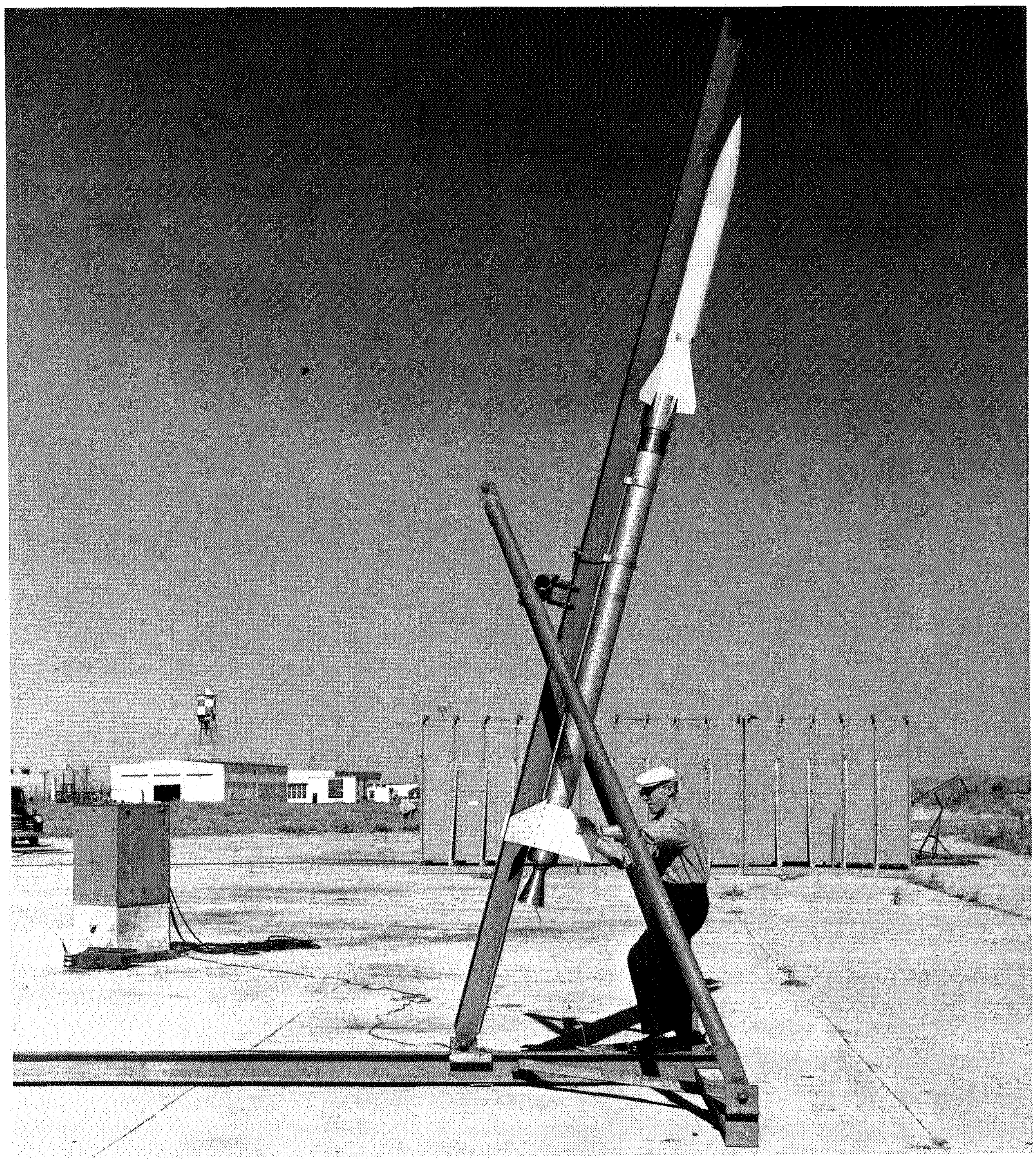


FIGURE 330. Paul Drury of American Machine and Foundry Company adjusts wiring of two-stage NOL instrumentation rocket, shown at Wallops, September 24, 1957.

Eddy returned to PARD on January 5, 1956, with a redesigned version of the Terrapin incorporation all the changes suggested by PARD except the adoption of a Cajun motor. He had calculated a good increase in performance with the Cajun, but Singer would not approve the change because of uncertainty about obtaining delivery when needed. The revised performance estimates for the Terrapin now indicated a maximum altitude of 435,000 feet for a vertical launch.

The only item in contention between Republic and PARD in the design was the structure of the fins on the T55 stage. They were untapered and sweptback 45 degrees with a thickness—or rather, a thinness—of only 2 percent of the chord. These lightweight, low-drag fins contributed to the high performance calculated, but violated the flutter-design criteria used by rocket-model designers at Langley. Despite many objections of PARD personnel, informal as well as official, the fins were not changed. They caused no trouble in flight, however, much to the surprise and embarrassment of Langley.

By March 1956, no official request had been received for permission to launch the first Terrapin vehicles at Wallops, although all visitors had stated that such was the plan. The contract with Republic required delivery by March 1, 1956, and numerous contacts with Republic and Singer indicated that a launch date was imminent. Langley Director H. J. E. Reid brought the matter to the attention of NACA Headquarters and suggested that the National Security Agency be asked, not only to give a flight program at Wallops its official sanction, but to send a representative to Langley to discuss the unsettled differences.[3]

On June 15, 1956, the National Security Agency requested the assistance of the NACA in conducting developmental launchings of the Terrapin at Wallops. NACA Headquarters approved the request and issued RA A74L209 on July 5, 1956, to cover the project. The PARD designation of the project was "H121." The first two Terrapin vehicles with a simple launcher arrived at Wallops early in September 1956 along with personnel from the University of Maryland and Republic.

Wallops personnel handled the firing and tracking details while Singer supplied a ground receiver for his onboard telemeter. His telemeter was arranged to transmit readings of temperature, longitudinal acceleration, spin rate, and cosmic ray intensity. The first vehicle flown is shown in figure 331 on its launcher at Wallops.

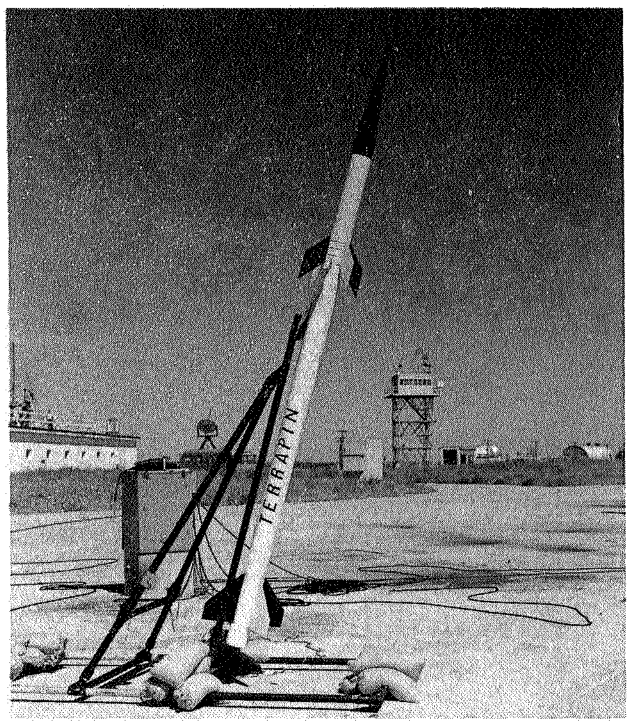


FIGURE 331. University of Maryland-Republic Terrapin sounding rocket mounted on special launcher, September 21, 1956.

The first test, on September 21, 1956, was unsuccessful because the second-stage motor did not ignite. The second firing on the same day, however, was quite successful and indicated the soundness of the design and the accuracy of preflight estimation of performance. Although there was no beacon in the nose section to aid radar tracking to apogee, the SCR-584 radar with skin-tracking followed the vehicle to 130,000 feet, right along the predicted flightpath. The velocity obtained at burnout of the first stage equaled the predicted value, while the velocity at burnout of the second stage exceeded the

3. Letter from H. J. E. Reid to NACA Headquarters, Mar. 5, 1956, regarding Terrapin sounding rocket and the difficulties encountered in establishing a mutually acceptable project.

predicted value by 6 percent. A maximum altitude of 400,000 feet with an 8-pound payload was assured, therefore, for a vertical launching (ref. 16).

Republic was very much impressed by the generous assistance given by Wallops personnel during the launching, and letters of appreciation from the Guided Missiles Division and the Public Relations Office were received by J.C. Palmer.[4] [5]

The remaining four Terrapin vehicles were launched during the next year by Singer for the National Security Agency. At the end of this program, Singer sent Palmer a letter thanking him for his earlier assistance and informing him of the success of the later firings. Singer stated, "At this writing, we can report that all rockets fired perfectly, but findings of scientific results are awaiting development of films."[6]

HEAT TRANSFER TO BALLISTIC MISSILE BLUNT NOSES

The original nose cones under development by General Electric and Avco for the Western Development Division of the Air Force ARDC for use on the Atlas and Titan ICBM's were essentially large hemispheres with short converging afterbodies. This design inspired many research investigations by many facilities, regarding heat transfer to hemispherical shapes. In the PARD program of research on aerodynamic heat transfer to nose cones for ballistic missiles, a wide range of large blunt shapes was investigated. The shapes consisted, not only of hemispheres and spherical segments, but wide-angle cones up to 100 degrees and, as an extreme case, a flat nose.

At Wallops, the earliest data on a hemisphere were obtained in the 8-inch B Jet of the Preflight Jet during February and March, 1952. The interest at that time was on the use of such a nose shape for a small guided missile with a seeker in its nose. A 4-inch-diameter hemisphere-cylinder was mounted in the jet, as shown in figure 332. Fourteen pressure orifices were located on the nose and spiraled rearward from the stagnation point to the cylindrical portion. Mach numbers of the tests were 2.05, 2.54, and 3.04. The Reynolds number, based on the body diameter, was about 4.5 million. The pressure measured were in good agreement with those from other investigations (ref. 17).

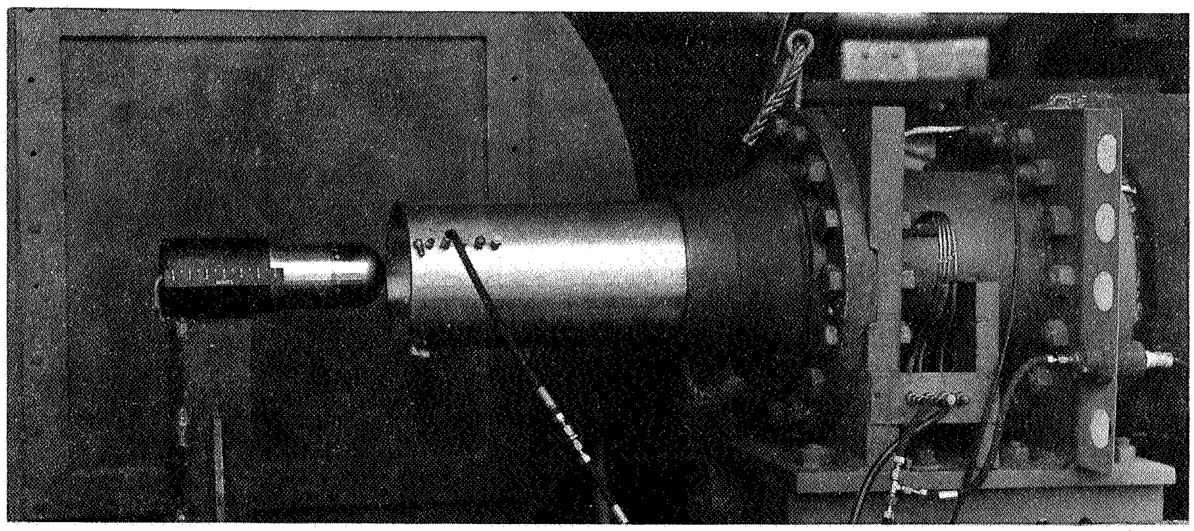


FIGURE 332. View of hemispherical nose in 8-inch nozzle of Preflight Jet for pressure distribution test at supersonic speeds.

4. Letter from Robert G. Melrose, General Manager, Guided Missiles Division, Republic Aviation Corporation, to Jack Palmer, NACA, Wallops Island, Va., Sept. 28, 1956, regarding assistance during Terrapin firings.
5. Letter from Ivan Sherman, Public Relations, Republic Aviation Corporation, to John Palmer, Wallops Island, Va., Oct. 4, 1956, regarding assistance and cooperation on Terrapin project.
6. Letter from S. F. Singer, Associate Professor, University of Maryland, to J. Palmer, NACA, Wallops Island, Va., Nov. 7, 1957, regarding Terrapin sounding rocket.

The heat transfer to a hemisphere was also measured in tests in the Preflight Jet in 1952. A 4-inch hemisphere was tested at Mach numbers of 1.62, 2.05, 2.54, and 3.04 in the 8-inch B Jet. Then a 6-inch hemisphere was tested at Mach 1.99 in the 12-inch A Jet. Both the 4-inch and 6-inch models were tested with smooth surfaces; then one test was made with the 6-inch model roughened by light sandblasting. The models were inserted into the jet after steady-flow conditions were established, and were left there until equilibrium temperatures were established. The equilibrium temperatures were found to be equal to the stagnation temperature at the center of the nose, and to decrease uniformly along the hemisphere to a value of 95 percent of stagnation at the 90-degree station. In all tests, the flow was laminar back to the 45-degree station, at which point transition to turbulent flow began for all tests with smooth bodies. The local Reynolds number for this transition was about 1.5 million for the 4-inch body and 2.2 million for the 6-inch body. The rough 6-inch body had turbulent flow at all stations. The heat transfer, in terms of local Stanton number, agreed well with theory when the flow was definitely laminar or turbulent. Behind the transition point, (45-degree station) the heat transfer varied between the two conditions. The heat transfer at the stagnation point agreed well with the theory of Sibulkin (ref. 18).

The heat transfer to a hemisphere-cylinder at higher Mach and Reynolds numbers was obtained from flight test of a rocket model in September 1955. The basic test body was 8 inches in diameter and was propelled by a two-stage Nike-Deacon vehicle, as shown in figure 333. The cylindrical body fitted around the Deacon, and the overall length was 138 inches. Temperatures were measured at points around the nose and along the length of the cylinder to a distance of 118 inches. The model was accelerated to a Mach number of 3.05 by the Nike booster and then was allowed to decelerate to Mach 1.2 before the Deacon was ignited to accelerate it to Mach 3.88.

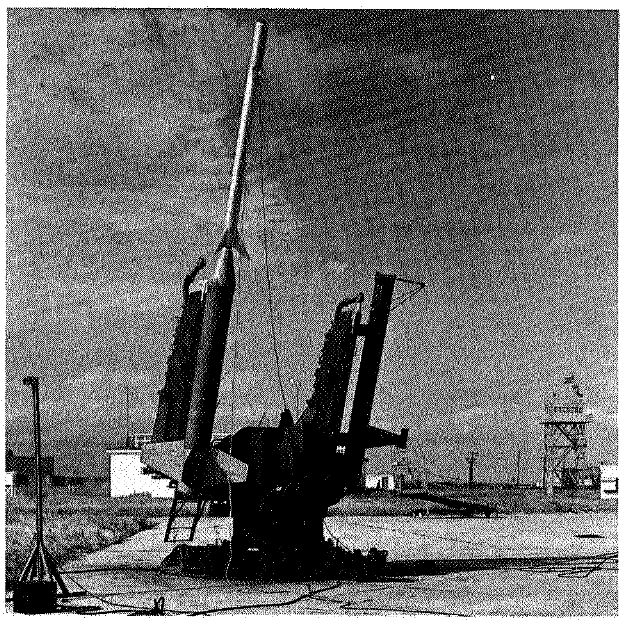


FIGURE 333. Nike-Deacon rocket model used for heat-transfer test of hemisphere-cylinder, September 27, 1955.

By this method, greatly different values of Reynolds numbers were obtained at a given Mach number. When the freestream Reynolds number was fairly high (greater than 12 million per foot), transition from laminar to turbulent flow occurred well forward on the nose, ahead of the 45-degree station for a Reynolds number between 1 and 3 million. For lower freestream Reynolds numbers, however, such that the flow remained laminar at the 45-degree station, transition generally occurred downstream on the cylinder at Reynolds numbers as high as 25 million. The heat transfer rates for laminar flow were in agreement with the theory of Stine and Wanlass (NACA TN 3344) over the hemisphere and with the theory of Van Driest (NACA TN 2597) over the cylinder. For turbulent flow, the measurements were about 20 percent lower than Van Driest's theory. Heat transfer at the stagnation point was somewhat lower than theory. It was of interest that experimental heat transfer data were provided by this experiment for turbulent flow conditions at a Reynolds number of 189 million at a Mach number of 3.05 (ref. 19).

It was thought that perhaps the low transition Reynolds number on the hemisphere was caused by roughness, which was estimated to have been about 25 microinches. To explore this thought further, a second model was flown, this time with a highly polished, mirrorlike surface, having roughness measurements as low as 1 microinch. A Nike-Cajun propulsion system was used, as shown in figure 334. Interest was centered on the data during the early part of the flight when the Reynolds number reached a freestream value of 17.8 million per foot at Mach 3. Laminar flow was maintained to a higher Reynolds number with this highly polished model than with the earlier model, by a factor of about 3. Transition now occurred at the 75-degree station on the hemisphere at a Reynolds number of 7.4 million based on freestream conditions and distance along the hemisphere. The Reynolds number, in terms of momentum thickness of the boundary layer, was around 1400. The heat transfer data, whether laminar or turbulent, agreed well with the theories of Van Driest and of Stine and Wanlass (ref. 20).

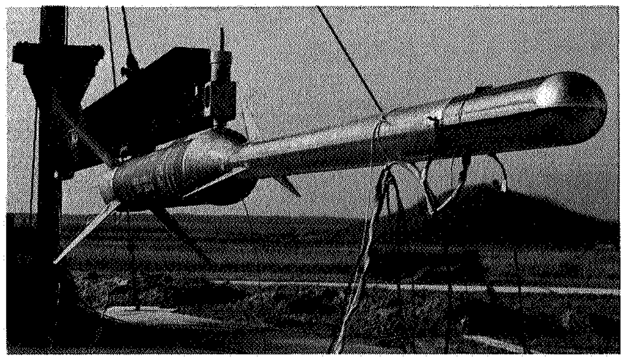


FIGURE 334. Nike-Cajun rocket model used for heat-transfer test of highly polished hemisphere-cylinder, December 7, 1956.

The transition characteristics of a large hemispherical nose on a short 29-degree cone with a mirror finish (2 microinches) was determined in a flight test on October 11, 1956, with the Honest John-Nike vehicle shown in figure 335. The nose radius was about 6.5 inches. The Honest John stage propelled the vehicle to a Mach number of 2.23 in about 5 seconds. This acceleration was followed by a coast period of 1.7 seconds, at which time the Nike stage was ignited and a maximum Mach number of 4.70 was reached.

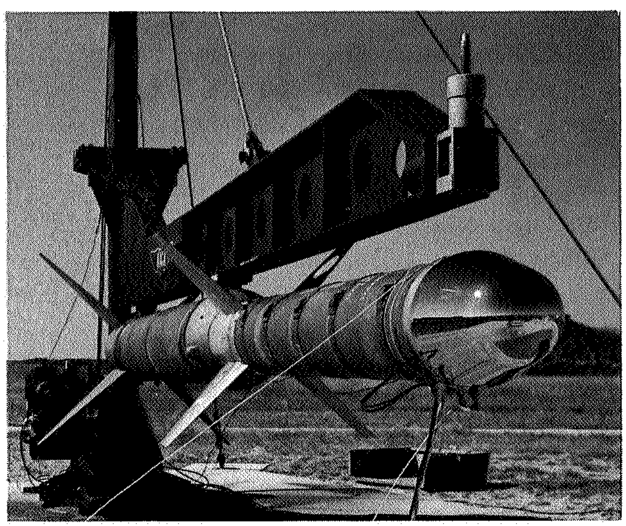


FIGURE 335. Highly polished, blunt, 29-degree cone mounted on Honest John-Nike booster for heat-transfer test, October 11, 1956.

During the early part of the burning period of the second stage, it was found that laminar flow existed over the entire hemispherical nose and most of the conical portion. The Mach number was 2.47; the Reynolds number based on freestream conditions was 13.8 million per foot; and the Reynolds number based on momentum thickness at the point of transition was 2,190, even higher than that noted on the polished hemishere-cylinder. It was concluded that the high polish greatly delayed transition.

Unfortunately, as the Mach number was increased further, the transition point moved forward on the hemispherical nose. The heat transfer rates were adequately predicted by theory (ref. 21).

The extensive interest in attempting to achieve high transition Reynolds numbers on hemispherical noses stemmed from the ICBM project. It has been pointed out in Chapter 13 that the findings of Allen and Eggers of the advantages of using blunt bodies for reentry at high supersonic speeds had dictated the shapes used by both General Electric and Avco, the contractors for the nose cone. The use of a thick copper heat shield was indicated, to provide ample protection to the warhead during reentry at ICBM speeds—approximately Mach 23. Copper was used because of its high heat capacity and high conductivity. Heating during ICBM reentry was a highly transient phenomenon as the nose cone simultaneously decelerated rapidly and entered denser atmosphere. Heat to the outer surface of the copper shield was conducted into the mass of copper, and heating could continue until the outer surface reached its melting point. The blunt shapes provided the high drag required to reduce the deceleration period, and at the same time kept the heat transfer to the surface at an acceptably low value. With the blunt shape, most of the heating energy heated the large mass of air enveloping the blunt body. The heat that was transferred to the skin was still large and was, of course, dependent upon whether the boundary layer was laminar or turbulent. Both nose-cone contractors initially assumed that the flow would be laminar over most of the front face because of the low value of the local Reynolds number. WDD and Ramo-Wooldridge concurred in this assumption but established the Lockheed X-17 flight project to determine the actual condition. The early finding of transition to turbulent flow at a Reynolds number of about 1 million with the slightly rough hemisphere (ref. 19) was most upsetting to Ramo-Woolridge and led to the program to determine whether roughness was the true cause of early transition, by testing the highly polished models (ref. 20). When such a polish on the 8-inch hemisphere extended the transition Reynolds number by a factor of 3, and the highly polished 29-degree hemisphere-cone increased this value by another factor of about 2, it was felt that high polish might be the answer. When the Cape Canaveral X-17 tests of 9-inch-diameter hemisphere-cylinders at Mach numbers to 14 showed transition well forward on the nose, even on a highly polished nose, all concerned were in agreement that the low transition was the valid result of an aerodynamic phenomenon but was still unexplained.

An analysis of available data on transition on hemispherical surfaces was made by Stewart and Donaldson for General Electric, with the use of data from Wallops, the X-17, and the hypersonic test vehicle (HTV) flight projects (ref. 22). They attempted a correlation of all of the data by relating wall-to-local-stream-enthalpy ratio, Reynolds number based on momentum thickness, and body position of transition. The correlation went a long way toward providing a satisfactory design chart, but had some inconsistencies. A correlation by Wisniewski of Lewis in 1958 brought all of Stewart and Donaldson's data, as well as additional data available by that time, into an almost perfect line separating laminar and turbulent flow. Wisniewski's correlation related the wall-to-total-enthalpy ratio and a factor described as Reynolds number based on displacement thickness divided by local Mach number at the transition point. Wisniewski applied his results to a 6-foot-diameter hemisphere undergoing a typical nose cone reentry condition and found that transition from laminar to turbulent flow would be expected to occur near the 20-degree station during the entire reentry period. He concluded, "The results indicate a serious question as to the possibility of obtaining extensive laminar flow on a hemisphere under full-scale reentry conditions" (ref. 23).

In 1959, M. J. Krasnican and L. Rabb of Lewis, while in the process of analyzing the test results of several heat-transfer rocket models air-launched over Wallops (discussed in Chapter 13), found correlating parameters that were easier to evaluate than Wisniewski's factors yet correlated the data as well, as shown in figure 336. The new parameters were wall-to-local-temperature ratio at the station and the factor, local Reynolds number at the 45-degree station, divided by the freestream Mach number. Regarding an explanation for the success of this correlation, Krasnican and Rabb stated, "The authors recognize that the parameters are entirely empirical and no explanation is offered to tell why the correlation is valid" (ref. 24).

The effect of the ratio of wall temperature to stagnation temperature on heat transfer to a hemisphere was evaluated in a special series of tests with a 5-inch-diameter model in the Preflight Jet at Mach 2. In earlier tests, some indication was obtained that as this ratio increased, the heat transfer

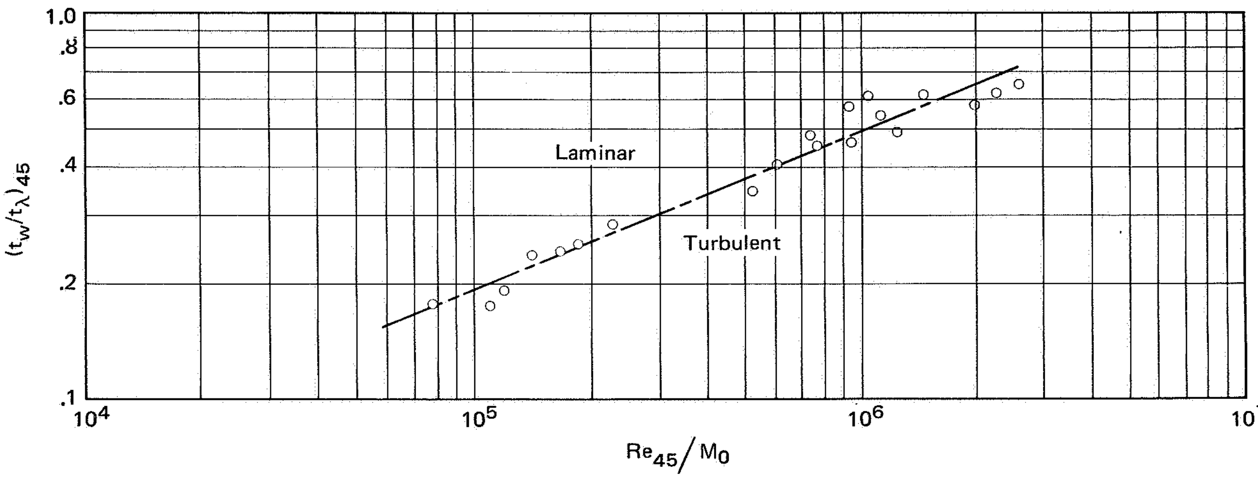


FIGURE 336. Graph showing Krasnican-Rabb correlation of transition data for blunt noses.

coefficient decreased by a factor much greater than that predicted by the turbulent theory of Van Driest. This decrease had been attributed to conduction to the model-support system or to radiation.

A special model was designed, with which an attempt was made to eliminate radiation and conduction effects. The inconel skin of the model was plated with a thin layer of platinum on both the inside and outside surfaces to minimize radiation, and the space inside the hemisphere was evacuated to eliminate conduction effects. Tests were made in the 12-inch nozzle at stagnation temperatures of 300° F and 570° F and in the Ethylene Jet at a stagnation temperature of 920° F. The model was kept outside the jet until stable flow conditions were reached. The location of the transition point on the hemisphere changed during the series of tests as the surface became rough because of exposure to the contaminated jet. It was possible, therefore, to study the effects of temperature ratio at a given station for different local flow conditions. It was found that with laminar flow there was no effect of temperature ratio, but with turbulent flow the heat transfer coefficient decreased as much as 30 percent at some stations as the temperature ratio increased from 0.60 to 0.90 (ref. 25). This decrease was in agreement with the theory of Beckwith and Gallagher (ref. 26).

Large-angle blunt cones were also given consideration for use as reentry bodies, and heat-transfer tests with large models propelled by Honest John-Nike systems were conducted at Wallops. The first of these, shown ealier in figure 285, Chapter 13, was a 50-degree cone with a hemispherical nose of 4.44-inch radius. It was made of 0.031 inconel and had chromel-alumel thermocouples welded to its inner surface along its entire length. Pressure measurements were also made. The surface roughness of the model was about 24 micro-inches. The propulsive system provided a maximum Mach number of 4.7 at an altitude of about 15,000 feet, at which point the fins on the Nike stage apparently failed from aerodynamic heating as discussed in Chapter 13. The data were good up to that point.

The measured pressures in flight agreed well with modified Newtonian theory. Transition from laminar to turbulent flow occurred at the 20-degree station at all Mach numbers, at local Reynolds numbers between 1 and 2 million. The heat transfer coefficients, for either turbulent or laminar flow, agreed well with theory.

The second model was also a 50-degree cone, but its nose was quite pointed, with a radius of only 0.08 inch. This time, the Nike fins failed a little earlier in flight, and the maximum Mach number was only 4.0 at an altitude of 14,000 feet. Most of the flow over the nose was turbulent, with an indication of some laminar flow at the most forward station and transition at a Reynolds number between 1 and 2 million, as before (ref. 27). Although the Reynolds numbers at transition were disappointingly low, the data for the blunt cone were successfully used in Wisniewski's correlation.

The next large cone, flown on January 24, 1957, on an Honest John-Nike vehicle, had an angle of 100 degrees and a nose radius of 0.19 inch. In this test, in an attempt to obtain the highest possible Reynolds number, the time delay for firing the second stage was set to equal the burning time of the first stage. For some unknown reason, this delay squib fired early, and the Nike flew away from the

Honest John while it was still thrusting. The maximum Mach number was, therefore, lower than planned. A value of 4.1 was reached at about 11,000 feet. The inconel skin was polished to about 2 micro-inches' roughness. Transition to turbulent flow occurred about 2 inches back of the nose, at local Reynolds numbers between 530 and 940, based on momentum-thickness of the boundary layer (ref. 28).

The search for the best nose shape for a reentry nose cone was a continuing one. In the PARD ceramic-heated air jet at Langley, some ½-inch-diameter cylindrical models of different materials and nose shapes were tested for survival or time-to-failure in a 4,000° F airstream.

Purser and Hopko tested a hemispherical nose, a 90-degree cone, and then a flat nose, as an extreme case (infinite radius or 180-degree cone). It was quickly seen that the flat nose was superior to the hemisphere. This is shown in figure 337 which is a composite photograph of three models, made of 347 stainless steel, which were exposed to a 4,000° F air jet for the time shown. The first model was hemispherical and was badly burned in 13.6 seconds, whereas the other two models, having flat faces, were not destroyed, even after as long as 33.1 seconds.

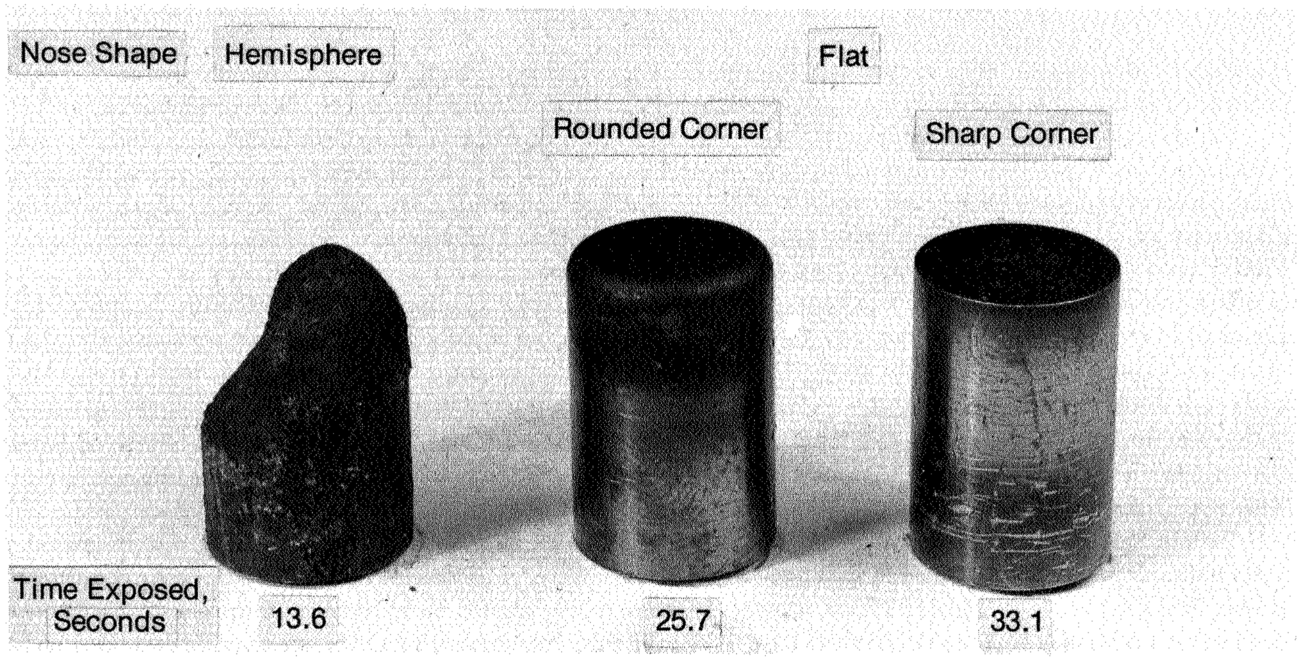


FIGURE 337. View of ½-inch-diameter stainless steel blunt noses, showing effect of exposure to 4,000° F air jet at Langley.

Figure 338 shows comparison of the damage to three 90-degree cones, made of three different materials and tested in a 3,800° F air jet. The first model, made of 1020 steel, burned nearly flat in 7.3 seconds. The second model, made of 347 stainless steel, suffered less damage after 11.5 seconds. The third model, made of AGR graphite, suffered some spalling but was still intact after 17 seconds. Despite earlier fears that graphite would be consumed by oxidation at high temperatures, interest in graphite was revived after an analysis by M. A. Faget indicated that the heat absorbed by sublimation would be far greater than that generated by oxiation. Graphite could also be used at higher temperatures than metals, thereby decreasing the aerodynamic heat input and increasing the radiative heat output and the usable heat capacity of the material (ref. 29).

M. A. Faget took a cue from the results of Purser and Hopko and laid out a series of six nose shapes for temperature and pressure distribution measurements at Mach 2 in the Preflight Jet, to provide data of assistance in setting up a flight test program. All six shapes started with a basic 29-degree cone, about 4 inches long, and had the following nose shapes: Model A—a basic hemisphere with a radius of 2.5 inches; three truncated (flat-faced) cones with corner radii of 0.1 inch (Model D), 0.4 inch (Model C), and 1.0 inch (Model B); a dimpled nose with a corner radius of 1.0 inch (Model E); and a truncated cone with a rim around the front face 0.2-inch high, and with a 0.1-inch radius (Model F). The tests were made in the

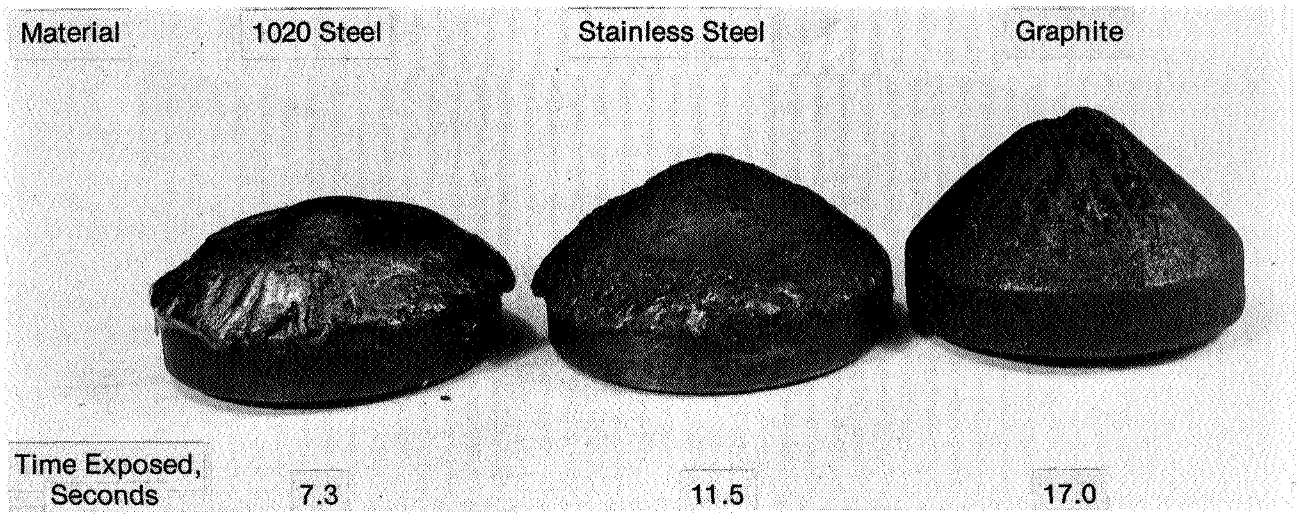


FIGURE 338. View of 90-degree cones of various materials, showing effect of exposure to 3,800° F air jet at Langley.

12-inch jet with each model mounted on the swing arm, as shown in figure 339. In addition to temperature and pressure measurements shadowgraphs were made to show the flow pattern around the models. These shadowgraphs (example in figure 340) indicated that the sharpness of the corner of the front face influenced the flow pattern. Distinct shock waves developed at the corners of the three models with a corner radius of either 0.1 inch or 0.4 inch (Models C, D, and F); but such shock waves were not seen on the three models having larger radii (Models A, B, and E). From the heat-transfer measurements, it was found that the models with the shocks at the corners (C, D, and F) had turbulent flow on the conical surfaces behind the shock. The hemispherical nose (Model A) had the highest heating rate, and transition developed well forward on the nose. The dimpled nose had less heating than the hemisphere but more than the other shapes. Apparently the full potential of a convex hemisphere was not realized with this "in-between" shape. On model B, turbulent flow was not obtained until the last station on the conical sides. This shape, a flat face with a fairly large radius at the corner, was considered the best of the six tested (ref. 30).

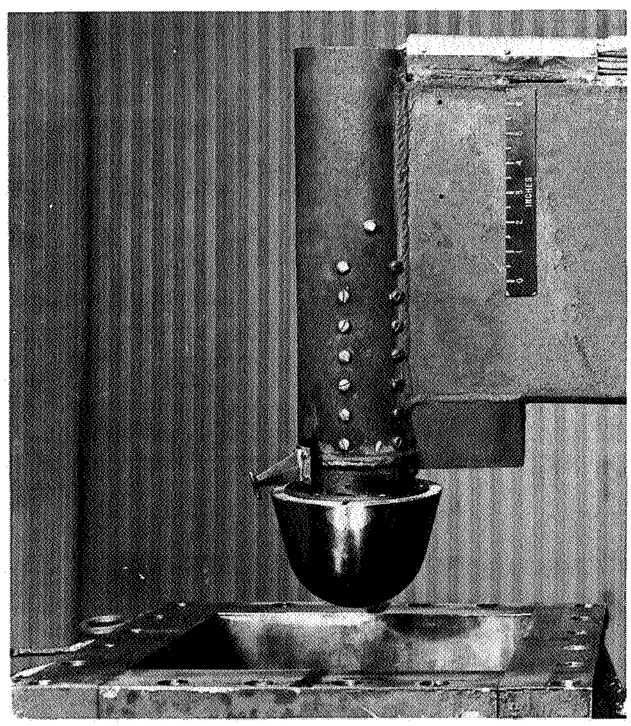


FIGURE 339. Blunt-nosed shape "A" under test for heat transfer and pressure distribution. Test was performed in 12-inch nozzle of Preflight Jet, August 1956.

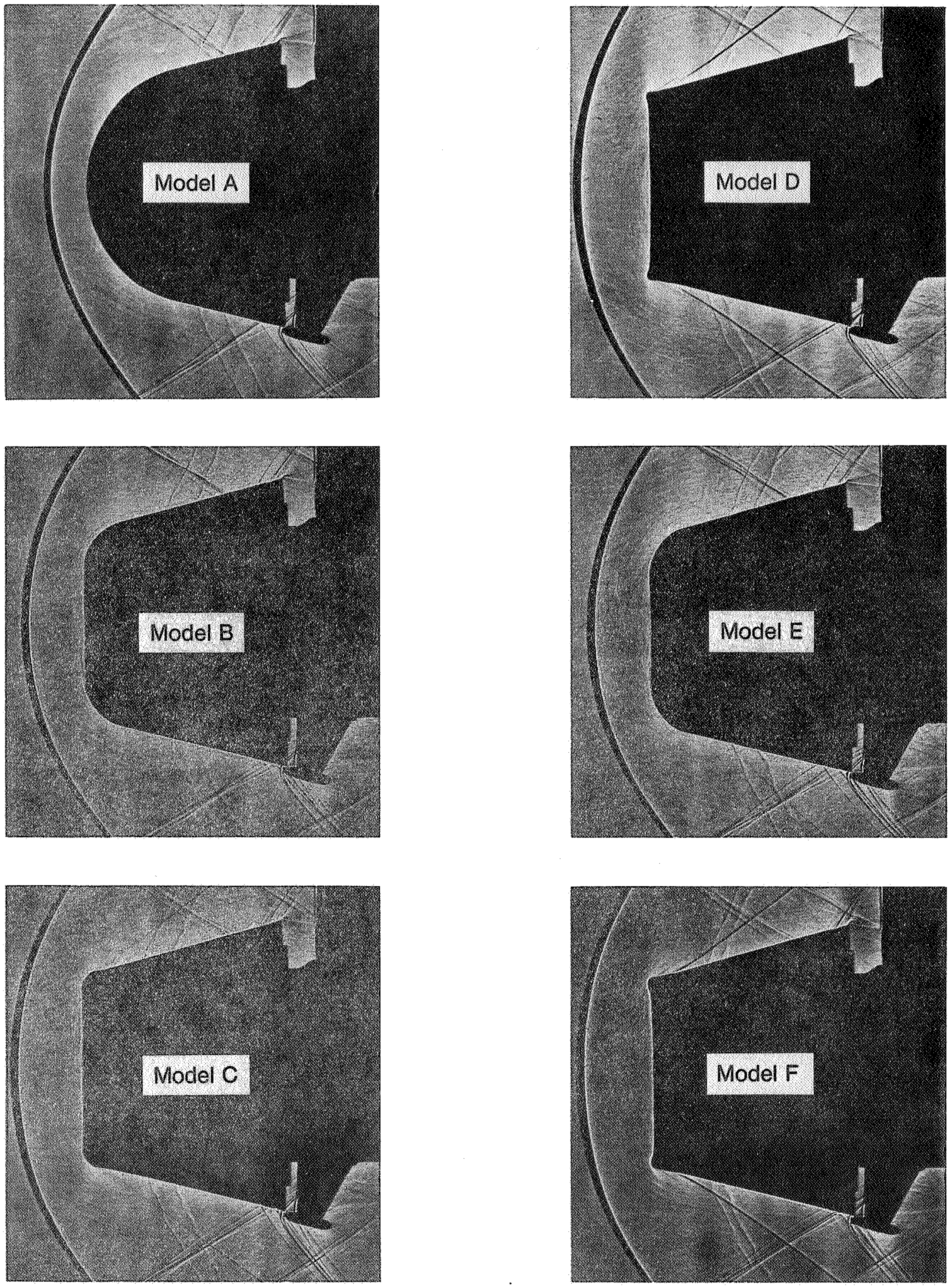


FIGURE 340. Shadowgraphs showing flow patterns around six blunt noses tested in 12-inch nozzle of Preflight Jet, August 1956.

Although it was known that a flat-face shape had the lowest heating rate at the stagnation point, the transition characteristics over the face were not known, and numerous flight tests were initiated. For example, the second model flown on a five-stage Honest John vehicle on December 20, 1956, had such a flat-face cylinder as the test body, as may be seen in figure 289, Chapter 13. A Mach number of 13.9 was attained in an over-the-top trajectory. The last three stages followed about a 10-degree downward trajectory from an altitude of 89,000 feet. The test nose was 5 inches in diameter and was made of copper extending around the cylinder a distance of 5.25 inches. The corners of the cylinder were rounded with a 0.125-inch radius. The heat transfer measured at the stagnation point was slightly lower than calculations based on the method of Fay and Riddell (ref. 31), which assumes equilibrium conditions in the boundary layer and includes an estimation of real gas effect. The heating increased away from the stagnation point, but the corner was not the hottest spot. The temperature at the corner was influenced by conduction to the cool sides of the cylinder. Comparison of measured and calculated heat transfer along the face and sides indicated fair agreement. Transition could not be determined from the heat-transfer data because at the low local Reynolds numbers, about 1.5 million, the theoretical laminar and turbulent rates were approximately the same. The flight test demonstrated the effectiveness of copper as a heat sink for a reentry body at Mach 14. The model survived to splash and the telemeter signal was good throughout the flight (ref. 32). This was in marked contrast to the slightly blunt 29-degree cone, made of inconel, which failed because of heating during burning of the last stage, as has been discussed in Chapter 13.

As an aid in determining local flow conditions for a flat-face cylinder, pressure measurements were made on a 4-inch-diameter and a 12-inch-diameter flat-face cylinder in the 27-inch nozzle of the Preflight Jet at Mach 2. Heat transfer to the face was also determined with the aid of additional models of the same diameter fitted with thermocouples. The tests were made in the 27-inch nozzle, the 12-inch nozzle, and the 8-inch circular nozzle of the Preflight Jet. The pressures measured on the 4-inch cylinder agreed well with theory and previous tests. Those on the 12-inch model appeared high, possibly because of interaction between the model and the flow from the jet. The heat transfer to the 4-inch model agreed fairly well with laminar theory, but the 12-inch model showed much higher results, because of either turbulent flow or jet interaction (ref. 33).

The state of knowledge regarding methods for calculating heat transfer to hemispherical or flat-nose bodies with such experimental verification as existed from rocket flights, use of the Preflight Jet, and other wind-tunnel tests, was summarized in a paper presented by William E. Stoney, Jr., at the NACA Conference on Aircraft Loads, Structures, and Flutter, held at Langley in March 1957. He pointed out that the major unknown was the methodology for accurate prediction of transition (ref. 34).

A second, almost identical, flat-face cylinder made of copper was flown on another five-stage Honest John vehicle on June 19, 1957. The vehicle was allowed to coast longer over the top so that the last three stages fired along a 38-degree downward trajectory to provide a more severe reentry condition. The launch is shown in figure 341. Because of the higher air density, the maximum Mach number attained was only 10.9 at an altitude of 49,300 feet. The maximum Reynolds number, based on nose diameter, was 6.57 million, as compared with 1.6 million in the previous test. The side walls of the cylindrical part of the test nose had a thickness of 0.133 inch, while the flat area was .20 inch. The side walls were made thinner to reduce the heat loss at the corners from conduction to the cool sides. Measurements by 18 thermocouples and 4 accelerometers were transmitted during the flight test by a six-channel telemeter. The thermocouples were made of No. 30 chromel and alumel wires beaded together into balls that were peened into small holes in the inner surface of the copper nose. The thermocouples were divided between two telemeter channels, and each reading was transmitted at least six times each second. Atmospheric conditions at the time of the test were determined to an altitude of 103,000 feet by a Rawinsonde carried aloft by a large balloon. The aerodynamic heating rate at each temperature-measuring station was obtained by making a thick-wall analysis by a method developed by Paul R. Hill (ref. 35). By this method, temperatures of the outside of the skin were determined from the measured temperatures on the inside, which then allowed a determination of the heat input to the wall.

The heat transfer at the stagnation point was found to be slightly lower than that predicted by the method of Fay and Riddell for laminar flow for a real gas assuming equilibriun dissociation in the

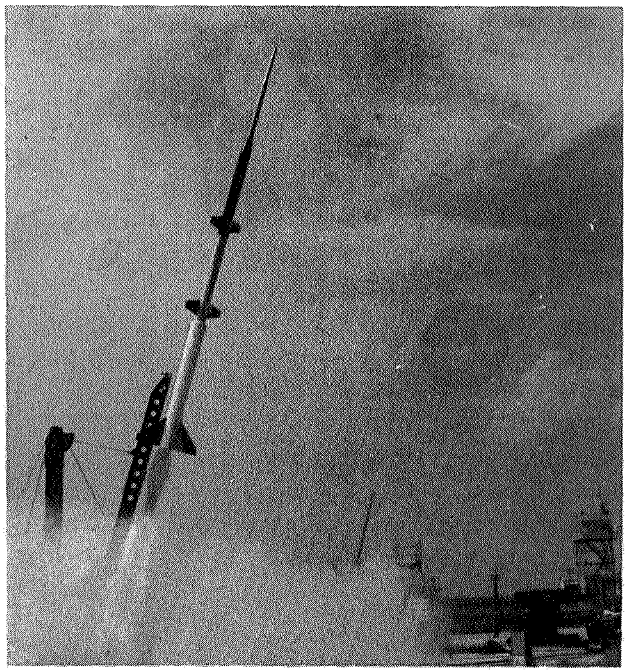


FIGURE 341. Launch of five-stage Honest John vehicle with flat-nosed cylinder instrumented for heat-transfer measurement. Launching took place on June 19, 1957.

boundary layer. The heat-transfer rates increased from the stagnation point out toward the edge of the front face in general agreement with the laminar theory of either Lees or Stine and Wanlass. The actual values were about 50 percent higher near the edge than they were at the center of the face. Because of the relieving effects of conduction through the thick copper skin, however, the actual temperature measured across the face was fairly uniform, with the maximum readings being 975° F at the stagnation point and 1,085° F at the 0.82-radius station. The investigators pointed out that "Relieving effects of this nature could be of importance in the practical design of a missile nose." The heat-transfer rates along the sides were low and agreed well with calculations assuming laminar flow (ref. 36).

A large model was constructed with a flat nose on a 29-degree cone and was flown on an Honest John-Nike propulsion system, as shown in figure 342. The diameter of the face of the model was 10 inches and the length of the truncated cone was 14.25 inches. The surface of the model was made of inconel and was highly polished. The front corner of the model had a radius of 0.25 inch. A Mach number of 4.6 was reached at an altitude of 15,000 feet, but the temperature channels of the telemeter failed when the second stage fired, limiting the data to Mach 2.2.

Data on pressures on the nose were obtained throughout the flight. The pressures indicated flow separation and very low pressures at the corner followed by pressures on the conical sides lower than those indicated by Newtonian theory. Heat transfer at the stagnation point was as much as 40 percent lower than Sibulkin theory. The heat transfer along the front face away from the stagnation point had the variation predicted by the method of Stine and Wanlass for laminar flow but was about 35 percent lower. Transition to turbulent flow was indicated at a point falling between 70 and 90 percent of the radius, but right at the corner and behind it the heating rate dropped to a very low value, confirming the flow separation indicated by the pressure measurements. There was a short length of laminar flow behind the separated region, followed by transition to turbulent flow. The turbulent heating rates were of about the same level as those predicted by Van Driest's theory, provided the measured, lower than Newtonian, pressures were used in establishing local conditions (ref. 37). Integration of the measured heating rate around this flat-face cone was only about 50 percent that of the hemisphere-cone of the same size tested earlier.

A smaller 29-degree cone with a flat face was tested on a five-stage Honest John vehicle to a Mach number of 14.6. The last three stages were fired on a downward trajectory of about 26 degrees with maximum Mach number reached at an altitude of 66,300 feet. The heating rate at the stagnation point was found to agree well with theory for laminar flow, assuming equilibrium-dissociated air up to Mach 13.6. Above Mach 13.6, for some unexplained reason, the heating rate became progressively lower

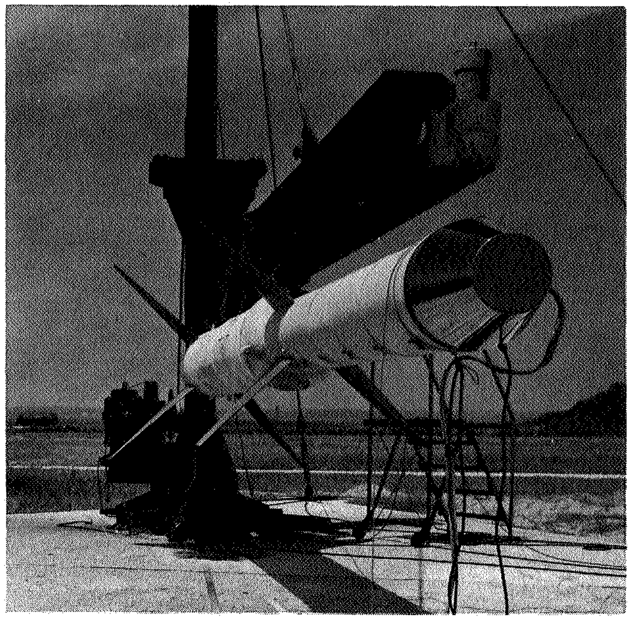


FIGURE 342. Flat-nosed, truncated, highly polished, 29-degree cone, shown on Honest John-Nike booster, August 2, 1957.

than theory and was 29 percent lower at Mach 14.6. The heating rates across the face away from the stagnation point agreed with laminar flow calculations. The heating rates on the conical sides of the nose cone were in good agreement with laminar theory using the assumption of theoretical sharp-cone static pressure on the conical section (ref. 38).

The low heating rates obtained with a flat-face cylinder were considered significant for reentry nose cones of long-range ballistic missiles. This fact, coupled with the earlier findings of safe ejection and stability of a short cylinder with a flared base, as discussed in Chapter 12, led PARD researchers to give consideration to the heating problems of such a complete configuration.

The first measurement of heat transfer to a flat-face cylinder with a flare was made with a model consisting of a 3.50-inch-diameter cylinder 5.25 inches long, followed by a 15-degree flare. The total length was 10.65 inches. The model was attached directly ahead of the second stage of a Nike-Recruit vehicle, the front of which is shown in figure 343. Because of a short circuit in the firing leads, the second stage never fired, and data were obtained only to a Mach number of 2.7 at an altitude of 4,000 feet. The maximum Reynolds number, based on the diameter of the nose, was 4.9 million. Comparison of measured with calculated heating rates indicated that the flow was laminar over the front face but was turbulent over the side of the cylinder and along the flare. The heating rate just past the corner was very low, believed to have been associated with separated flow around the fairly sharp corner. Turbulent flow along the cylinder also may have resulted from this separated flow condition (ref. 39). This was also in accord with the Preflight Jet tests discussed earlier.

A feasibility study of the use of such a cylinder-flare configuration for an Intermediate Range Ballistic Missile (IRBM) of the Army's Jupiter or the Navy's Polaris class was made by James R. Hall and Benjamine J. Garland of PARD. Heat sinks were assumed in the calculations, with the materials being copper, graphite, or beryllium for the nose and inconel or beryllium for the afterbody. The study included graphite and beryllium for the nose because of their special properties, even though they required further development for practical use at that time. Graphite was chosen for its ability to withstand high tempertures. Beryllium had the advantage of five times the heat capacity of copper of equal weight. The study assumed a cylindrical warhead 19 inches in diameter and 42.5 inches in length, with a weight of 650 pounds. The body was the minimum size to contain the warhead plus the stabilizing flare. The flare had a 10-degree angle and extended about 20 inches behind the basic body. The drag of the face of the cylinder, plus friction and base drag, was sufficient to provide subsonic impact. The study also included a supersonic-impact configuration formed by adding a truncated cone to the front of the nose. Both shapes are shown in figure 344. The final total weight varied with the materials used, as indicated.

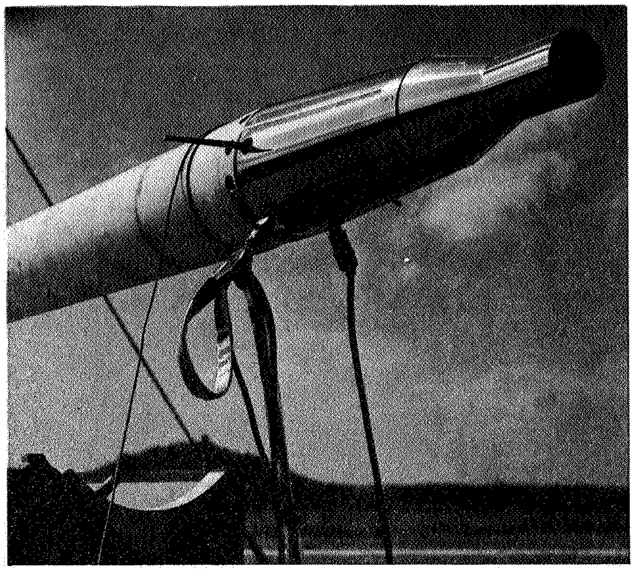


FIGURE 343. Rocket model with flat-nosed cylinder and flare. Model was used with Nike-Recruit booster for heat-transfer test, August 13, 1957.

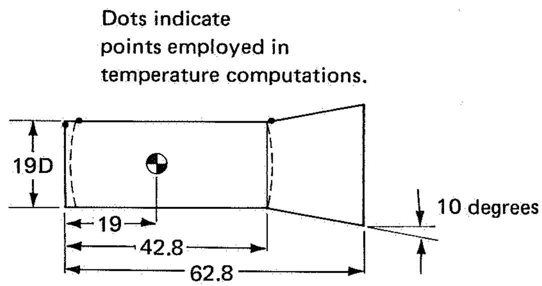
In the calculations, reentry at a velocity of 14,800 feet per second at 316,000 feet was assumed, with a downward angle of 38.7 degrees. Four shapes were used in the calculations: the full-face cylinder which gave an impact Mach number of 0.5; the truncated cone, shown in figure 344, which gave an impact Mach number of 1.49; a longer cone with impact Mach number of 1.89; and a shorter cone with impact at Mach number 1.05. The heat input at the stagnation point was calculated by the method of Sibulkin for a hemisphere, with the value divided by 2 to allow for the flat face. The flow over the front face was assumed to be laminar until the Reynolds number, based on momentum thickness of the boundary layer, reached 250. From this point, turbulent flow was assumed along the sides of the cylinder and the flare.

The computed temperatures for the subsonic configuration with copper and inconel were well below the melting point of the materials, thus verifying that the weights assumed for the calculations were realistic. The total weight was 822 pounds. Substituting beryllium for the copper and inconel also yielded a safe temperature condition, with a saving of 134 pounds in total weight. The supersonic-impact configuration had much higher temperatures, but the graphite nose never reached its subliming temperature. The temperature difference through the skin was very high, which posed a possible serious thermal shock problem. Nevertheless, it was concluded that "a nose could be developed with graphite as the principal component which would withstand the heating associated with supersonic reentry" (ref. 40). Indeed, follow-on nose cones for ballistic missiles were to have supersonic-impact shapes somewhat related to those analyzed here, and were to use compositions containing graphite in the heat shield.

That a flat-face cylinder had about one-half the heating rate at the stagnation point as a hemisphere of the same diameter was demonstrated in many tests. Away from the stagnation point, the heating rate decreased on a hemisphere but increased to a maximum near the corner on a flat face. A series of noses of equal diameter was tested in the Preflight Jet with different nose radii representing different spherical segments. Six shapes from a hemisphere to a flat face were tested. Expressed as the ratio of body radius to nose radius the hemisphere had a value of 1.0 while the flat face had a value of 0. It was found that the heating at the stagnation point varied linearly with this ratio. It was also found that with a ratio of 0.33, the heating rate remained about constant across the face, with a value about 20 percent above that of the stagnation point of the flat face. Reducing the heating rate near the edges was important because more area was involved. This spherical radius ratio of 0.33 was a significant finding and was to be the one initially selected for the heat shield of the Mercury manned satellite capsule. These data were included in a paper presented by William E. Stoney, Jr., at the NACA Conference on High-Speed Aerodynamics, held at Langley in March 1958 (ref. 41).

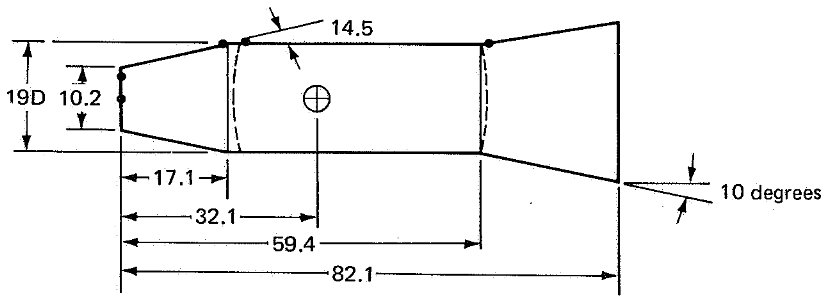
In early versions of the ICBM nose cones with their large hemispherical front faces and sharply coverging afterbodies, the intent was to restrict the high heating to the front face and ensure separated

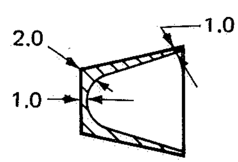
All dimensions in inches; weight in pounds.



Component	Conventional			Unconventional		
	Material	Thickness	Weight	Material	Thickness	Weight
Nose	Copper	.50-.75	55	Beryllium	.50-.75	13
Cylinder	Inconel	.10	75	Beryllium	.10	16
Flare	Inconel	.10	42	Beryllium	.10	9
Bomb	—	—	650		—	650
Total			822			688

(a) Subsonic Impact Configuration





Component	Material	Thickness	Weight
Nose	Graphite	1.0-2.0	59
Cylinder	Beryllium	0.5	80
Flare	Beryllium	0.5	46
Bomb	—	—	650
Total			835

(b) Supersonic Impact Configuration

FIGURE 344. Analysis of reentry missile nose cones according to kind of heat-protection materials used.

flow over the afterbody. In order to provide information on the type of flow behind typical shapes of the ICBM type as well as some generalized shapes, pressures on the afterbody of such shapes were measured in a series of tests in the Preflight Jet at Mach 2. The tests were conducted by Katherine C. Speegle. Shadowgraphs verified that the flow was separated in all cases, and that the base pressures were unaffected by forebody shape (ref. 42).

One nose shape that combined the features of a flat center area and a rounded corner, yet was defined by a simple equation, was one called a "1/10-power nose." The radius of the body of revolution that formed the nose was made proportional to the 1/10-power of the axial distance from the front end. Such a nose of 6-inch diameter was faired into a 9.6-degree cone on the front end of a Recruit rocket motor. A Nike booster completed the two-stage propulsion system. The model was launched at an elevation angle of 70 degrees, and a maximum Mach number of 7.0 was reached at an altitude of 14,000 feet. Temperatures and pressures were measured on the nose section. The nose was not given a superpolish finish but was smoothed to an average roughness of 8 microinches. The flow was found to be laminar over almost the entire nose, at a Mach number of 2.2. The transition point moved forward with increasing Mach and Reynolds numbers, and jumped from a side station to one around the corner on the front face, as the freestream Reynolds number exceeded 30 million per foot. The transition Reynolds number, based on momentum thickness of the boundary layer, was as high as 1,600 but dropped to 250 when the transition point moved forward of the corner. These values were somewhat higher than those obtained earlier with a highly polished nose, which indicated either that this was a superior nose shape or that transition was insensitive to roughness between 2 and 14 microinches. Agreement of measured with calculted heating rates was poor on the front face but good farther back on the nose (ref. 43).

The aerodynamic heating research with blunt bodies discussed so far was aimed at providing design data for use in selecting shapes for the nose cones of long-range ballistic missiles, as well as for use in structural design. The end product was a military weapon. Another aspect of weapon design was vulnerability to countermeasures. In this regard, there was a concern over the events that might follow a partial penetrating of a thick heat shield. The concern was whether the heating rate in such a depression might be excessive and lead to a local burn-through, followed by destruction of the nose cone. In 1951, Fred Whipple of the Harvard Observatory had explained holes in meteorites as resulting from intensified burning and enlarging of tiny depressions. This conclusion was based on tests at the Ballistic Research Laboratory which showed that a magnesium bullet with a depression in the nose ignited as a result of aerodynamic heating. A few exploratory tests were made to investigate this phenomenon, first at Langley, in the ceramic-heated air jet, and then at Wallops, with three rocket models (ref. 44).

In the tests in the ceramic-heated air jet at Langley, two small models (of 3/8-inch diameter) having thermocouples at their stagnation points, were inserted into the 3,500° F jet for a few seconds and then removed. The first model had a hemispherical nose, while the second had an inverted hemisphere or cup-shaped nose to represent a depression. The two models were also referred to as convex and concave shapes. Surprisingly, the concave nose had only one-third the heating rate of the convex nose. Next, models of the same size were fitted around the midsection of the last stage of two rocket models flown for other purposes. These little models were hitchikers. Eight of the models were mounted on short pylons about 0.75 inch away from the surface, as shown in figure 345. This particular model, except for the additions, was identical to the one flown on the four-stage vehicle that first reached Mach 10 at Wallops.

Two separate tests of this type were made. The first flight, on October 7, 1955, provided data only to Mach 4 because of failure of the telemeter. The second, on June 7, 1956, provided data as planned to a Mach number of 8.4. Each vehicle had both convex and concave models on the short pylons. In these tests, it was found that at Mach 2 the heating rate at the stagnation point of the concave nose was about one-third that of the convex; and that at Mach 8 the concave shape had only one-tenth the heating of the convex.

The third rocket model was designed solely for testing the effects of simulated impact depressions. The conical test body had a 29-degree angle with a hemispherical nose of 0.92-inch radius. Hemispherical depressions of 3/8-inch diameter were located at the stagnation point, the 45-degree station, and three places along the conical sides, as may be seen in figure 346. Temperature

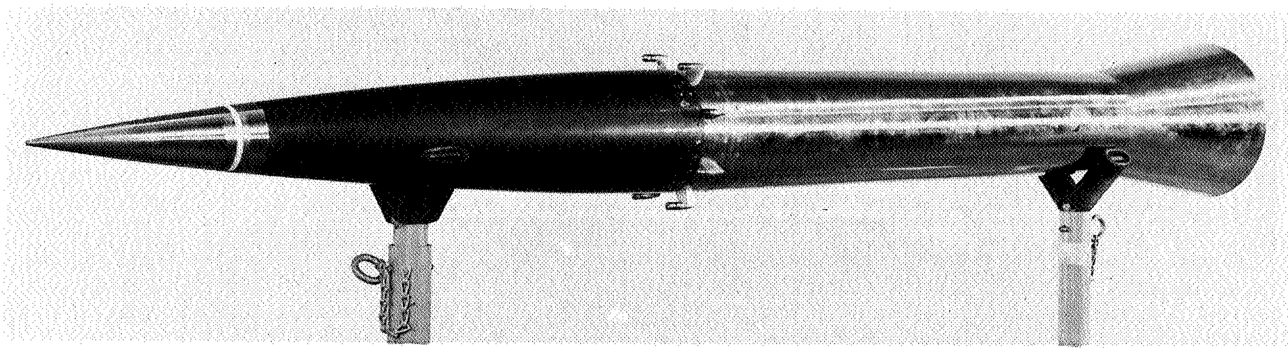


FIGURE 345. Ogive-cylinder-flare model with eight small "hitch-hiking" models mounted on short pylons for preliminary comparative tests of concave and convex hemispherical models. The model with its eight small "riders" was flown on a four-stage Mach 10 vehicle on October 7, 1955.

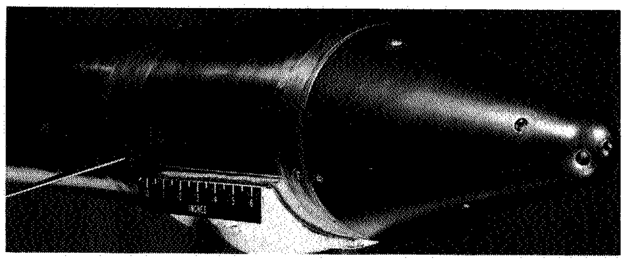


FIGURE 346. Blunt 29-degree cone with various simulated impact depressions. Cone was used with Nike-T40-T55 vehicle for heat-transfer test.

measurements were made inside each depression as well as along the smooth surface. A three-stage Nike-T40-T55 vehicle was used in the test. Although a Mach number of 7 was planned, a structural failure at the end of first stage burning limited the data to Mach 3.2. The heating rate inside the depression at the stagnation point was only a small fraction of the laminar theoretical value calculated for a smooth nose. The heating inside the other depressions was somewhat higher than the measurements on the smooth surface (ref. 44). Although these tests did not indicate that slight damage to a nose cone would lead to catastrophic burning, they did indicate a possible shape for extremely low heat transfer.

Another flight test was made of a model with hemispherical depressions in the face of a flat-truncated, 29-degree cone. This time, the holes were located away from the center of the 5-inch face. A Nike-Recruit launch vehicle was used to reach a Mach number of 7 at an altitude of 14,500 feet. The Reynolds number was 31.5 million per foot. Laminar flow was indicated over the face, but inside the depressions the heating rate increased by as much as 93 percent. This unexpected finding was attributed to transition to turbulent flow within the depression (ref. 45).

The first detailed experimental study of heating inside a concave hemispherical nose was conducted in the Preflight Jet with a 5.5-inch-diameter model. Thermocouples were located inside the concave portion of the nose, around the rounded lip, and back along the sides of the cylindrical body. The tests, beginning in August 1957, were made in the 27-inch Mach 2 nozzle at angles of attack of 0 degrees, 5 degrees, and 10 degrees. It was found that the heating rate at the stagnation point was about 40 percent of that for the same size of convex hemispherical nose. Angle of attack had practically no effect. The highest heating rate was at a station just inside the lip (ref. 46). Tests of a concave nose in a wind tunnel at Langley indicated the possibility of two types of flow inside the nose, with widely varying heating rates. A steady-flow condition gave results in general agreement with the Wallops results, while with an unsteady-flow condition the heating increased by a factor of about 6 (ref. 47). The need for additional research was indicated.

Flight tests were made of a model with a concave nose of the same diameter as that tested in the Preflight Jet. It was attached to the front end of a Recruit rocket motor, as shown, in figure 347. With a Nike booster rocket, a maximum Mach number of 6.6 was reached at an altitude of 14,000 feet. Temperatures were measured inside the cup nose and back about 3 inches along the side of the cylinder. Heating rates inside the cup varied from 5 to 13 percent of the theoretical value at the

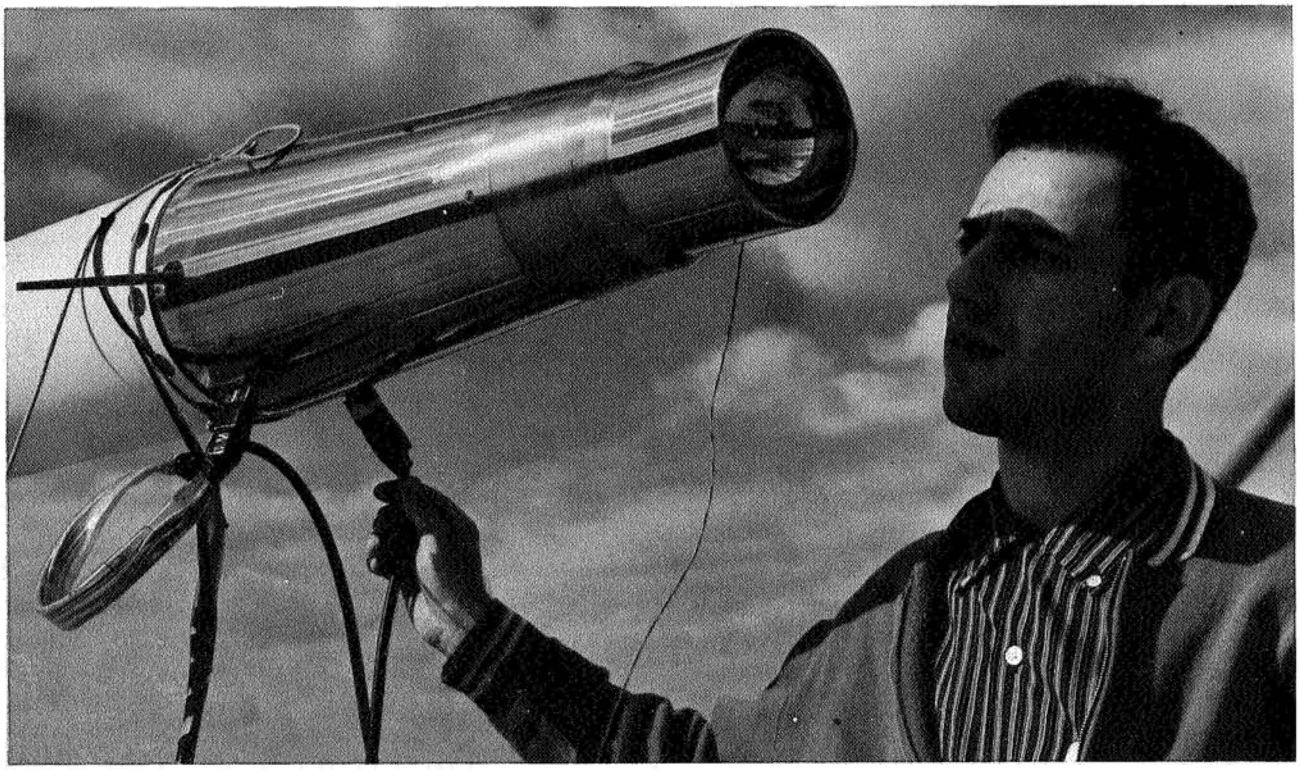


FIGURE 347. Engineer Jack Levine examines concave test nose of Nike-Recruit vehicle prior to launch, October 10, 1957.

stagnation point of the same size of hemisphere and were only 20 percent of the values obtained in wind-tunnel tests under steady conditions. As mentioned earlier, heating under an unsteady-flow condition in the wind-tunnel tests increased by a factor of 6. Accelerometers in the present flight model indicated a maximum angle of attack during the heating tests of 0.10 degree, which ruled out angle of attack as a possible explanation for the discrepancy. Both the wind-tunnel and flight researchers were convinced that their results were correct, but neither could explain the discrepancy (ref. 48). An additional test with a second rocket model on May 29, 1959, confirmed the previous flight results (ref. 49).

The NACA Executive Committee held one of its regular meetings at Wallops on September 19, 1957. The members are shown in figure 348 beneath a five-stage Honest John vehicle, just prior to receiving a briefing on the multistage rocket model program.

TELEMETER BLACKOUT AT HYPERSONIC SPEEDS

The impairment or loss of radio communications from a body traveling at hypersonic speeds had been predicted theoretically for some time because of ionization of the high-temperature air surrounding the missile. The exact speed at which total blackout would occur had been predicted as being at Mach 10, then at Mach 15, and certainly at some higher speed. The effect was expected to show up initially as a loss of signal strength from the radio transmitting antenna. The strength of the signal reaching the ground receiver, of course, depended upon the power of the transmitter, the type of antenna, and the distance from the receiver, as well as upon the ionization effects. With the rocket models at Wallops, as the speeds increased, the distance between the transmitter and receiver also increased, and losses from this source were usually overcome by increases in the gain of the receiving antenna on the ground.

When the predicted blackout at Mach 10 did not materialize with the four-stage rocket model at Wallops in 1954, the problem was not taken seriously. With the five-stage models traveling at Mach 15,

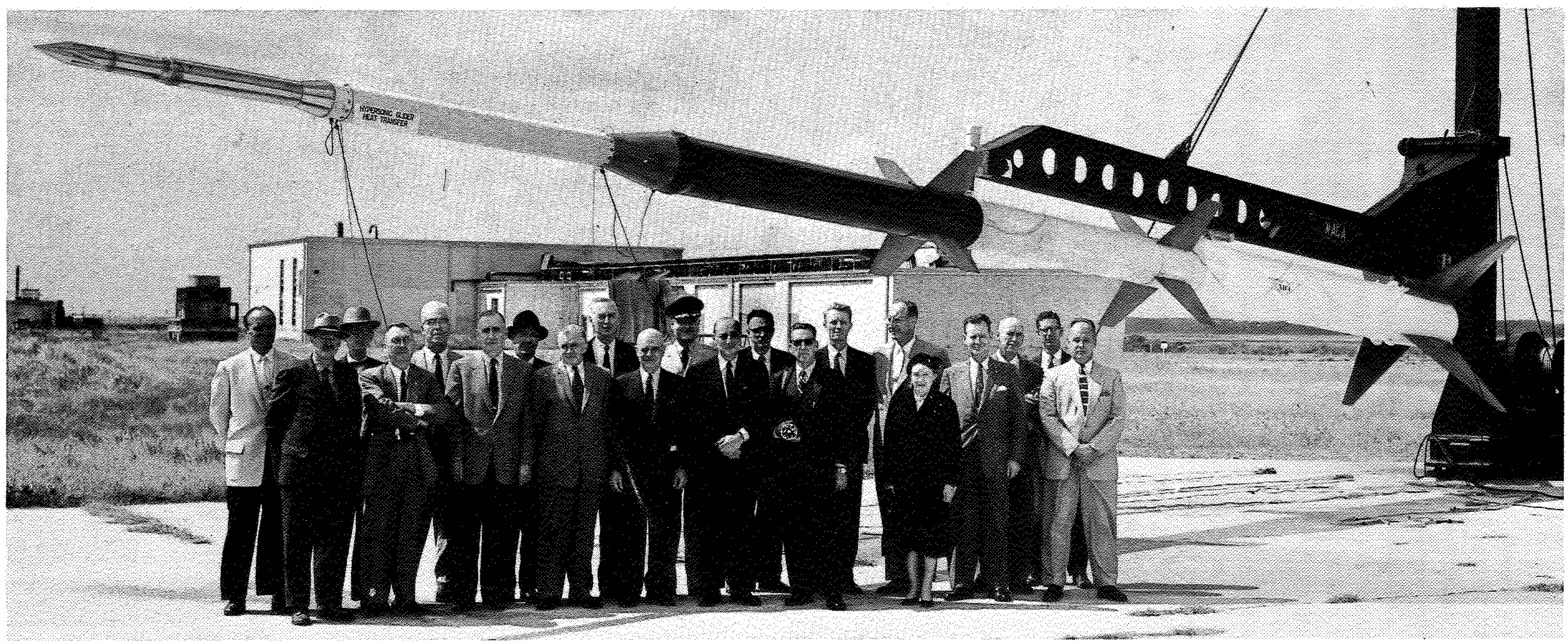


FIGURE 348. The NACA Executive Committee assembles beneath five-stage Honest John vehicle with a simulated delta-wing model. Model is shown with a conical body at an angle of attack. Photograph was occasioned by meeting of the Executive Committee at Wallops on September 19, 1957. Left to right: J. A. Shortal, Chief, PARD; J. C. Hunsaker, MIT; J. F. Victory, Executive Secretary, NACA; H. L. Dryden, Director, NACA; H. J. E. Reid, Director, Langley; C. J. McCarthy, Chance Vought Corp.; E. R. Quesada; P. R. Bassett, Sperry Rand Corp.; L. Carmichael, Smithsonian Institution; J. H. Doolittle, Chairman, NACA; D. L. Putt, Lt. General, USAF; S. Rothschild, Under Secretary of Commerce; A. V. Astin, Bureau of Standards; P. D. Foote, Asst. Secretary of Defense; F. L. Thompson, Associate Director, Langley; R. V. Rhode, NACA Hq.; Catherine Wheeler, NACA Hq.; W. T. Hines, Rear Admiral, U.S. Navy; R. R. Gilruth, Asst. Director, Langley; J. C. Palmer, Head of Research Section, Wallops; R. L. Krieger, Engineer-in-Charge, Wallops.

however, concern increased, and although telemeter transmission from models at that speed was received satisfactorily on the ground, the magnitude of the problem was expected to increase as the speed increased, as the altitude decreased, and as the size of the body increased. Blackout of a large blunt ICBM nose cone reentering at Mach 20 and above would certainly present a problem during flight tests in which a telemeter was used as the cone plunged into the denser atmosphere. The lack of knowledge about the actual physical state of the gases surrounding the missile (such as the degree of dissociation, ionization, and recombination) plus the lack of knowledge of the interaction of these gases with the electromagnetic field of the transmitting antenna made it difficult to calculate the losses.

In order to provide some information on this subject, an analysis was made of telemeter transmission from two rocket models traveling at speeds near Mach 15. Both models were propelled by the five-stage Honest John vehicle described earlier. Parts of the trajectory corresponded closely to the speeds and altitudes expected to be experienced by a nose cone reentering the atmosphere at a speed of Mach 20. One of the models was flown as a part of the heat-transfer program, while the other was designed specifically to study telemeter blackout. This second model is shown in figure 349.

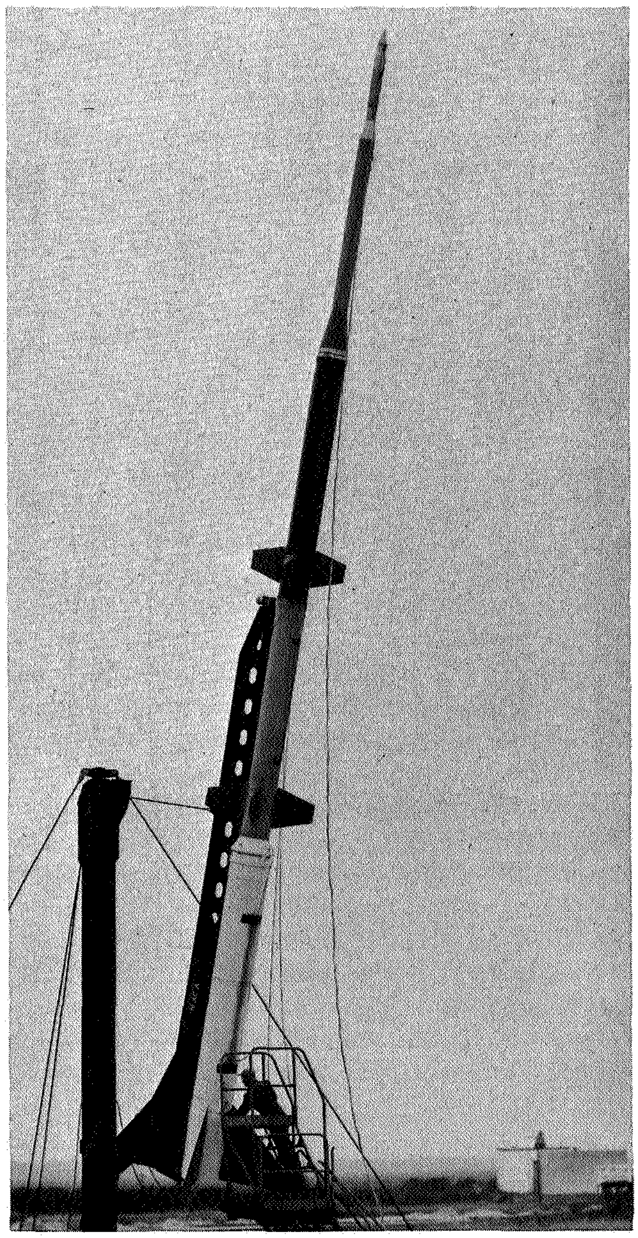


FIGURE 349. Technician Durwood Dereng checks elevation angle on five-stage Honest John vehicle used in telemeter blackout investigation, March 18, 1957.

The first model reached a Mach number of 15.5 at 98,000 feet, and from the temperature measurements loss of telemeter signal was believed to have been caused by burning of the structure. The second model, flown to reenter on a steeper trajectory, was lighter in weight and reached a Mach number of 15.8 at an altitude of 71,500 feet. The telemeter signal failed on this model also, near peak Mach number; but since no temperatures were measured it could only be surmised that it, too, burned up.

Both models had 29-degree cones ahead of the cylindrical body surrounding the T55 fifth stage, and had flared skirts for stability. The first model had a blunt hemispherical nose with a radius of 0.62 inch; the second had a flat nose with a radius of 0.50 inch. The antenna on each model was an aluminum oxide ring that insulated the conical nose from the remainder of the model. Both models were instrumented with NACA telemetry transmitting at 219.5 megacycles and a nominal power of 1.5 watts. Calibration of the antenna pattern of each model was made prior to flight. The receiving antenna at Wallops was a 20-turn helix, shown in figure 350. During the flight, the antenna was pointed at the model according to information supplied from the tracking radar or from trajectory calculations. This antenna had a gain of 18 decibels over an isotropic radiator. A preamplifier in the receiving station with a gain of 15 decibels was also used. The signal level at the receiver was recorded. Calibrations were made following each flight, to obtain the signal power received at the antenna terminals.

In the flight tests, both models indicated a change in signal strength of about 22 decibels at a Mach number of 15.5, compared with the signal at Mach 8. The attenuation up to Mach 8 was negligible. It was considered significant that successful telemeter transmission was obtained under these flight conditions despite the apparent large attenuation from thermal ionization (ref. 50).

This was the first attempt at Wallops to obtain data on the attenuation of radio transmission from thermal ionization at hypersonic speeds, and it was to be the forerunner of an extensive flight project in later years, identified as Project RAM (Radio Attenuation Measurement).

REENTRY MISSILE NOSE CONE STABILITY: E48

With the introduction of the bluff-body concept of Allen and Eggers for reentry missile nose cone design, the way was opened for a myriad of shapes to meet different requirements. The attractiveness of simple cylinders as internally carried bombs for the F-105 airplane has been discussed in Chapter 12. This shape could be safely ejected and, in addition, had a low lift-curve slope, which meant that angular disturbances would not affect the resultant flight path materially. The addition of a flare to the base for added stability has been discussed, as well as changes in the nose for drag reduction.

In 1956, a general flight program to investigate dynamic stability of many of these blunt nose cones was initiated by PARD. Initially, such models were designated as an extension of the E2 drag program, but by 1957 a new designation, E48, was assigned them. This program was under the direction of the Aircraft Configurations Branch.

The technique was to propel the model to the desired flight speed by a solid-rocket booster and then separate the model from the booster. The high drag of the models sometimes made separation difficult. In some cases, small separation rocket motors were placed in the base of the model, while in others large drag flaps or "shovels" were opened at the forward end of the booster motor to increase its drag after burnout. The structural integrity of such a drag flap was investigated by special tests in the Preflight Jet. After separation, the model was disturbed in pitch by a series of small pulse rockets. Analysis of the resulting motion was made from simultaneous measurements of accelerations of the center of gravity in the pitch and yaw planes. In some cases, additional accelerometers were placed away from the center of gravity to allow determination of the pitching and yawing moments. Despite the apparent symmetry of these models, there was inevitably some rolling motion throughout the flight. Analysis of the stability was complicated by the rolling motion, particularly if the roll rate was near the pitch or yaw frequencies. Robert L. Nelson's development of an analytical procedure for such conditions greatly contributed to the success of the reduction of the flight data to aerodynamic derivative form (ref. 51).

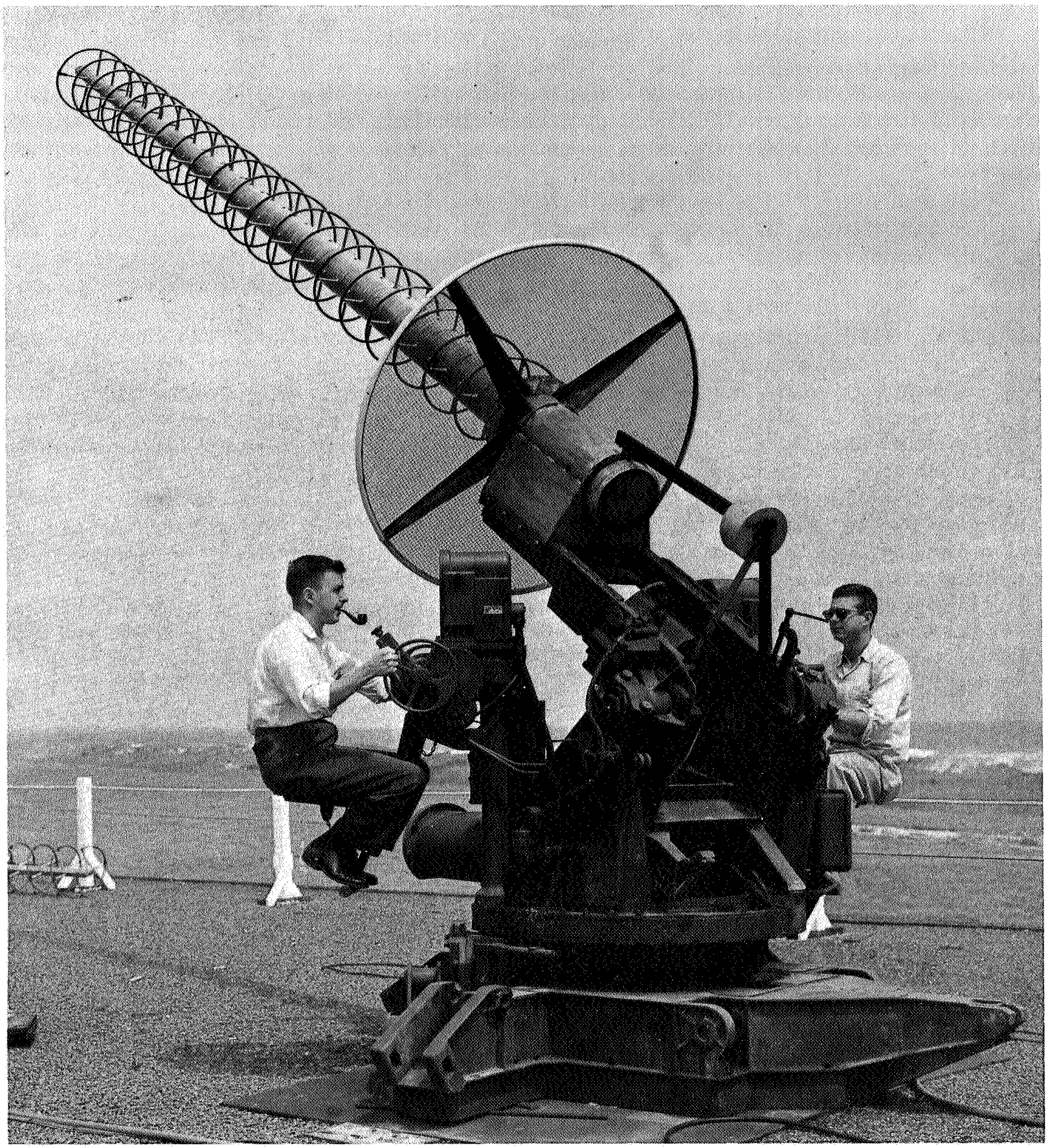


FIGURE 350. Twenty-turn helical antenna mounted on roof of Control Center 1. View shows J. B. Aaron (left) and R. R. Johnson pointing antenna at model in flight.

The first model in this program was a simple cylinder of fineness ratio 2.56, boosted by a Deacon rocket motor to a Mach number of 1.8. The model had a diameter of 8 inches, a length of 21.5 inches, and a weight of 71 pounds. At separation from the booster, the model received a disturbance which, in combination with the action of the first pulse rocket, produced a 30-degree angle of yaw. A resulting combination yaw, pitch, and roll oscillation damped to a low amplitude as the model quickly decelerated to subsonic speeds. The low-amplitude oscillation persisted throughout the remainder of the flight at a Mach number of about 0.4. The second model was a cylinder of fineness ratio 4.0 with a 13-degree flare at the base. This model behaved in a manner similar to that of the plain cylinder. The flare increased the total drag about 20 percent (ref. 52).

The effect of rounding the corners of the flat nose of a cylinder of fineness ratio 4.0 with a 13-degree flare was determined from flight tests of a model boosted by a Cajun rocket motor to a Mach number of 2.15. A plain cylinder of fineness ratio 2.71 was also tested for comparison. The flared model is shown in figure 351. The location of the aerodynamic center of the cylinder was found to vary from 60 percent of the length back of the nose at subsonic speeds to 45 percent at Mach 2. The flared model rolled at an inexplicably high rate (ref. 53).

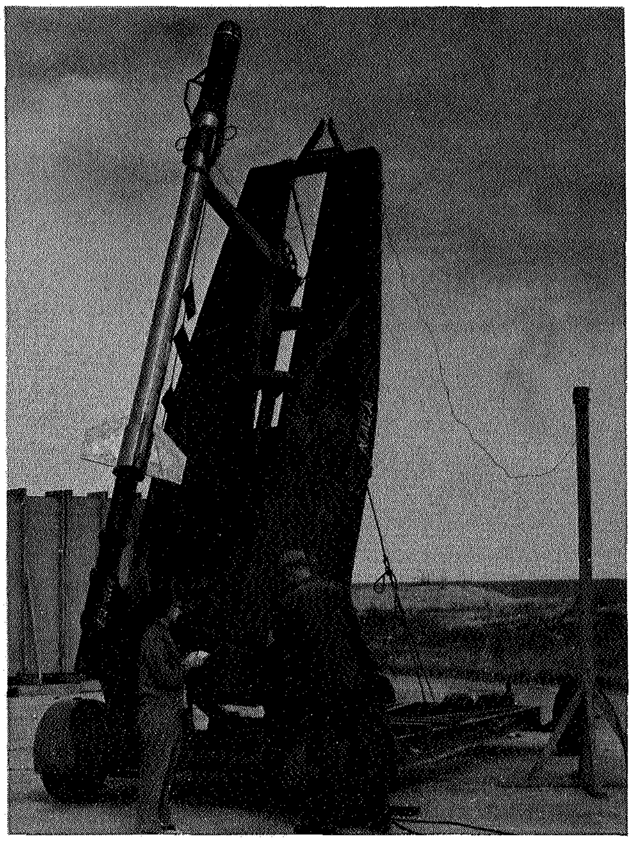


FIGURE 351. Engineer Lucille Coltrane records elevation angle of launcher as measured by technician Durwood Dereng in preparation for launch of Cajun-boosted cylindrical reentry body with rounded nose and flared base. Launching took place on April 8, 1957.

The next two models had a bluff nose shape described as a 1/10-power nose. This shape has been described earlier in this chapter and consists essentially of a flat nose with rounded corners. The first model had the nose attached to a 10-degree cone, whereas the second model was a basic cylinder faired into a square base. Both models had fineness ratios of about 2.5 and were boosted by Cajun motors to a Mach number of 2.14. The tests indicated both static and dynamic stability throughout the speed range except for the conical shape at transonic speeds, where a slight instability was observed. The center of gravity was located at about the 31-precent lengthwise station back of the nose. The instability corresponded to a 4-percent shift in aerodynamic center (ref. 54).

The next two models were propelled by a Recruit booster to a Mach number of 3.0. One of these models is shown in figure 352. The first model was a 21.4-degree blunted cone with a nose radius of 1.6 inches. The base diameter was 14 inches and the length was 30.03 inches. The second model was a cylinder 8 inches in diameter, with an ogival nose and a 20-degree flare. This model had a base diameter of 12.93 inches and a length of 28.45 inches. Both models were statically and dynamically stable over the speed range with the center of gravity at the 50-percent station. For the ogive-cylinder-flare, the aerodynamic center was at a constant location of 56 percent over the speed range, but moved rearward with increasing Mach number for the blunt cone, fron the 60- to 66-percent station (ref. 55).

The next two models were boosted by Gosling rocket motors.[7] Both were basic ogive-cylinder shapes with flared bases and were flown to a maximum Mach number of about 3.3. On one, the flare

7. The Gosling rocket motor was procured from Great Britain and had sightly more impulse than a Recruit, with lower acceleration. It was 10.9 inches in diameter and 132 inches in length, and weighed 446 pounds. The motors were delivered by British destroyer to Norfolk Naval Base.

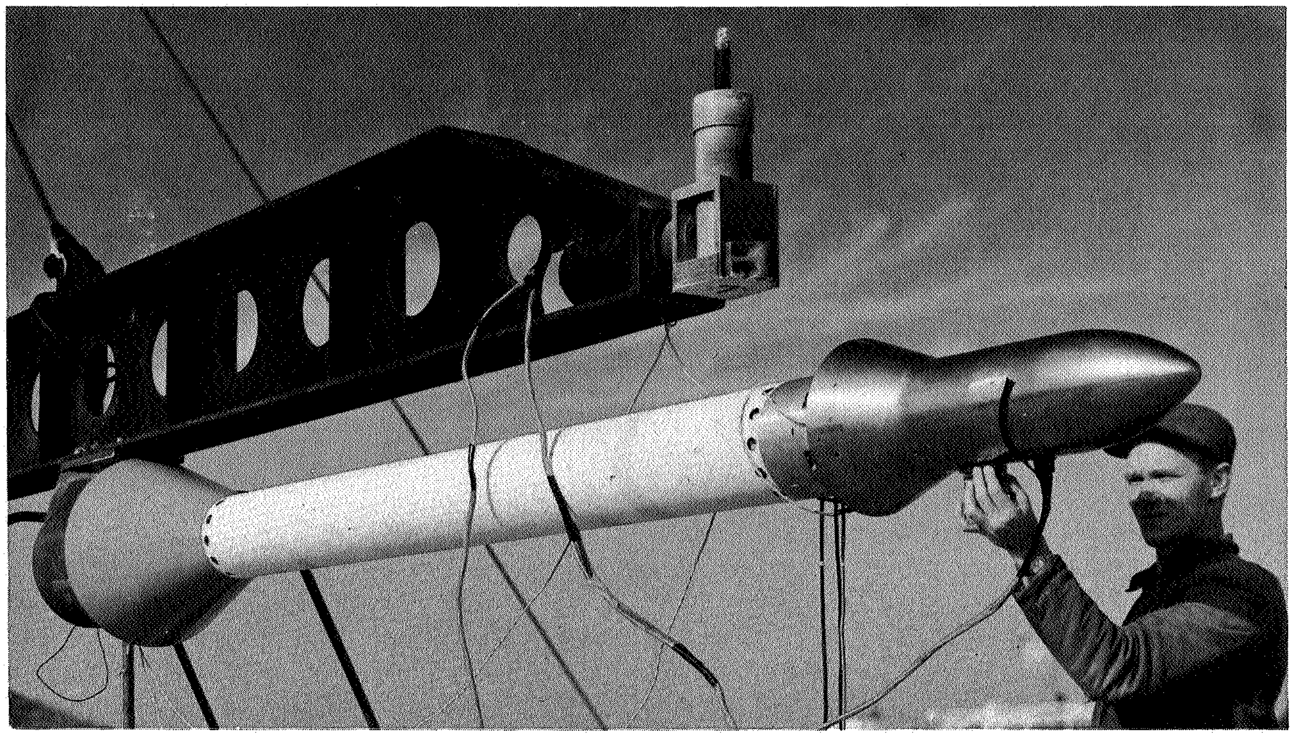


FIGURE 352. Technician Durwood Dereng checks alignment of ogive-cylinder-flare reentry body for test with Recruit booster, January 28, 1959.

had an angle of 9.5 degrees, while on the other the angle was reduced to 5 degrees, and eight small 80-degree delta wedge fins were spaced around the flare. Both models were designed for supersonic impact. The tests indicated that both models were stable in flight over the speed range. The one with the reduced flare angle and eight fins had about one-third less drag than the other (ref. 56).

The next models in the series consisted of three shapes designed for supersonic impact. Each one was flown to a Mach number of 4.2 by a Nike-Recruit two-stage booster. One of the models is shown in figure 353. The three shapes were a round-nose cylinder with a 10-degree flare; a 20-degree truncated-cone-cylinder with a 10-degree flare, and a 20-degree truncated-cone-cylinder with a two-step flare. The two-step flare had a 14-degree angle where it joined the cylinder and a 5-degree flare at the rear. Good data on stability and drag were provided over the speed range (ref. 57).

The two last models in the E48 series were flown to even higher speeds in October 1960 with the three-stage Honest John-Nike-Gosling booster shown in figure 354, but the data were not satisfactory for analysis.

COMPLETION OF PROGRAM ON AERODYNAMIC HEATING AND FLUTTER OF STRUCTURAL PANELS

The discussion in Chapter 10 has dealt with the research program in the Preflight Jet on the effects of aerodynamic heating on built-up structural panels representing actual aircraft wing structures. Some of the panels tested failed a short time after the start of a test, because of a flutter induced by changes in structural properties brought on by the aerodynamic heating. (See figures 214 and 215, Chapter 10.)

This program was continued at Wallops through July 1956, with the test of additional panels in the Preflight Jet. Except for the first wing panel, designated MW-1, and a later repeat test, all of the built-up panels had a 20-inch wing chord and a circular-arc airfoil section of 5-percent thickness. The wing span was also 20 inches. All of the tests were made in the 27-inch Mach 2 nozzle. For a given panel, the test variables were angle of attack and stagnation temperature of the air in the jet. The general results from the tests of wings MW-2 through MW-7 have been given in Chapter 10. These results were

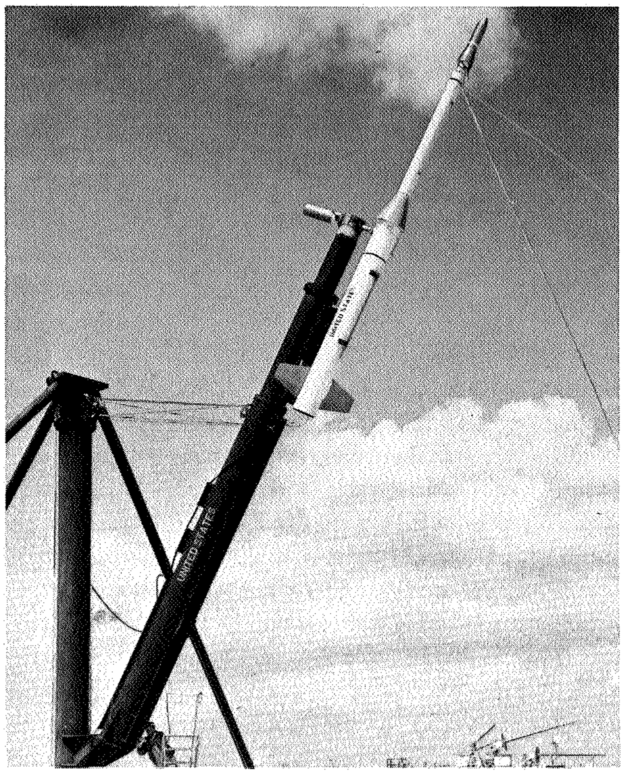


FIGURE 353. Reentry stability body, shown with Nike-Recruit booster, April 7, 1961.

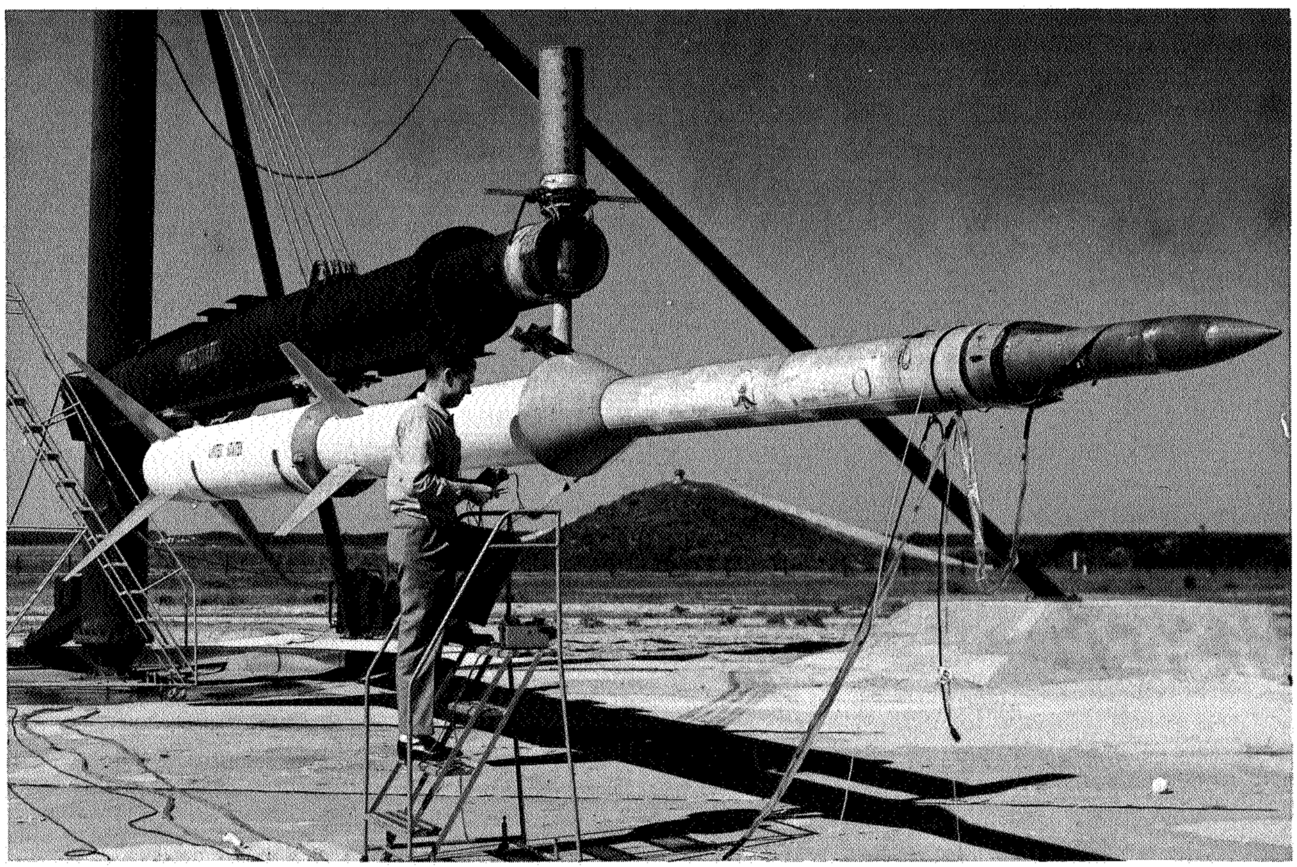


FIGURE 354. Technician Gene Waldron checks firing circuit to Honest John-Nike-Gosling booster for high-speed reentry nose cone test, October 19, 1960.

based chiefly on visual and photographic data. A detailed analysis of the recorded data on temperatures, pressures, and stresses was then made and published in two separate reports. The first of these (ref. 58) covered wings MW-2 and MW-3. Model MW-2 was a scaled version of the larger MW-1 and failed just as dramatically. Its skin was 0.064-inch aluminum alloy. MW-3 was similar except that it had a skin of 0.081-inch thickness. A preliminary test with this model was made first at a stagnation temperature of 100° F without failure; then a run was made at 500° F, again without failure. Apparently the thicker skin was a solution to the flutter problem. Several more tests were then made at angles of attack of 1.5 degrees, 3 degrees, and 5 degrees to obtain temperature, pressure, and loads under these conditions. The loads at the 5-degree angle were too great for the wing panel, and it folded over as soon as the jet was turned on.

The second detailed report covered the remaining four models, MW-4 through MW-7. MW-4 was exactly like MW-2 except that a much lighter bulkhead was used at the tip to permit freer chordwise expansion in the tip region. Failure due to flutter in the test of this model was even more dramatic and catastrophic than had been the case with MW-2. The sequence of events leading to destruction was vividly recorded by means of a Fastax camera operating at 650 frames per second. The model was stationary for 5.22 seconds. Then a flag-waving type of flutter began with a frequency of 240 cycles per second. The amplitude increased sharply at 5.57 seconds, and failure, beginning at 5.58 seconds, was complete at 5.60 seconds. Only 0.38 second had elapsed from the beginning of flutter to destruction.

Model MW-5 was the same as MW-2 except that seven chordwise ribs were used in addition to the six spanwise webs. Model MW-6 was like MW-5 but had the skin thickness reduced to 0.051 inch from 0.064 inch. In the tests, neither MW-5 nor MW-6 fluttered, and both remained intact throughout the full time. The last model, MW-7, was made of steel instead of aluminum and had the same type of construction as MW-2 except that the thickness of the steel members was reduced to maintain approximately the same buckling stress. MW-7 survived the test with only minor buckling of the skin. The heating rates obtained on the model surface in the tests were in general agreement with Van Driest's theory for turbulent flow (ref. 59).

Model MW-2 served as a reference model for the follow-on tests. Because of this, two additional MW-2 models were constructed and tested between September 1953 and May 1954, under different conditions. The first of these, designated MW-2 (2) was tested six times before it failed at an angle of attack of 2 degrees. The second duplicate, MW-2 (3), was tested twice without failure. The fact that only slight modifications to the original design produced a safe structure had indicated that the MW-2 design was close to being a marginal one. The new tests with the duplicate models confirmed this finding. The only apparent differences between these duplicate models and the original was an indication of lower joint conductivity in the duplicate models. Heat transfer to the unsupported skin was in fair agreement with Van Driest's turbulent theory (ref. 60).

Because of the importance of the behavior of actual structural panels under aerodynamic heating conditions, Gilruth suggested that PARD test a duplicate of the MW-2 panel on a rocket model to obtain actual flight data. The PARD program was assigned to H. Kurt Strass, who by this time was in the Structural Dynamics Section of the High-Temperature Branch of PARD, organized November 1, 1955.

Three models were flown, one of which is shown in figure 355. The models were propelled by a two-stage rocket system consisting of a double Deacon first stage for the first two models and a double Cajun first stage for the third model, with a T40 rocket motor located within the test model to provide the second stage of propulsion in all three cases. The four stabilizing fins of the model were of the same size and general construction as the MW-2 test wing panel. They were clamped at their roots in much the same manner as had been the model in the Preflight Jet. One of the fins contained thermocouples and was considered the test panel. The other three fins were made stiffer than the test panel by the addition of several ribs to ensure that they would not be the ones to fail first. The test wing was identical to MW-2 except that a single rib had been added halfway between the root and tip. On June 27, 1956, this model was launched at an elevation angle of 25 degrees and reached a maximum Mach number of 2.67, with the double Deacon-T40 propulsion system. No flutter was encountered, although skin temperatures were higher than they had been in the tests in the Preflight Jet (ref. 61). Nevertheless, valuable data on aerodynamic heat transfer to an unswept wing were obtained.

The second flight model, flown on May 23, 1957, suffered a structural failure unrelated to the test purpose; but on November 20, 1957, the third model was flown successfully. Since the test panel on the

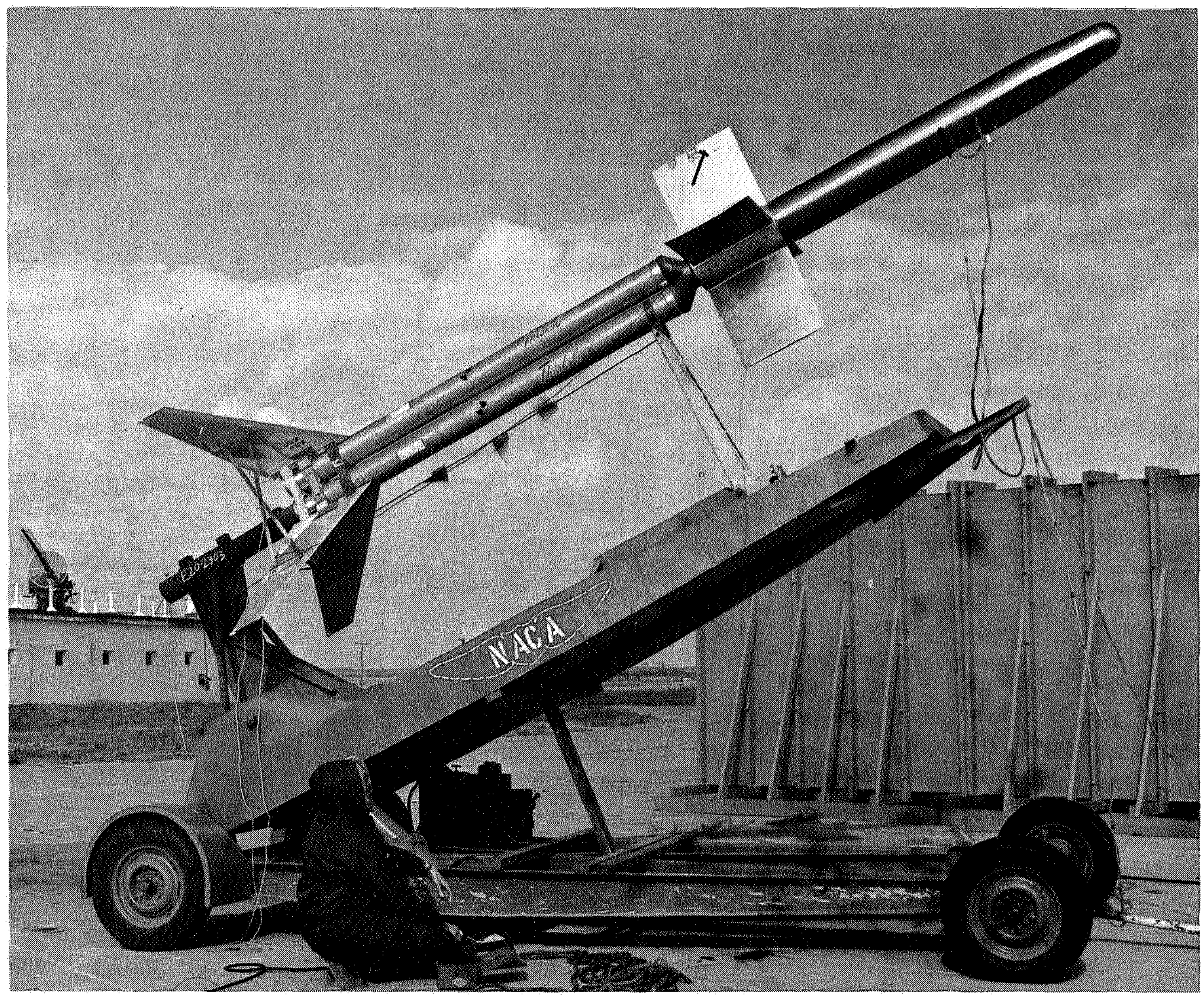


FIGURE 355. Rocket model with structural MW–2 wing panel as flown with T40 internal rocket and double Cajun booster, November 20, 1957.

first model did not flutter, the central rib was not placed in the third model, in order to make it exactly like MW-2. In addition, the flight was planned so that the T40 motor would be a true sustainer and hold the flight Mach number at 2 for several seconds. The loss of a booster fin early in the flight upset this plan, however, and caused the trajectory to be steeper than planned, and the Mach number increased from 1.6 to 2.2 at a higher altitude than planned. No flutter or failure was noted in the test. The temperatures reached on the wing panel in flight were about 100° lower than those reached on an identical wing in the Preflight Jet at the time the wing failed. The lower temperature resulted from the less severe conditions in flight, for when the heat transfer was compared on a nondimensional basis good agreement with the ground test was obtained (ref. 62).

Because of the marginal character of the flutter experienced in some cases by wing panels of the MW-2 type, a duplicate of wing MW-1, the original 40-inch-chord wing, was constructed and tested in the Preflight Jet on April 28, 1954. The only difference in the test condition was that the restraining cables used in the initial tests were not used this time. More extensive instrumentation was used and a higher speed camera was used (1,600 frames per second, compared with 24). Two types of flag-waving flutter were encountered. A mild, nondestructive flutter with a frequency of 210 cycles per second was noted early, and then a more severe flutter with a frequency of only 115 cycles developed after the wing began to get hot. The latter flutter led to destruction of the wing, as may be seen in figure 356. The catastrophic flutter that occurred after the wing became hot was felt to be the result of a reduction in structural stiffness caused by thermal stresses as well as by some reduction in elastic moduli. The

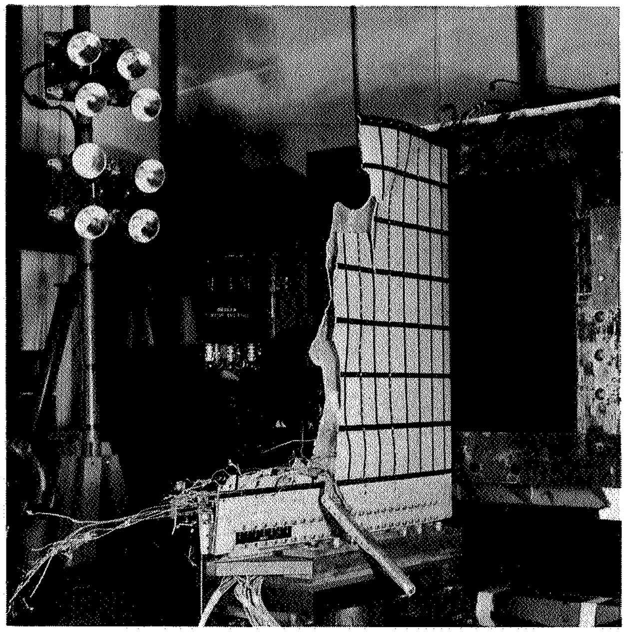


FIGURE 356. Structural MW–1(2) wing panel in 27-inch nozzle of Preflight Jet after destructive flutter test, April 28, 1954.

investigators concluded, "In the design of supersonic airfoils, a knowledge of the flutter characteristics and the effects of aerodynamic heating in changing the behavior of the structure may well be crucial to the design" (ref. 63).

After it was found from tests of wing MW-4 that changing the tip chord member from a stiff version to a more normal thin-skin design resulted in a more severe flutter condition under aerodynamic heating, three more models were constructed with additional chordwise stiffeners. One, MW-16, had three chordwise ribs; the second MW-17, had two chordwise ribs; and the third, MW-18, had a single chordwise rib added. A duplicate of MW-4, designated MW-4(2), also was constructed. In the tests, the only wing that fluttered and failed was the duplicate of MW-4. Again, the failure was just as dramatic as before, with time to failure from start of flutter being 0.35 second. Before the hot test was run, this wing had been tested in the jet with the stagnation temperature reduced to 100°. The fact that no evidence of flutter had appeared confirmed the earlier conclusion that aerodynamic heating effects were the cause of flutter in the hot tests (ref. 64).

Because of the marginal flutter behavior of model MW-2, a wing was constructed with the skin thickness reduced from 0.064 to 0.050 inch. This model was designated MW-19. Two other models of the same stiffness but made of different materials were also constructed for comparison. One of the models, MW-10, was made of magnesium alloy, with a skin thickness of 0.064 inch; the other, MW-13, was made of titanium alloy with a skin thickness of 0.040 inch. In the tests, a retractable clamp restrained the tip during the starting period of the jet. This device, termed a "model stabilizer," was retracted after the first second or so and reduced the effects of rough flow associated with starting the jet. (See figure 322, Chapter 13.) In the tests, all three models fluttered and failed almost as soon as the stabilizer was retracted. Apparently the stiffness of the models had been reduced too much below that of MW-2 (ref. 65).

The continued finding of flutter induced by aerodynamic heating under transient conditions intrigued flutter-expert Harry L. Runyan of Dynamic Loads Division at Langley. He therefore performed a special test to determine if this type of flutter could be verified by theory for a simple structural case. He chose a solid aluminum-alloy wing with a chord of 8 inches, a span of 11.75 inches, an NACA 65A003 section at the tip, and a 65A004 section at the root. The wing was mounted in the 27-inch jet at Wallops in the same manner as the earlier built-up structures except that it was given a sweepback of 10 degrees, as shown in figure 357. The 10-degree sweepback was used to raise the divergence speed of the wing to a value above the test speed. Another trick was employed to lower the flutter speed to fall within the operating conditions of the test. This was to mount the wing with its trailing edge forward in order to place the center of gravity of the sections in a rearward location. Two

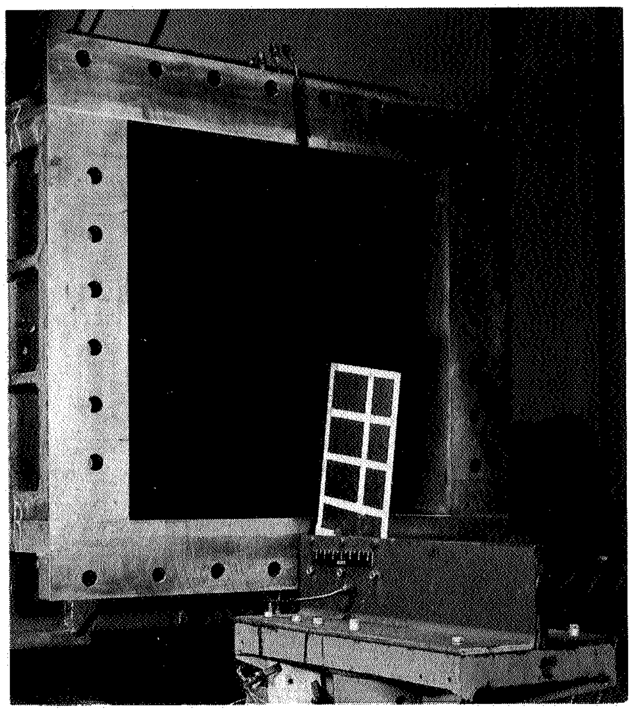


FIGURE 357. Solid aluminum wing panel shown in 27-inch nozzle of Preflight Jet for test of flutter theory for heated wings, November 1, 1955.

tests were made in the jet at Mach 2 in November 1955, first with cold air and then with the air heated to 800° F. In the cold test, the wing did not flutter; but in the hot test, the wing began to flutter after being exposed to the airstream for 2 seconds, continued to flutter for 2 more seconds, and then stopped. This behavior was explained by theoretical calculations of flutter under the heating conditions.

As has been mentioned earlier, heating of a structure was known to reduce the torsional stiffness of a wing by two effects. First, the modulus of elasticity was reduced from the increase in temperature, and then, more importantly, the stiffness was reduced by the induced thermal stresses caused by uneven temperature distribution. Runyan, with the assistance of Nan H. Jones, computed the changes in torsional and bending stiffnesses of the wing under the conditions of the test. They found that the torsional frequency was reduced about 38 percent after 2 seconds and then returned toward its original value as the temperature of the model approached equilibrium. This trend was exactly the same as the finding in the test. Next, the flutter speed for the model was calculated for supersonic flow, by the use of second-order unsteady aerodynamic theory, which takes into account the nonlinear effects of airfoil shape and thickness. Three degrees of freedom were used, which, when superimposed upon the experimentally determined flutter coefficients, almost exactly predicted the flutter behavior (ref. 66). Runyan was naturally elated over this finding, one of the best vertifications of supersonic flutter theory, and the first one to include transient heating effects.

DEVELOPMENT OF SPHERICAL SOLID-ROCKET MOTORS

The solid-propellant rocket motors developed during World War II for jet-assisted takeoff (jato) were rather stubby motors because drag was not of great importance during the takeoff period. The motors used by PARD to propel models to high speeds, on the other hand, were generally of much higher fineness ratio because drag was important at high speeds. Fineness ratios of from 10 to 15 were common. By 1955, long-range ballistic missiles and satellites had been designed to fly trajectories in which at least one stage would be operating outside the atmosphere and drag would again present no problem. In addition, the trajectories would be more or less parallel to the surface of the earth, and gravitational forces would no longer reduce the velocity increment. In such cases, the true vacuum velocity would be realized. This being the case, the highest velocity would be obtained by the motor having the highest propellant-mass fraction. Since the case of a solid-rocket motor operated as a pressure vessel, and since the optimum shape for such a vessel is a sphere, it was natural that a spherical rocket motor would attract attention. The first successful spherical rocket motor was designed and patented by J. G. Thibodaux, Jr., Robert L. Swain, and Carl M. Styles of PARD. The idea was conceived in March 1955, and the first drawings were made in June of that year. The first test firing of such a motor was on the PARD rocket test range at Langley on January 18, 1957. This motor had a 10-inch diameter and a heavy-walled steel case. A lightweight motor was flight tested at Wallops on July 8, 1958. This was the first of a long series of spherical motors, from 5 to 40 inches in diameter, that were to see extensive use, not only at Wallops, but in satellites launched from other ranges.

Some of the spherical motors to be used later were developed by other agencies. H. L. Thackwell, Jr., of Grand Central Rocket Company, filed an application for a patent on a spherical solid motor on October 10, 1955, but its internal design was quite different from the PARD design. Aerojet, Thiokol, and NOTS, as well as Grand Central, became interested in such motors.

For a case of minimum weight for the spherical rocket motor, a one-piece shell was desirable. Advanced techniques of welding made this possible with thin-skin structures. The main problem, then, was to design a charge shape with fairly constant internal-burning area, and to conceive of a scheme for casting the propellant with the desired core shape and for removing the casting mandrel through the small nozzle area. Several charge designs were studied, but the one adopted consisted of seven internal semicircular radial cavities leading to a central cavity. The exposed propellant resembled melon slices.

By this time, PARD had acquired a small propellant-processing plant in which Thiokol T-21 polysulfide-perchlorate propellants could be cast. The problem of removing the casting mandrel was solved by making it of Cerrobend, eutectic alloy of lead, tin, bismuth, and cadmium, which melts at 158° F. The mandrel remained intact during the curing of the propellant but could be melted and poured out by heating the propellant to 165° F. This temperature did not harm the propellant. Another problem developed, however—a small amount of the metal remained attached to the surface of the propellant. This was removed, ingeniously, by dissolving the metal with mercury which, when poured out, left a perfectly clean surface.

Application for a patent on the charge design and manufacturing technique was made by Thibodaux, Swain, and Styles on April 27, 1957. As was customary for the NACA, the Navy Department, on March 4, 1958, filed an application for a patent for the inventors, who had assigned all rights to the Government. Patent No. 3,001,363 was eventually issued on September 26, 1961. The NASA Inventions and Contributions Committee awarded the inventors $250 in 1962 and $1,000 in 1966.

On January 18, 1957, ground tests of the first motor indicated that the charge design was good. A total impulse of 5,786 pound-seconds was obtained with 29.77 pounds of propellant. The burning time was about 5 seconds, as planned. Combustion was smooth, with no evidence of reasonance (ref. 67).

The main application of spherical rocket motors was believed to be outside the atmosphere, which meant that aerodynamic stabilization could not be used. One simple method for achieving stabilization was by spinning about the longitudinal axis. Because of the internal web design of the spherical motor, a possibility existed for amplification of the spin rate by movement of the burning gases. In order to explore this possibility, as well as to gain flight experience, two 10-inch motors were launched at Wallops from a special launcher that imparted a spinning velocity prior to launch, as shown in figure 358. One motor was similar to the earlier motors used in the ground tests, while the other was of lightweight design intended for flight use. The flight motor was constructed of 0.015-inch steel in two halves which were then welded together. The nozzle was also made of steel and was welded to the case. A graphite insert formed the throat of the nozzle. The propellant-mass fraction of this motor was 0.93, the highest value achieved up to that time for a solid-propellant motor.

In order to stabilize the spherical motor by spinning, it was necessary that some asymmetry be provided. The addition of a spinsonde to the front of the motor, together with the location of the nozzle at the rear, provided the asymmetry needed for stabilization at 1,200 revolutions per minute. The flight test provided a verification of this spin stability as well as a measure of spin amplification. The motor was attached to the launcher with a blowout diaphragm and was mounted in a bucket rotated by an electric motor.

In the first test, an unexpected event occurred as a result of ignition delay or hang-fire. After the motor had reached the desired spin speed, ignition was initiated and the spinning motor rose out of the

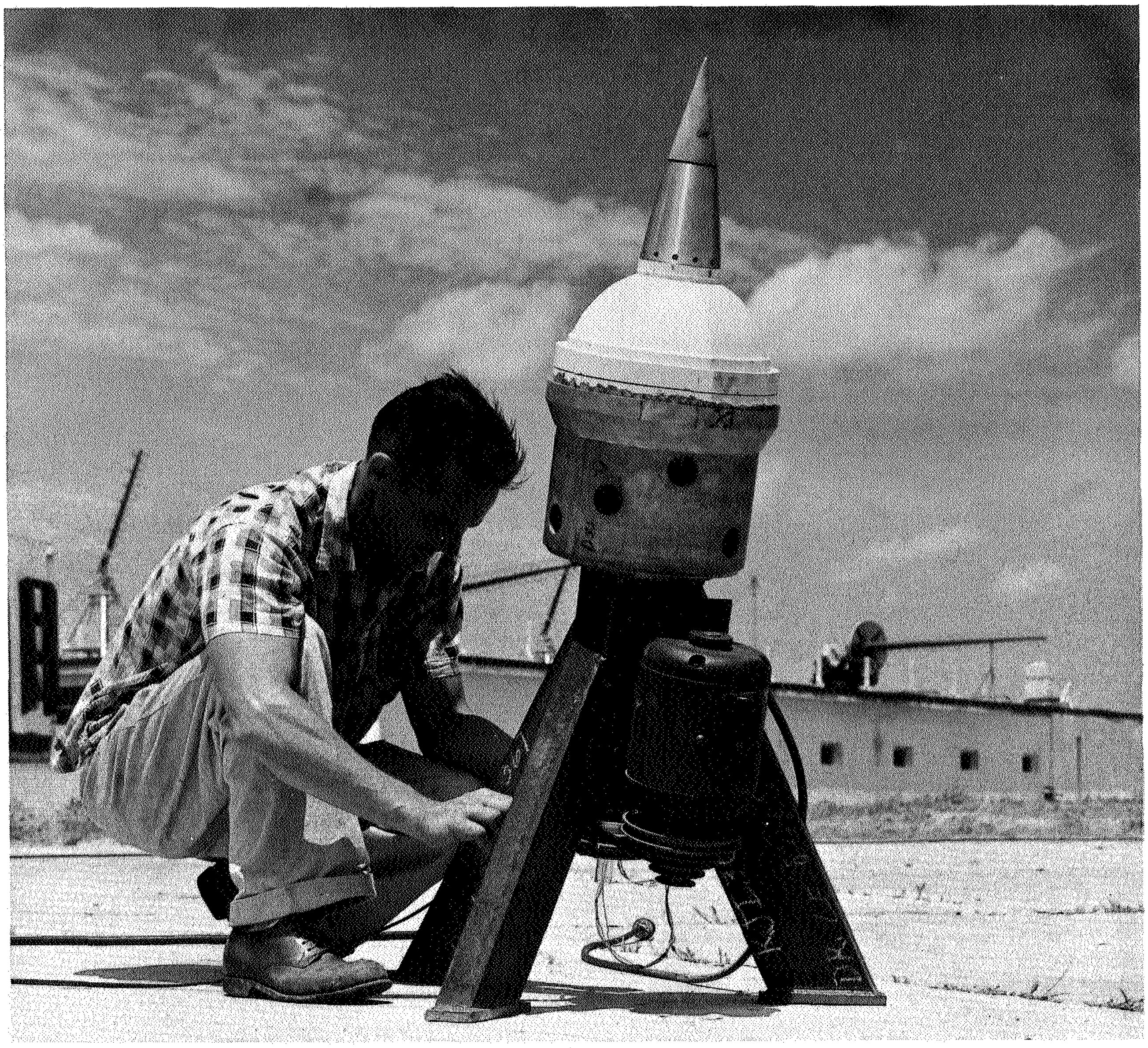


FIGURE 358. Technician Roy Hindle connects firing leads to 10-inch spherical rocket motor mounted in special spinning launch bucket, July 8, 1958.

bucket under the impulse provided by the igniter. Instead of rapidly accelerating away, however, it rose about 8 feet and then, as described in the Wallops Daily Log, "settled back to earth and spun like a top until the propellant ignited. The model then relaunched to a trajectory not much different than that planned. The gyroscopic stability induced by the spinning saved the test from being a failure." The spin rates measured in flight indicated an increase of 10 percent in rate for the heavy-wall motor and 19 percent for the lightweight one. Both of these values were explainable by a theory that considered the transfer of angular momentum from the propellant to the motor case (ref. 68).

The success of the 10-inch spherical motor led to the design of a 20-inch flight motor. When it was indicated that such a motor had the possibility of achieving an incremental velocity of 18,600 feet per second with an 8-pound payload (ref. 67), plans were made to manufacture such a motor for additional propulsion in the PARD hypersonic flight program. A 20-inch case was successfully formed and welded in the Langely shops, but the loading with propellant was too big a job for the small mixer at PARD. Loading was done, therefore, under contract by the Thiokol Chemical Corporation, Elkton, Maryland. The empty case plus the nozzle weighed 21 pounds. The motor was loaded with 239 pounds of propellant, for a propellant-mass fraction of 0.92.

For a flight test of the 20-inch motor, a four-stage vehicle was designed with the spherical motor as the last stage. The first three stages were Honest John-Nike-Nike motors. The complete system is shown in figure 359. The spherical motor was attached to the front end of the last Nike stage through a blowout diaphragm, and the base was embedded in plastic foam. A tubular section was glued to the front end of the motor case and contained an AN/DPN-19 radar transponder for range tracking by the Reeves Mod II radar at Wallops. The last stage may be seen in figure 360. A four-channel telemeter in the third stage provided information on accelerations and spin rate. Spin stabilization of the 20-inch spherical motor was provided by canting the fins on the third stage 1 degree. This amount of cant produced a spin rate of 7.2 revolutions per second, sufficient for stability.

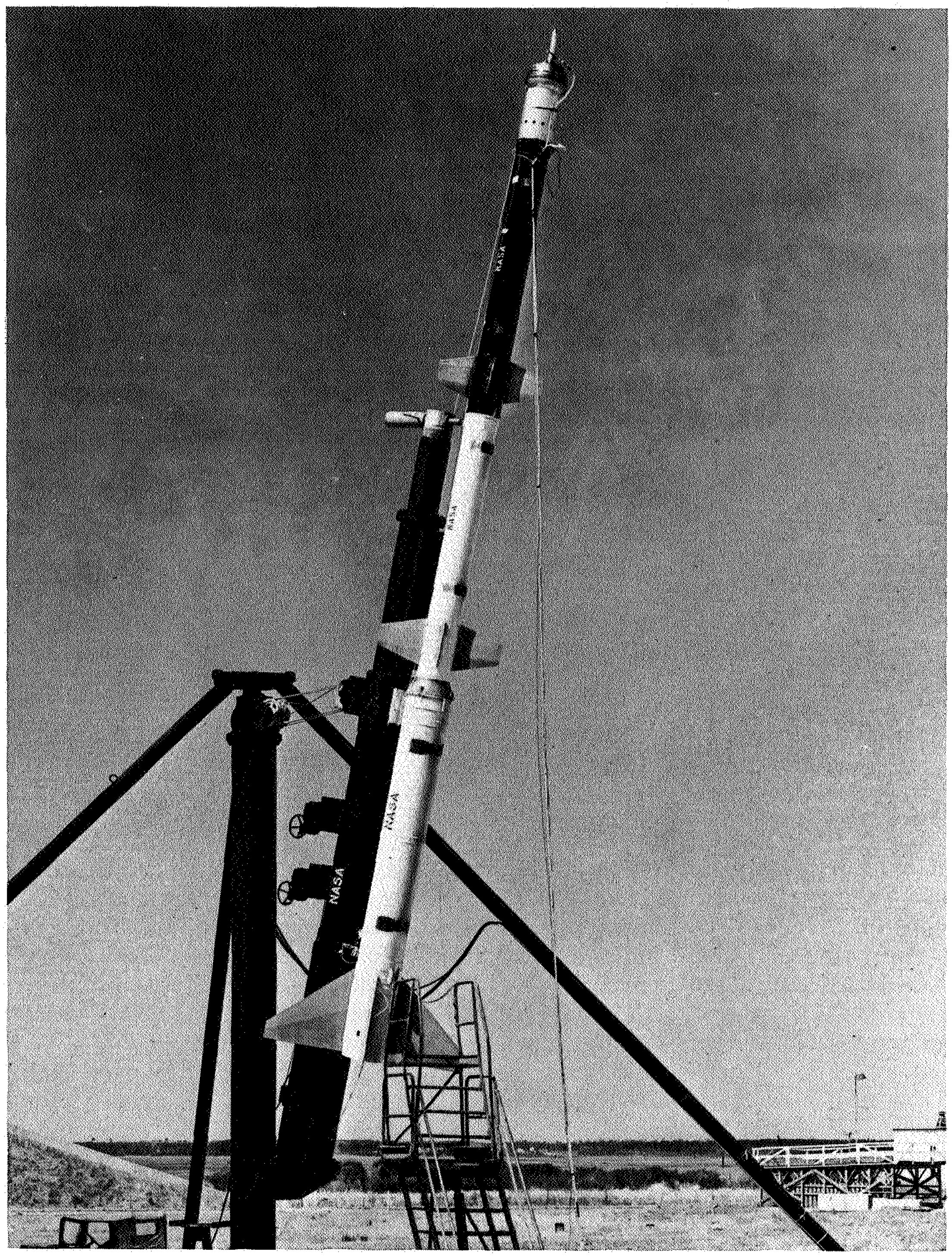


FIGURE 359. Final preparations for flight test of 20-inch spherical rocket motor with Honest John-Nike-Nike booster, March 17, 1959.

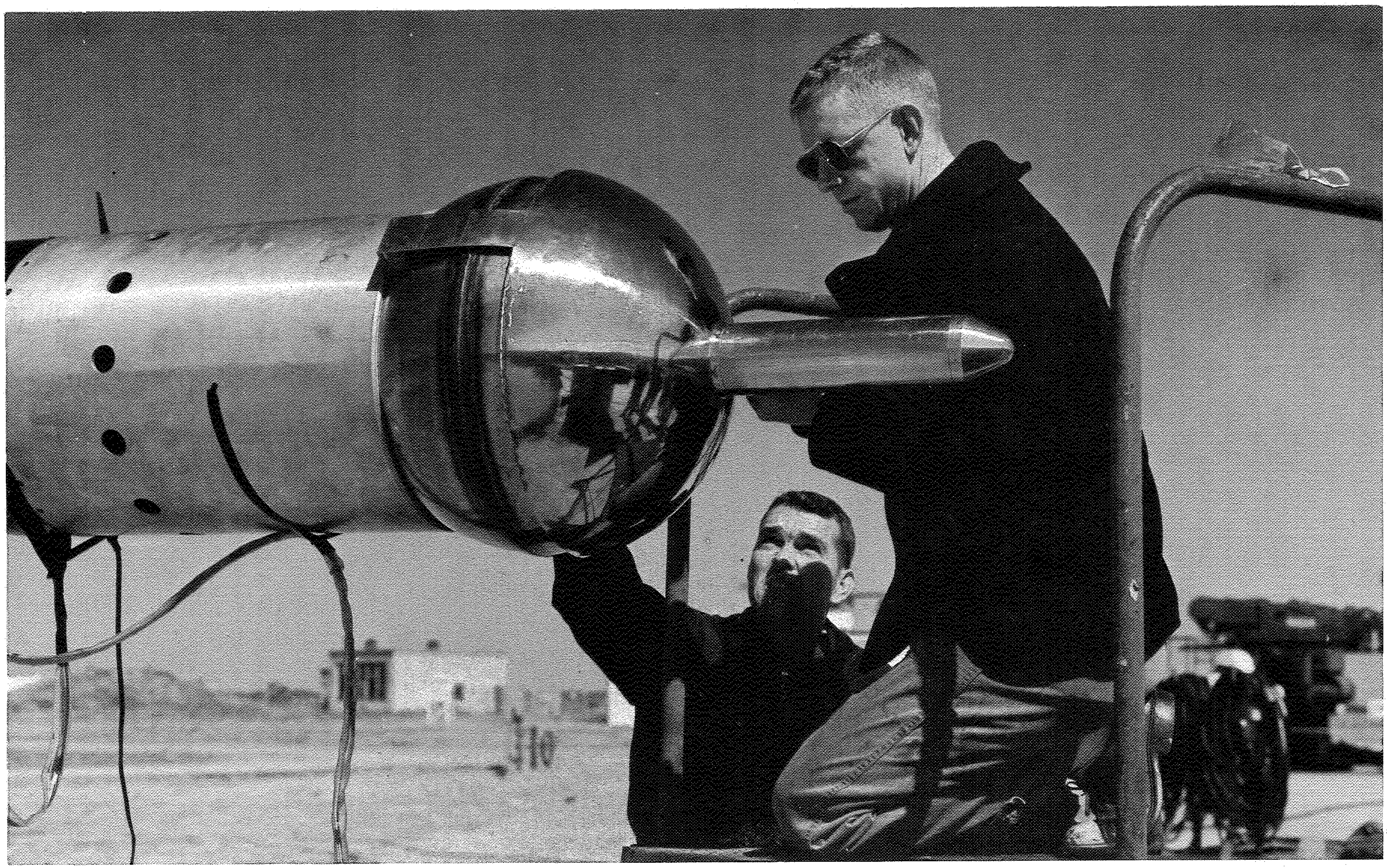


FIGURE 360. Technicians Gene Waldron and Carl Styles prepare 20-inch spherical rocket motor for flight test with three-stage booster, March 17, 1959.

The firing sequence of the four stages was designed to test the spherical motor at high altitudes. Coast periods were as follows: 7.8 seconds between the first and second stages; 19.2 seconds between the second and third stages; and 26.9 seconds between the third and fourth stages. The vehicle was launched at a 78-degree elevation angle and followed a climbing trajectory that averaged about 70 degrees during the burning period, with the spherical motor being ignited at an altitude of 163,000 feet and burning out at 260,000 feet. Considerable velocity was lost during the coast periods, but even so a maximum Mach number of 16.7 was reached, of which 12,120 feet per second were contributed by the spherical motor. The radar transponder in the nose of the last stage failed before ignition of the spherical motor, but two other radars were able to skin-track it. The RCA FPS-16 radar at Wallops (see Chapter 15) tracked the sphere to an altitude of 104 miles, while the Millstone Hill experimental radar of the MIT Lincoln Laboratory acquired the spherical motor at an altitude of 160 miles and tracked it throughout the remainder of the trajectory, although the MIT radar data above 690 miles had a considerable amount of scatter. The indicated maximum altitude was 860 miles, and the splash point was estimated to have been at a range of 1,070 miles. The flight results on the performance of the spherical motor agreed well with ground test results (ref. 69).

Plans were initiated to design a complete launch vehicle with three spherical-motor stages on top of a Sergeant motor, to reach a maximum Mach number of about 40. To achieve this goal, two new spherical motors of 25-inch and 40-inch diameter were designed, and a contract was awarded Thiokol for their construction. Although the motors were eventually constructed, no application was ever to be made. The role of spherical motors was more in the nature of serving as upper stages, and such motors were to find many applications in aerospace projects, including satellites.

References

1. Hastings, Earl C., Jr.; and Dickens, Waldo L.: *Results of the Flight Test of a 0.13-Scale Rocket-Boosted Model of the McDonnell F4H–1 Airplane Between Mach Numbers of 0.20 and 1.90.* NACA RM SL57K20.
2. *Jane's All The World's Aircraft,* 1961–1962, p. 282.
3. *Air Force Magazine,* Sept. 1967, p. 218.
4. *Jane's All The World's Aircraft,* 1961–1962, p. 409.
5. Lee, John B.: *Investigation of Ejection Releases of an MB-1 Rocket From a 0.04956-Scaled Model of the Convair F–106A Airplane.* NACA RM SL57E07.
6. Lee, John B.; and Basford, Robert C.: *Investigation of Ejection Releases of an MB–1 Rocket From a 0.04956-Scaled Model of the Convair F–106A Airplane at Several Mach Numbers and Simulated Altitudes.* NACA RM SL57I11.
7. Hinson, William F.; and Lee, John B.: *Effect of Six Missile-Bay Configurations and a Rocket End Plate on Ejection Releases of an MB–1 Rocket From a 0.05-Scale Model of the Convair F–106A Airplane.* NASA Memo 4-29-59L.
8. Carter, Howard S.: *Effect of Some Crosswise Stiffeners on the Heat Transfer and Pressure Distribution on a Flat Plate at Mach Numbers of 0.77, 1.39, and 1.98.* NACA RM L57E31a. Reissued as NACA TN 4333, Sept. 1958.
9. Graham, John B., Jr.; Chauvin, Leo T.; and Speegle, Katherine C.: *Heat-Transfer and Pressure Measurements From a Flight Test of a 1/18-Scale Model of the Titan Intercontinental Ballistic Missile Up to a Mach Number of 3.95 and Reynolds Number Per Foot of* 23.4×10^6. NACA RM SL57L16a.
10. Graham, John B., Jr.: *Heat-Transfer and Pressure Measurements From a Flight Test of the Second 1/18-Scale Model of the Titan Intercontinental Ballistic Missile Up to a Mach Number of 3.91 and Reynolds Number Per Foot of* 23.4×10^6. NACA RM SL58B10.
11. Graham, John B.: *Heat-Transfer and Pressure Measurements From a Flight Test of the Third 1/18-Scale Model of the Titan ICBM Up to a Mach Number of 3.86 and Reynolds Number Per Foot of* 23.5×10^6 *and a Comparison With Heat Transfer of Two Other Models.* NASA Memo 11–158L.
12. Krieger, R. L., Memorandum for Associate Director, Feb. 28, 1957, regarding visit of NOL personnel to Wallops on Feb. 19, 1957, to discuss special rocket tests.
13. O'Sullivan, W. J., Jr., Memorandum for Associate Director, June 8, 1955, regarding visit of Dr. S. F. Singer to PARD.
14. Thibodaux, J. G., Memorandum for Associate Director, July 19, 1955, regarding visit of Morris S. Roth of Republic Aviation Corporation Missile Division to PARD on July 8, 1955.
15. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Dec. 5, 1955, regarding visit of E. A. Eddy of Republic Aviation to PARD to discuss Terrapin sounding rocket.
16. Hopko, Russell N.; and Wade, William R.: *Flight Performance of the Terrapin High-Altitude Sounding Vehicle.* NACA RM SL57B06.
17. Chauvin, Leo T.: *Pressure Distribution and Pressure Drag For a Hemispherical Nose at Mach Numbers 2.05, 2.54, and 3.04.* NACA RM L52K06.
18. Chauvin, Leo T., and Maloney, Joseph P.: *Experimental Convective Heat Transfer to a 4-Inch and 6-Inch Hemisphere at Mach Numbers From 1.62 to 3.04.* NACA RM L53L08a.
19. Garland, Benjamine J.; and Chauvin, Leo T.: *Measurements of Heat Transfer and Boundary-Layer Transition on an 8-Inch-Diameter Hemisphere-Cylinder in Free Flight For a Mach Number Range of 2.00 to 3.88.* NACA RM L57D04a.

20. Hall, James R.; Speegle, Katherine C.; and Piland, Robert O.: *Preliminary Results From a Free-Flight Investigation of Boundary-Layer Transition and Heat Transfer on a Highly Polished 8-Inch-Diameter Hemisphere-Cylinder at Mach Numbers Up to 3 and Reynolds Numbers Based on a Length of 1 Foot to 17.7* $\times$ *10^6*. NACA RM L57D18c.
21. Buglia, James J.: *Heat Transfer and Boundary-Layer Transition on a Highly Polished Hemisphere-Cone in Free Flight at Mach Numbers Up to 3.14 and Reynolds Numbers Up to 24* $\times$ *10^6*. NACA RM L57D05. Reissued as NASA TN D–955, Sept. 1961.
22. Stewart, J. D.; and Donaldson, C. D.: *An Analysis of Experimental Data on Transition For Blunt Bodies.* General Electric Co., Thermodynamics Tech. Memo. No. 73, June 24, 1957.
23. Wisniewski, Richard J.: *Note on a Correlation of Boundary-Layer Transition Results on Highly Cooled Blunt Bodies.* NASA Memo 10–8–58E.
24. Krasnican, M. J.; and Rabb, L.: *Effects of Nose Radius and Extreme Cooling on Boundary-Layer Transition For Three Smooth 15° Cone-Cylinders In Free Flight at Mach Numbers to 8.50.* NASA Memo 3–4–59E.
25. English, Roland D.; and Carter, Howard S.: *Variation in Heat Transfer During Transient Heating of a Hemisphere at a Mach Number of 2.* NASA TM X–399, June 1960.
26. Beckwith, Ivan E.; and Gallagher, James J.: *Heat Transfer and Recovery Temperature on a Sphere With Laminar, Transitional, and Turbulent Boundary Layers at Mach Numbers of 2.00 and 4.15.* NACA TN 4125, Dec. 1957.
27. Chauvin, Leo T.; and Speegle, Katherine C.: *Boundary-Layer-Transition and Heat-Transfer Measurements From Flight Tests of Blunt and Sharp 50° Cones at Mach Numbers From 1.7 to 4.7.* NACA RM L57D04.
28. Rashis, Bernard; and Bond, Aleck C.: *Free-Flight Skin-Temperature and Surface-Pressure Measurements on a Highly Polished Nose Having a 100° Total-Angle Cone and a 10° Half-Angle Conical Flare Section Up to a Mach Number of 4.08.* NACA RM L57G30.
29. Purser, Paul E.; and Hopko, Russell N.: *Exploratory Materials and Missile-Nose-Shape Tests in a 4,000° F Supersonic Air Jet.* NACA RM L56J09.
30. Carter, Howard S.; and Bressette, Walter E.: *Heat-Transfer and Pressure Distribution on Six Blunt Noses at a Mach Number of 2.* NACA RM L57C18.
31. Fay, J. A.; and Riddell, F. R.: *Stagnation Point Heat Transfer in Dissociated Air.* Avco Research Laboratory, Research Note 18, June 1956.
32. Stoney, William E., Jr.; and Swanson, Andrew G.: *Heat Transfer Measured on a Flat-Face Cylinder in Free Flight at Mach Numbers Up to 13.9.* NACA RM L57E13.
33. Stoney, William E., Jr.; and Markley, J. Thomas: *Heat-Transfer and Pressure Measurements on Flat-Faced Cylinders at a Mach Number of 2.* NACA TN 4300, July 1958.
34. Stoney, William E., Jr.: "Local Heat Transfer to Blunt Noses at High Supersonic Speeds." Paper presented at NACA Conference on Aircraft Loads, Structures, and Flutter, Langley Field, Va., Mar. 5–7, 1957. Reissued as NACA RM L57D25c.
35. Hill, P. R.: *A Method of Computing the Transient Temperature of Thick Walls From Arbitrary Variation of Adiabatic-Wall Temperature and Heat-Transfer Coefficient.* NACA TN 4105, Oct. 1957. Reissued as NACA TR 1372, 1958.
36. Bland, William M., Jr.; Swanson, Andrew G.; and Kolenkiewicz, Roland: *Free-Flight Aerodynamic-Heating Data at Mach Numbers Up to 10.9 on a Flat-Faced Cylinder.* NACA RM L57K29.
37. Speegle, Katherine C.; Chauvin, Leo T.; and Heberlig, Jack C.: *Heat Transfer For Mach Numbers Up to 2.2 and Pressure Distributions For Mach Numbers Up to 4.7 From Flight Investigations of a Flat-Face-Cone and a Hemisphere-Cone.* NACA RM L58B18.
38. Rumsey, Charles B.; and Lee, Dorothy B.: *Heat-Transfer Measurements in Free Flight at Mach Numbers Up to 14.6 on a Flat-Faced Conical Nose With a Total Angle of 29°.* NACA RM L57L03.
39. Lee, Dorothy B.; and Swanson, Andrew G.: *Heat Transfer Measured on a Flat-Face Cylinder-Flare Configuration in Free Flight at Mach Numbers From 1.6 to 2.7.* NACA RM L58A06.
40. Hall, James R.; and Garland, Benjamine J.: *A Feasibility Study of the Flare-Cylinder Configuration as a Reentry Body Shape For an Intermediate Range Ballistic Missile.* NACA RM L58C21.
41. Stoney, William E., Jr.: "Aerodynamic Heating of Blunt Nose Shapes at Mach Numbers Up to 14." Paper presented at NACA Conference on High-Speed Aerodynamics, Moffett Field, Calif., Mar. 18–20, 1958. Reissued as NACA RM L58E05a.
42. Speegle, Katherine C.: *Pressure Measurements on an Afterbody Behind Various Blunt Nose Shapes at a Mach Number of 2.* NACA RM L57J14.
43. Garland, Benjamine J.; Swanson, Andrew G.; and Speegle, Katherine C.: *Aerodynamic Heating and Boundary-Layer Transition on a 1/10-Power Nose Shape in Free Flight at Mach Numbers Up to 6.7 and Free-Stream Reynolds Numbers Up to 16* $\times$ *10^6*. NACA RM L57E14a. Reissued as NASA TN D–1378, June 1962.
44. Hopko, Russell N.; and Strass, H. Kurt: *Some Experimental Heating Data on Convex and Concave Hemispherical Nose Shapes and Hemispherical Depressions on a 30° Blunted Nose Cone.* NACA RM L58A17a.
45. Tyner, Thomas W.: *Some Experimental Heating Data on a 5.0-Inch Flat Face With Hemispherical Depressions.* NASA TM X–68, Sept. 1959.
46. Markley, J. Thomas: *Heat Transfer and Pressure Measurement on a 5-Inch Hemispherical Concave Nose at a Mach Number of 2.0.* NACA RM L58C14a.
47. Cooper, Morton; Beckwith, Ivan E.; Jones, Jim J.; and Gallager, James J.: *Heat-Transfer Measurements on a Concave Hemispherical Nose Shape With Unsteady-Flow Effects at Mach Numbers of 1.98 and 4.95.* NACA RM L58D25a.
48. Levine, Jack; and Rumsey, Charles B.: *Heat Transfer Measurements on a 5.5-Inch-Diameter Hemispherical Concave Nose in Free Flight at Mach Numbers Up to 6.6.* NASA Memo 10–21–58L.
49. Levine, Jack: *Additional Heat-Transfer Measurements Obtained in Free Flight on a Hemispherical Concave Nose at Mach Numbers Up to 7.1.* NASA TM X–466, Apr. 1961.
50. Graves, George B., Jr.; and Markley, J. Thomas: *Telemeter Transmission at 219.5 Megacycles From Two Rocket-Powered Models at Mach Numbers Up to 15.7.* NACA RM L58D18a.

51. Nelson, Robert L.: *The Motions of Rolling Symmetrical Missiles Referred to a Body-Axis System.* NACA TN 3737, Nov. 1956.
52. McFall, John C., Jr.: *Dynamic Stability Investigation of Two Right Circular Cylinders in Axial Free Flight at Mach Numbers From 0.4 to 1.7. Fineness-Ratio-2.56 Cylinder and Fineness-Ratio-4.0 Cylinder With Flared Afterbody.* NACA RM L56L28.
53. Coltrane, Lucille C.: *Investigation of Two Bluff Shapes in Axial Free-Flight Over a Mach Number Range From 0.35 to 2.15.* NACA RM L58A16.
54. Coltrane, Lucille C.: *Stability Investigation of a Blunt Cone and a Blunt Cylinder With a Square Base at Mach Numbers From 0.64 to 2.14.* NACA RM L58G24.
55. Coltrane, Lucille C.: *Stability Investigation of a Blunted Cone and a Blunted Ogive With a Flared Cylinder Afterbody at Mach Numbers From 0.30 to 2.85.* NASA TN D–1506, Oct. 1962.
56. Hastings, Earl C., Jr.; Curry, T. Bradley, Jr.; and Dickens, Waldo L.: *Stability and Drag Characteristics of Two Low-Drag Reentry Bodies Obtained With Free-Flight Models at Mach Numbers Between 0.96 and 3.28.* NASA TM X–243, Mar. 1960.
57. Coltrane, Lucille C.: *An Investigation to Determine the Stability Characteristics of Three Supersonic-Impact Ballistic Reentry Shapes at Mach Numbers From 1.2 to 4.2.* NASA TM X–725, Nov. 1962.
58. Griffith, George E.; Miltonberger, Georgene H.; and Rosecrans, Richard: *Tests of Aerodynamically Heated Multiweb Wing Structures in a Free Jet at Mach Number 2. Two Aluminum-Alloy Models of 20-Inch Chord With 0.064- and 0.081-Inch-Thick Skin.* NACA RM L55F13.
59. Rosecrans, Richard; Vosteen, Louis F.; and Batdorf, William J., Jr.: *Tests of Aerodynamically Heated Multiweb Wing Structures in a Free Jet at Mach Number 2. Three Aluminum-Alloy Models and One Steel Model of 20-Inch Chord and Span With Various Internal Structures and Skin Thicknesses.* NACA RM L57H01.
60. Miltonberger, Georgene H.; Griffith, George E.; and Davidson, John R.: *Tests of Aerodynamically Heated Multiweb Wing Structures in a Free Jet at Mach 2. Two Aluminum-Alloy Models of 20-Inch Chord With 0.064-Inch-Thick Skin at Angles of Attack of 0° and ±2°.* NACA RM L57H19.
61. Strass, H. Kurt; and Stephens, Emily W.: *Aerodynamic Heating of a Thin, Unswept, Untapered, Multiweb, Aluminum-Alloy Wing From a Free-Flight Investigation of a Rocket-Propelled Model.* NACA RM L57F06.
62. Stephens, Emily W.: *Free-Fight Investigation of a Rocket-Propelled Model To Determine the Aerodynamic Heating of a Thin, Unswept, Untapered, Multispar, Aluminum-Alloy Wing at Mach Numbers Up to 2.22.* NASA Memo 12–15–58L.
63. Griffith, George E.; and Miltonberger, Georgene H.: *Tests of Aerodynamically Heated Multiweb Wing Structures in a Free Jet at Mach Number 2. An Aluminum-Alloy Model of 40-Inch Chord With 0.125-Inch-Thick Skin.* NACA RM L58C24.
64. Davidson, John R.; Rosecrans, Richard; and Vosteen, Louis F.: *Test of Aerodynamically Heated Multiweb Structures in a Free Jet at Mach Number 2. Four Aluminum-Alloy Models of 20-Inch Chord and Span With 0.064-Inch-Thick Skin, 0.025-Inch-Thick Ribs and Webs, and Zero, One, Two, or Three Chordwise Ribs.* NACA RM L57L13.
65. Davidson, John R.; and Rosecrans, Richard: *Tests of Aerodynamically Heated Multiweb Wing Structures in a Free Jet at Mach 2. Three Models of 20-Inch Chord and Span Constructed From Magnesium, Titanium, and Aluminum Alloys, Respectively.* NASA Memo 10–12–58L.
66. Runyan, Harry L.; and Jones, Nan H.: *Effect of Aerodynamic Heating on the Flutter of a Rectangular Wing at a Mach Number of 2.* NACA RM L58C31.
67. Thibodaux, Joseph G., Jr.; Swain, Robert L.; and Wright, George: *Analytical and Experimental Studies of Spherical Solid-Propellant Rocket Motors.* NACA RM L57G12a.
68. Martz, C. William; and Swain, Robert L.: *Experimental and Analytical Study of Rolling-Velocity Amplification During the Thrusting Process For Two 10-Inch-Diameter Spherical Rocket Motors in Free Flight.* NASA TM X–75, Sept. 1959.
69. Levine, Jack; Martz, C. William; Swain, Robert L.; and Swanson, Andrew G.: *Flight Performance of a Spin-Stabilized 20-Inch-Diameter Solid-Propellant Spherical Rocket Motor.* NASA TN D–441, Sept. 1960.

CHAPTER 15

MISSILES, SOUNDING ROCKETS, AND SPACE RESEARCH: 1958

INTRODUCTION

Russia's launching of the first successful artificial earth satellite on October 4, 1957, heralded the operational beginning of the space age and revealed the inadequacy of the space effort of the United States. On July 29, 1955, President Eisenhower had announced a modest effort, as a part of the IGY, to place a small satellite in orbit without interference with the guided missile program. Whereas Russia's satellite was orbited by a powerful missile launch vehicle, the United States developed a special three-stage vehicle, the Vanguard, as an extension of the sounding rocket program. Although directed by the military (NRL), it was made from two sounding rockets, the Martin Viking and the Aerojet Aerobee, as its first two stages, plus a new solid-rocket motor to be developed for the third stage.

When *Sputnik I* beat Vanguard into orbit, President Eisenhower approved a request of the Army's missile man, Wernher von Braun, to convert his Jupiter C vehicle into a satellite launcher. Such a vehicle launched the *Explorer I* satellite on January 31, 1958, to become the first launched by the United States. The President insisted on making space exploration a nonmilitary endeavor and assigned responsibility to such space flights to a greatly enlarged NACA, renamed NASA (National Aeronautics and Space Administration). The Vanguard group of NRL were immediately made a part of this new agency, while Von Braun's group was added several years later.

The establishment of NASA was to have a profound effect on the role of Wallops in the national effort. Although developmental firings of sounding rockets, such as the Nike-Cajun, had been conducted at Wallops, it was not an operational base for IGY launchings. The main emphasis at Wallops through 1958 continued to be on research projects of military significance. After October 1, 1958, when NASA was officially opened for business, Wallops became more and more an operational range for nonmilitary space-flight activities, and support effort for military missiles and airplanes began to decline, to eventually reach a minority status. Nevertheless, the research at Wallops during the remaining part of this history (through 1959) maintained a definite military flavor intermixed with a taste of such NASA space projects as Little Joe launchings of the Mercury capsule, developmental firings in support of Echo and other inflatable satellites, and development of the Scout solid-rocket satellite launch vehicle.

NEW CONSTRUCTION

During 1958, amidst rumors of a greatly expanded role for the NACA in the space age—and discussions of the need for a large expansion of facilities at Wallops in case the rumors proved to be correct—construction was completed of a camera tower south of the launch area, a long-range FPS-16 radar installation adjacent to the SCR-584 radar building, and additional launch facilities.

The camera tower, shown in figure 361, was constructed to provide a camera mount well above the ground haze, thereby ensuring better photographic coverage of rocket launches. It was a braced-steel structure about 50 feet high, with an elevator as well as a stairway. It was constructed by Henry Leonard, Chincoteaque, Virginia, under contract NA1-3533, for a total cost of $38,347, and was completed in March 1958. Construction was financed from regular GOE funds under Project 2016. The tower was located across the access road from South Camera Station.

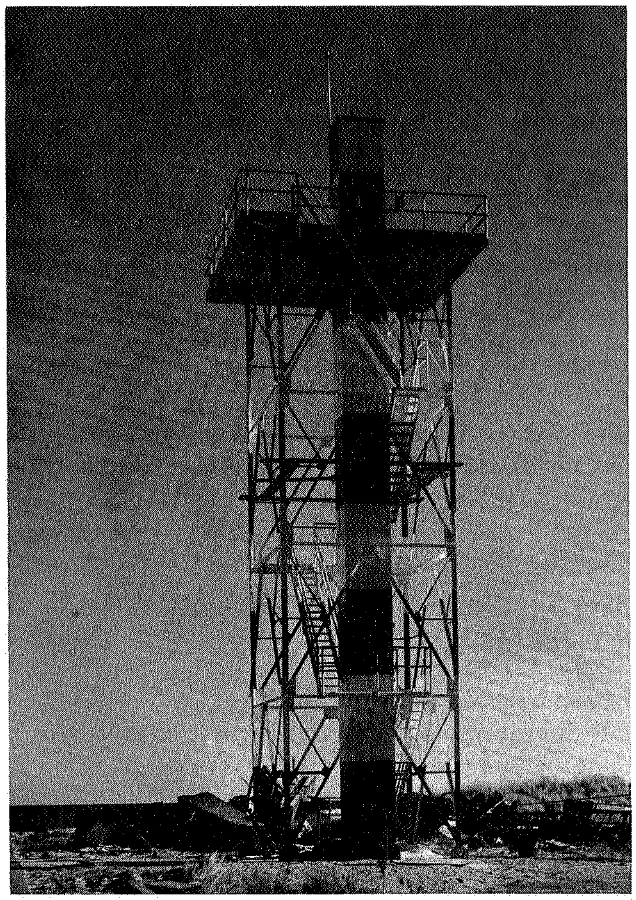


FIGURE 361. Camera tower completed in March 1958.

The FPS-16 radar was a real jewel, obtained through the generous support of the Air Force. Langley had learned of the RCA FPS-16 in 1956, at about the same time that information on the Reeves Mod II radar was obtained. The island tracking stations at Cape Canaveral were to be equipped with Mod II radars while the long-range FPS-16 was being developed for the tracking of long-range ballistic missiles. Both radars were desired at Wallops for tracking the multistage rocket vehicles. Langley asked NACA Headquarters to try to get the Air Force to place one of its Mod II radars at Wallops, and to investigate how an FPS-16 might be obtained (ref. 1). Dryden officially asked Lieutenant General Donald L. Putt of the Air Force for a Mod II, and indicated an interest in a FPS-16.[1] As a consequence of this request along with many discussions, Putt agreed to place a FPS-16 radar at Wallops on loan, if the NACA would provide the foundation and Dryden would agree to purchase a Mod II. Since the Mod II cost only $240,000 and the FPS-16 was valued at $1,000,000, the NACA felt it was getting a bargain. The Mod II was installed in 1957, as discussed in Chapter 14, but the FPS-16 was not completed until late in 1958.

The RCA FPS-16 radar is shown in figure 362. It was a C-band radar with a power of 1 megawatt. With its 12-foot dish, it could skin-track a target to about 190 miles. The FPS-16 delivered to Wallops was serial number 8 and had been produced under a BuAer contract. BuAer authorized the NACA to

1. Letter from H. L. Dryden to Gen. D. L. Putt, Hq. USAF, Apr. 18, 1956, regarding Mod II and FPS-16 radars.

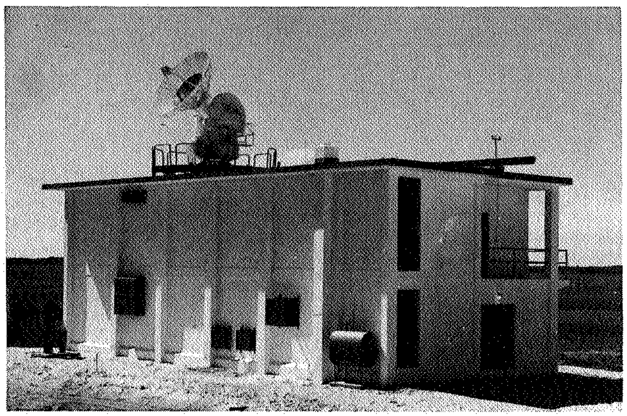


FIGURE 362. View of RCA FPS–16 radar installed at Wallops by the Air Force.

conduct acceptance tests of this set as the representative of BuAer. Official notification of acceptance by NASA was sent BuAer on February 3, 1959.[2] The boresight tower for alinement is shown in figure 363.

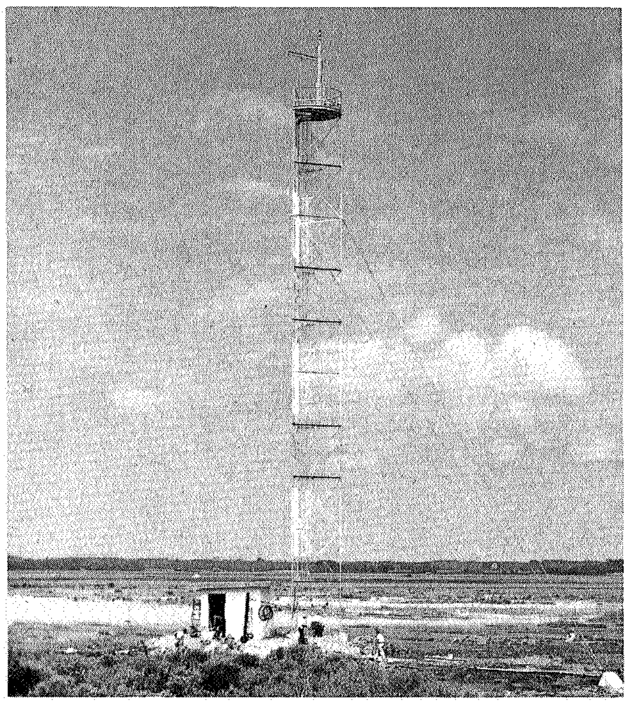


FIGURE 363. Boresight tower used for alignment of FPS–16 radar.

With the installation of the FPS-16 radar, Wallops now had a modern long-range radar that was to be of great value over the years to come. The complexity of the radar was such that a contract was negotiated with RCA Service Company to provide operational and maintenance personnel. Prior to its acceptance test, it performed an unexpected service to the U. S. Weather Bureau. When hurricane Daisy moved along the east coast on August 28, 1958, the FPS-16 was able to keep track of it over an area previously out of the range of existing ground-based tracking facilities at Cape Hatteras, North Carolina, and Nantucket, Rhode Island.[3] (See figure 364.) As stated by J. C. Palmer in the Wallops Log for that day, "The FPS-16 radar appears to be quite some radar."

The additional launch facilities installed in 1958 were required for the Jason project of the Air Force, to be discussed in detail later in this chapter. A large number of five-stage Honest John vehicles were to be launched, several in rapid succession. An additional launcher was installed in Launching

2. Letter from NASA to BuAer, Feb. 3, 1959, regarding acceptance of serial 8 FPS-16 radar.
3. Letter from F. W. Reichelderfer, Chief of Weather Bureau, to Director, Langley, Sept. 15, 1958, regarding tracking of hurricane Daisy on Aug. 28–29, 1958.

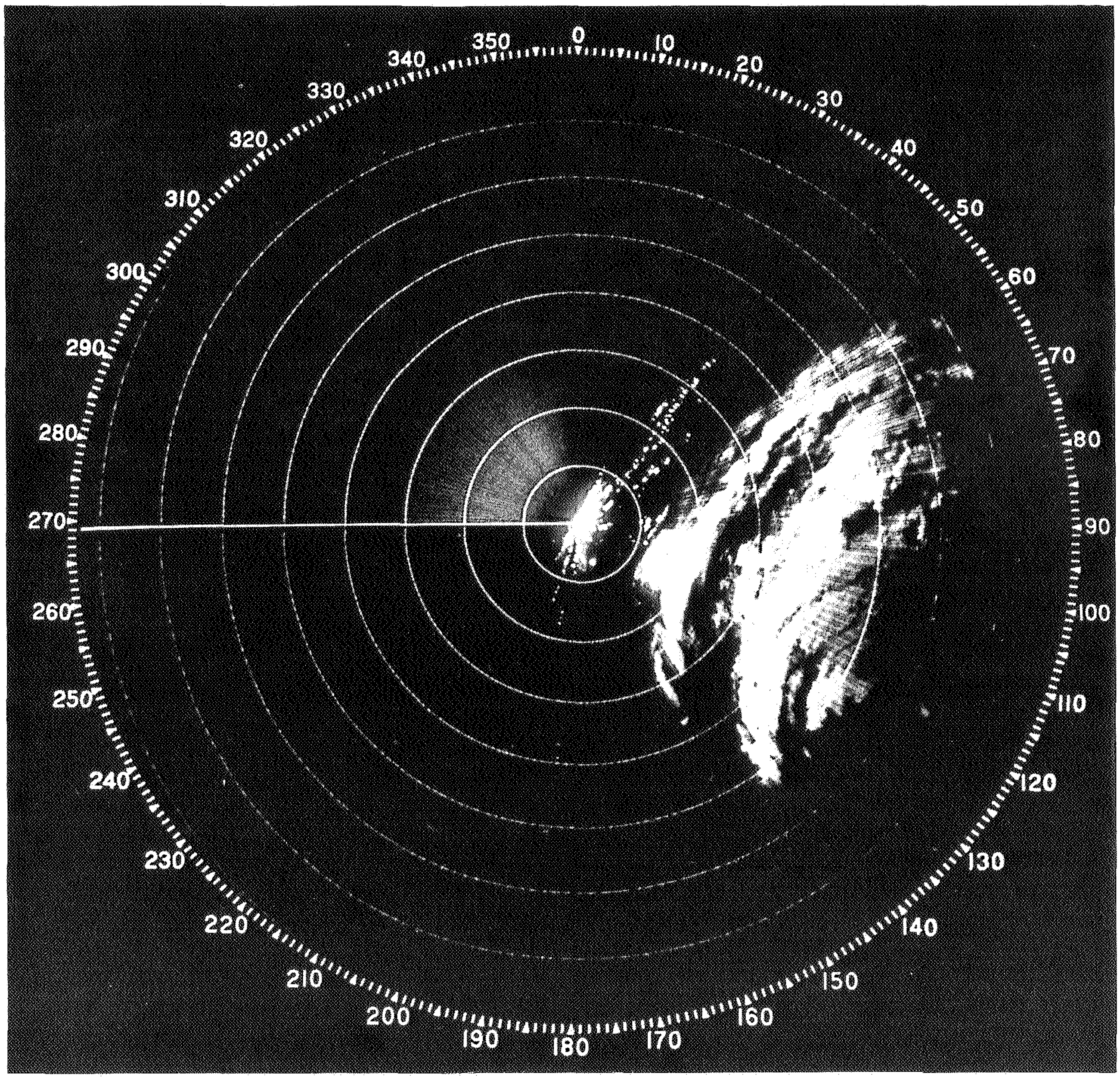


FIGURE 364. Hurricane Daisy as seen by FPS–16 radar, August 28, 1958.

Area 1 and an open-sided building was constructed behind the Assembly Shop, for ready storage of the component rocket stages. There were now three multistage launchers, a Terrier launcher, and a Nike launcher, all of which could be used for fairly large vehicles.

EMERGENCY HELICOPTER FERRY SERVICE

With the only access to Wallops Island being by water, the personnel who were required to travel to and from the island daily were at the mercy of the weather. On many occasions, the island was evacuated because of expected high water and winds from hurricanes, and on many winter days the ferry had to force its way through an icy channel. On February 18, 1958, however, ice in the channel became so thick that the ferry was blocked in (figure 365). A large Sikorsky HRS-1 helicopter, stationed at Langley for flight research, was pressed into service to ferry personnel and some equipment to and from the island on February 19th, and to the island on the morning of the 20th. The temperature had a low

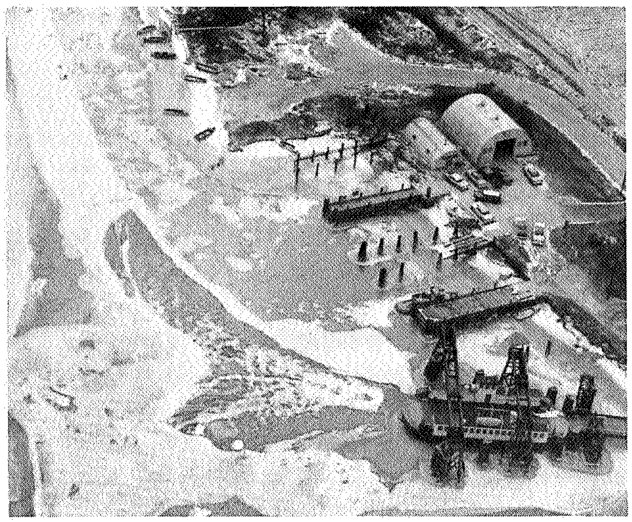


FIGURE 365. Aerial view of Mainland Dock and ferry channel under conditions of extreme icing, February 18, 1958.

reading of 15°F, and winds were gusting to 35 miles per hour. Seven canvas seats were installed in the helicopter for the trip. In six trips, made in less than an hour, 39 persons were airlifted from a field near the mainland dock to the island. They were returned to the mainland in the same manner in the afternoon. One flight is shown in figure 366.

FIGURE 366. Sikorsky HRS–1 helicopter leaving Wallops Island on a personnel ferry flight to the Mainland Dock, February 18, 1958.

On the following day, 61 persons were transported to the island in nine trips. By afternoon, the ice in the channel had cleared enough for the ferry to take over (ref. 2). John P. Reeder was the helicopter pilot on the first day, and W. L. Alford on the second. A. L. Murden was crew chief and supervisor of loading on both days. In addition to the ferry's being blocked, several small boats had sunk at the island dock and then had been frozen in. Fortunately this was the only time the channel was completely blocked, but the quick response of Langley and the availability of a suitable helicopter prevented a complete shutdown of operations.

H. J. E. Reid, Langley Director, was especially pleased with the operation and wrote to NACA Headquarters:

> The Flight Group did a splendid job in quickly getting Wallops Island staff back in operation. The operation showed excellent teamwork and esprit de corps of the entire organization, and I think the staff of Wallops Island and Flight Operations Branch at Langley are to be commended for a splendid job.[4]

From this time on, helicopters were to play an increasing role in Wallops operations.

4. Letter from H. J. E. Reid, Langley, to NACA Headquarters, Mar. 12, 1958, regarding helicopter airlift for Wallops Island personnel.

EJECTION OF FUEL TANKS AND BOMBS FROM A LOCKHEED F-104 AIRPLANE MODEL

The discussion in Chapter 12 has covered an experimental study of the behavior of internally carried stores after forcible ejection from the bomb bay of a Republic F-105 airplane model in the Preflight Jet. A similar study with a model of the Convair F-106 airplane has been discussed in Chapter 14. In both cases, the stores were ejected with a high vertical velocity, and there were only small errors in the calculation of vertical motion due to lack of complete dynamical similitude when the light-model method was used. For simple release of bombs, a method was developed by which the parent airplane model was accelerated upward at the time of release of the store, to correct this deficiency. The method was used first in tests of the Avco flight test vehicle, as described in Chapter 13. The Lockheed F-104 airplane carried different types of external stores, either fuel tanks to extend its range, or bombs for expanded mission capability. The bombs were mounted on the bottom of the fuselage, while the fuel tanks were mounted either at the wing tips or on pylons about halfway to the tips. On July 16, 1957, the Air Force requested the NACA to conduct tests of the behavior of these stores after release from a model in the Preflight Jet. The NACA approved the request with the issuance of RA A73L242 on October 1, 1957. The tests were made between December 1957 and August 1958, at Mach numbers of 0.9, 1.39, and 1.98. In figure 367, the model with all of the stores attached is shown in the Preflight Jet, ready for test. The model was accelerated upward in the tests by different amounts, varying from 0 to 10.9 g. The weight of the stores was varied to simulate different altitude conditions by both the light- and heavy-model methods. Ejection of the stores was initiated by activation of a squib which sheared the attachment pin.

In each test, pictures in high-speed sequence were recorded on a single piece of film by means of a rotating slotted shutter. Illumination was provided by a series of flashbulbs. A typical picture is shown in figure 368. The upward movement of the airplane model, as well as the downward movement of the store, is evident. Except for a store that had no fins, all of the stores tested left the airplane without any indication of striking it. Addition of fins provided a safe trajectory after release. The tests also indicated that the pylons could be released satisfactorily after the store was dropped although the pylon followed a quite erratic path after release (ref. 3).

GENERAL RESEARCH ON GLIDE ROCKETS

The term "glide rocket" was applied to an aircraft that would be accelerated to its top speed by a rocket engine and then glide to its destination. Although the X-1, X-2, and X-15 research airplanes operated in this fashion, their speeds were not high enough to provide the long range usually associated with glide rockets. The endpoint for range on earth would be infinite, achieved by an aircraft with orbital speed. In fact, the early studies of manned satellites envisioned reentry in a type of glide rocket. The NACA resolution that recommended research on the problems of space flight was prepared with glide rockets in mind, as well as missiles and satellites. (See Chapter 9 for resolution adopted by NACA Committee on Aerodynamics, June 24, 1952.) The Brown-O'Sullivan-Zimmerman study team at Langley, established as the first step in implementing this resolution, concluded that there were "no fundamental barriers to airborne flight at extreme altitudes at speeds up to orbital velocity" and "the outstanding problem is preventing structural failure from aerodynamic heating." They also proposed the use of Wallops as a launch base for flight test of a rocket-powered glide rocket model that would reenter the atmosphere and be recovered somewhere in the Sahara desert. (See Chapter 10.)

Although the first airplane to evolve from this study was the Mach 7 X-15 research airplane, the study team concentrated most of its efforts on the problems of a manned vehicle operating at near orbital speeds, because such a vehicle offered great promise as a long-range strategic bomber and an economical transport. This study was but the beginning of a continuing evaluation at Langley and at Ames of configurations suitable for safe reentry and landing from orbital and near-orbital flight.

The Air Force was extremely interested in such vehicles and had made many related studies. They were particularly interested in a glide rocket for a global-range strategic bomber. Many of the NACA

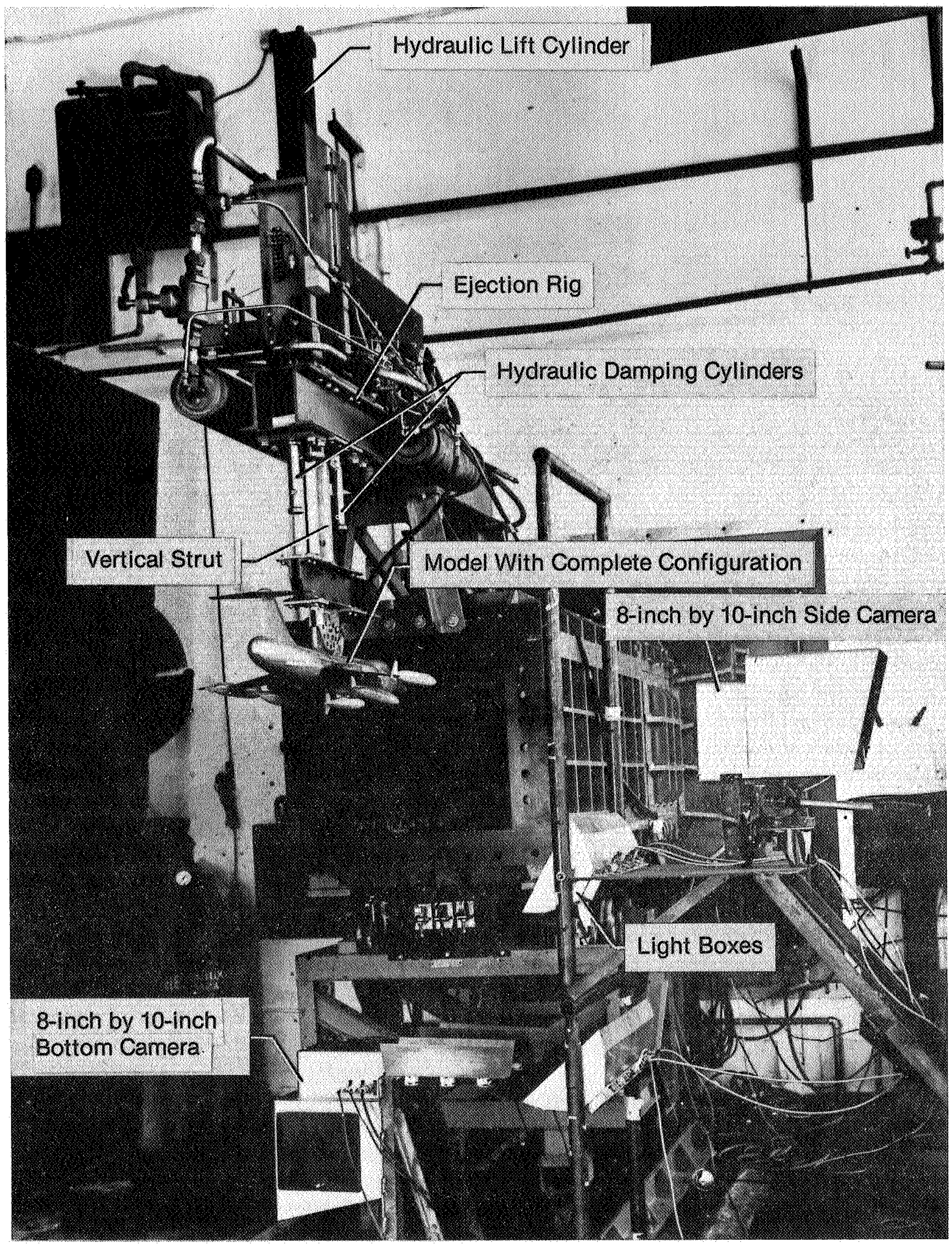


FIGURE 367. Model of Lockheed F–104 airplane mounted in 27-inch Preflight Jet for store release tests, December 1957.

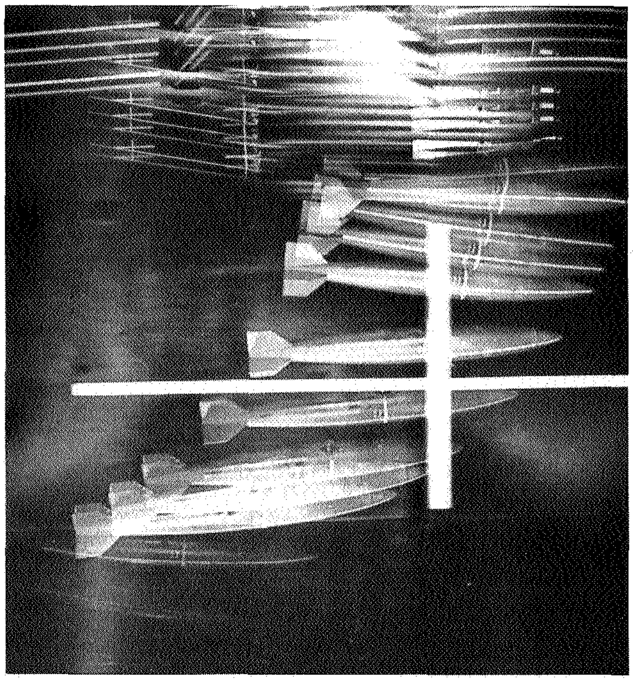


FIGURE 368. Typical simultaneous release of store and acceleration of model upward, as seen in test of Lockheed F–104 model in 27-inch nozzle of Preflight Jet.

research programs were directly responsive to this interest of the Air Force. Three separate studies, initiated by the Air Force early in 1956, were identified in 1957 as three phases of the Dyna-Soar program. Phase I was to be a test vehicle, to confirm the feasibility of a hypersonic glide rocket. Phase II was to be a hypersonic, high-altitude, reconnaissance vehicle with a range of about 5,000 miles. The vehicle had been previously designated "Brass Bell." Phase III was to be a hypersonic, global, strategic bombardment and reconnaissance system, previously called "Robo."

On February 14, 1957, the NACA established a steering committee to study the feasibility of a hypersonic boost-glide research airplane as a "Round Three" follow-on to the X-15 (ref. 4). On October 14, 1957, the NACA and the Air Force reviewed the preliminary studies completed by that time. The possibility of a hypersonic research airplane with NACA direct participation appeared to be a reality on May 20, 1958, when a Memorandum of Understanding was signed by the Air Force and the NACA, setting forth "Principles for Participation of NACA in Development and Testing of the Air Force System 464L Hypersonic Boost Glide Vehicle (Dyna-Soar I)" (ref. 5). Contracts were placed with Boeing and Glenn L. Martin Company on November 10, 1959, to develop Dyna-Soar but all contracts were canceled in 1963, in an economy move.

The whole concept of a hypersonic glide rocket generated many research programs in the NACA laboratories, including Wallops. The research at Wallops was divided into three parts. First, heat transfer measurements were made at hypersonic speeds on F40-type rocket models representing different vehicle concepts. Second, dynamic stability tests were made with a new series of rocket models designated F53. Third, structural panels were exposed to the high temperatures and dynamic loads of the Preflight Jet.

The trajectory of a glide rocket is quite different from that of the nose cone of a ballistic missile, and the methods pursued for solving the heating problem were correspondingly different. A re-entering nose cone of a ballistic missile could survive the aerodynamic heating with either a heat sink or an ablative heat shield, because of the extremely transient nature of the trajectory. High heating rates existed for only a short period. In contrast, a glide rocket followed a very flat trajectory at high altitudes, with much lower heating rates but for a long period. Under such conditions, the aerodynamic heat input could be brought into equilibrium with heat radiated from a hot external surface. This solution was used on the X-15 airplane, for which the equilibrium temperature was within the strength limitations of the inconel skin. For the glide rockets of higher speed, higher temperatures were envisioned and much research was conducted on various means for protecting the structure. One approach was to cover the structure with radiative heat-shield panels and have insulation between the panels and the primary structure. Before such panels could be designed, however, the aerodynamic heat transfer had to be determined. It was natural that the multistage rocket systems flown at Wallops to provide data for ballistic missile nose cones would now be used in the glide rocket problem. Although a flight project was planned in cooperation with Bell Aircraft Company and the Air Force, in which flight times at high speed and high altitude would be long enough to attain equilibrium temperatures, the project was abandoned in favor of measurements during transient conditions at lower altitudes.

The first rocket model flown at Wallops in the glide-rocket heat-transfer program is shown in figure 369. The basic five-stage Honest John vehicle was used, with the test model mounted on the front of the last stage. The lower surface of a delta wing at an angle of attack was simulated with a symmetrical model having the ingenious design shown. The model was essentially a three-sided pyramid, each side of which represented the bottom surface of a flat-bottom 75-degree delta wing having a blunt leading edge and flying at an angle of attack of 8 degrees. The surface was made from thin inconel and was fitted with numerous thermocouples. The model was flown on August 29, 1957, and reached a Mach number of 14.7 at an altitude of 88,000 feet on an over-the-top trajectory. (See figure 370.) The fifth stage, after separation, appeared to be unstable and flew at a large angle of attack which made the data after separation difficult to analyze. Prior to this, however, good data to a Mach number of 10 were obtained. The heat transfer data indicated laminar flow over the flat surface for Reynolds numbers up to 2 million. The experimental data were in good agreement with Van Driest's laminar theory for a flat plate, using wedge local flow conditions and basing Reynolds number on the length from the leading edge parallel to the centerline. Heat transfer to the swept leading edge was predictable by a modified three-dimensional stagnation-point theory, taking into account the sweep angle (ref. 6).

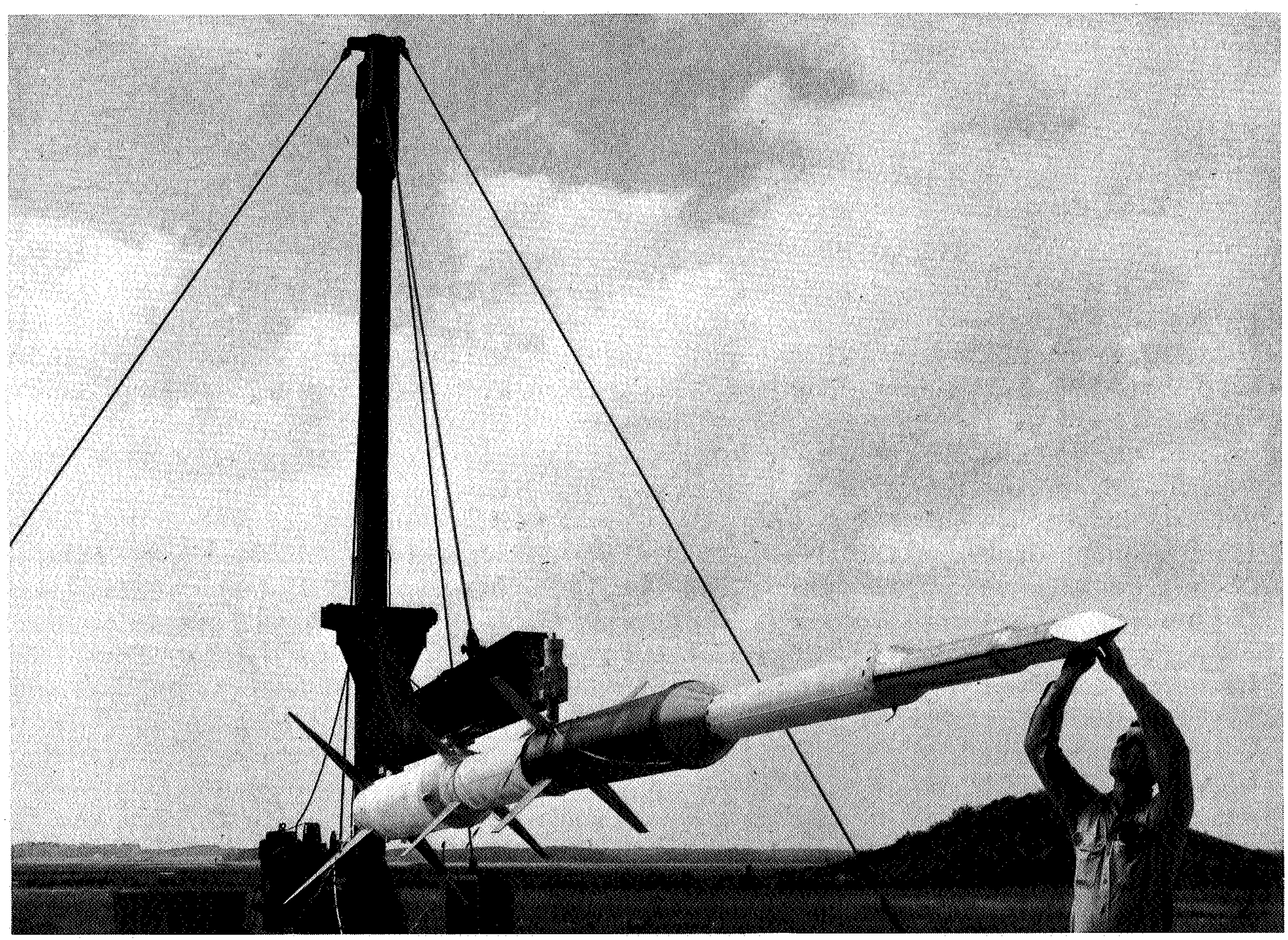


FIGURE 369. Project engineer Andy Swanson checks test model of simulated delta wing at an angle of attack. Model is shown on a five-stage Honest John vehicle, August 29, 1957.

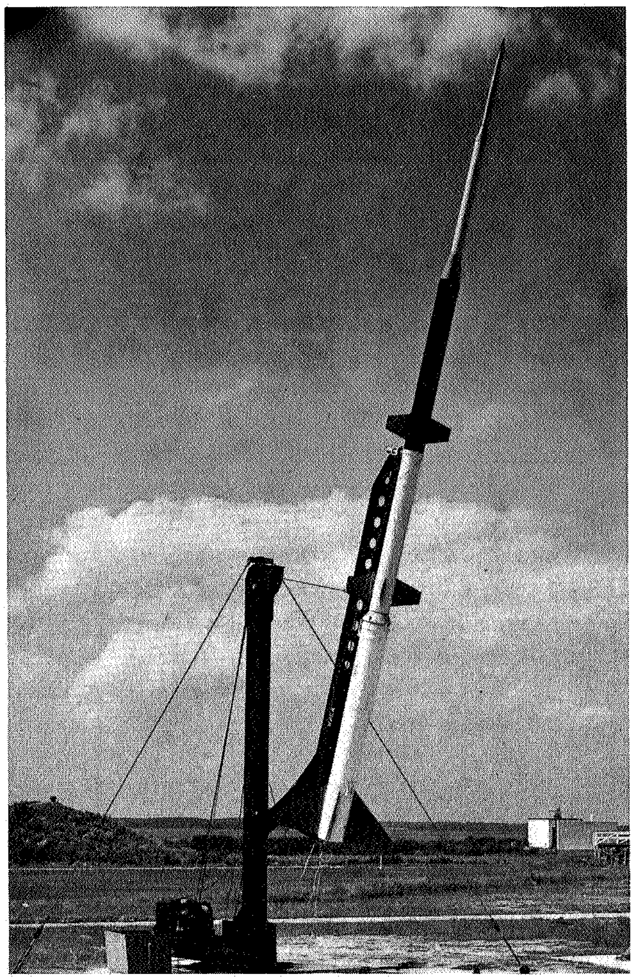


FIGURE 370. Delta-wing glide-rocket model mounted on five-stage Honest John vehicle ready for flight, August 29, 1957.

A larger model of the same type was flown to obtain heat transfer data under turbulent flow conditions. With this model, the same propulsion system was used except that the fifth stage was eliminated and the model was attached to the front of the fourth stage Recruit motor. The pyramidal model was 65 inches long, and each flat surface simulated an 82-degree delta wing at a 4-degree angle of attack. It was flown on August 3, 1960, and reached a Mach number of 9.8 at an altitude of 79,000 feet. Laminar and turbulent flow were indicated by the heat transfer data, which were in good agreement with the theories of Van Driest for either type of flow (ref. 7).

Two slender cone-cylinder configurations were flown for heat-transfer measurements on a single Honest John-Nike launch vehicle. The two-headed arrangement is shown in figure 371. Each model was 48 inches long, and the cylindrical portion had a diameter of 4 inches. The conical portion was 32 inches long and had an included angle of 7 degrees. The models were mounted in a vee arrangement to give an angle of attack of 8 degrees when the booster was in a zero-lift trajectory. One of the models was fixed, while the other was rotated by an electric motor at 5 revolutions per second. Pressures and temperatures were measured on the fixed model, and temperatures only, on the rotating one. It was known that, in actual use, this type of glider would have unequal temperature distribution around it at angles of attack. Rotation was provided in an attempt to equalize the temperatures. The Honest John-Nike booster accelerated the model to a maximum Mach number of 4.7. The loads on the rotating model were too large for the drive motor at the higher speeds, and it stopped rotating at Mach 3.7. A 10-channel telemeter was used to transmit normal and transverse accelerations, total pressure, and five static pressures on one cone; 24 thermocouples commutated at a rate of 5 complete samples per second.

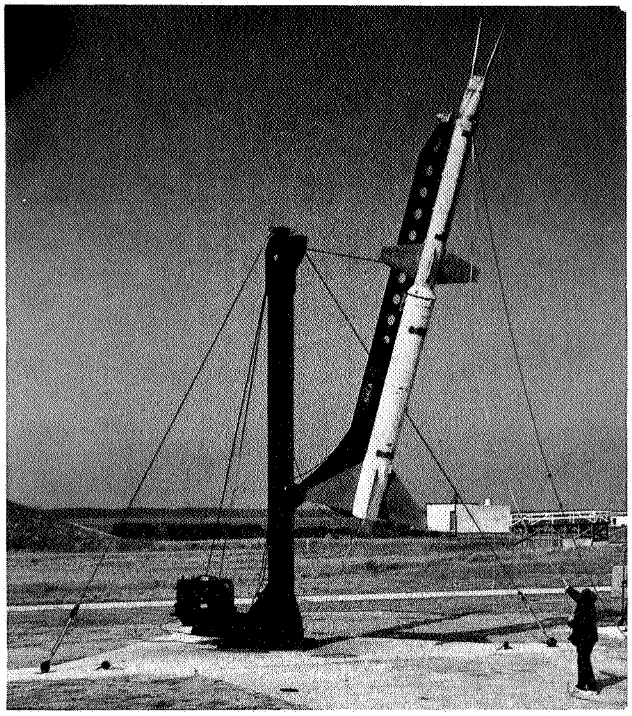


FIGURE 371. Photographer Don Foster adjusts external-power cable to double cone-cylinder model on Honest John-Nike booster, January 23, 1958.

The flight data showed that on the nonrotating body the temperatures varied considerably around the circumference. At Mach 4, for example, the temperatures were 245°F at the 0-degree station (windward), 485° at the 45-degree, 380° at the 135-degree, and 450° at the 180-degree station. The windward station was the coolest, because the flow was laminar. The Reynolds number at which transition to turbulent flow occurred was 39 million, based on distance from the apex of the cone. The heat-transfer rate at this station agreed with laminar theory. At the 45-degree station, the flow was turbulent and the heat transfer rate agreed with turbulent theory. Behind this station, the heating rate did not agree with theory, apparently because of separated flow conditions. The temperatures measured on the rotating body were close to the mean values measured around the nonrotating body (ref. 8).

Heat-transfer measurements were also made on the simulated lower surface of a half-cone added to the bottom of a 76-degree delta wing. As before, a triangular pyramid was used to simulate flight at an angle of attack of 8 degrees. The apex angle of the cone was 8.5 degrees. The test model is shown in figure 372. A maximum Mach number of 14.4 was obtained in an over-the-top trajectory of an Honest John five-stage launch vehicle. (See figure 373.) The test simulated the conditions on the forward one-fourth of a 70-foot-long glider cruising at an altitude of 160,000 feet. This model was hand polished to a roughness of 2 microinches. The heating rates corresponded to a mixture of laminar and turbulent flow (ref. 9).

Two complete models of a delta wing and cone configuration were flight tested to determine dynamic behavior in a follow-on program, but no data were obtained because of instrumentation failure. The first was flown in October 1958 and the second in April 1960.

A highly swept delta-wing configuration had been tested in wind tunnels and had been subjected to extensive analysis of the heating problem. The results indicated that such a configuration could be designed to survive the reentry phase of a boost-glide mission from near orbital speeds. Such a configuration, however, had been found to be subject to undesirable rolling behavior at low speeds. A rocket-model test was, therefore, made of such a model at supersonic speeds to assess the problem in that range. The configuration chosen is shown in figure 374. The model was basically a 79-degree delta wing with the tips cut off streamwise and vertical fins added to the upper and lower surfaces at the centerline of the model. All sections were wedge shaped. Because of anticipated difficulty with separation of the model from the burned-out Nike second stage by drag forces alone, two

FIGURE 372. Engineer Glenn Burton examines simulated delta-wing glide-rocket model with conical body at an angle of attack (photograph of October 8, 1957).

3.25-inch rocket motors were strapped to the forward end of the Nike to give it a rearward kick at the time of separation. The nozzles on these motors were facing upstream with a 20-degree cant angle so their exhausts would clear the model. In addition, the nozzles were plugged to prevent aerodynamic heating from igniting the motors prematurely. An additional separation force was provided by a small rocket motor located in the base of the model. A blowout diaphragm was used to connect the model to the front end of the Nike. A 10-channel telemeter was used to transmit accelerations, pressures, and rate of roll. The telemeter data were recorded on magnetic tape from which automatic plots of the data were made.

In the flight test, separation occurred as planned at a Mach number of 3.4 and an altitude of 35,000 feet. Dynamic behavior was recorded from this point to an altitude of 68,000 feet where the Mach number had decreased to 1.2. Two pulse rockets were fired to disturb the model in pitch. Prior to the firing of these rockets, the model had been rolling slowly and had had small-amplitude oscillations in pitch and yaw. After the first pulse rocket was fired, however, the model pitched to an angle of attack of about 12 degrees, and large oscillations in pitch, roll, and yaw were experienced, indicating a coupling between longitudinal and lateral forces. An analog study on which the motion was simulated indicated that the change of rolling moment due to sideslip with angle of attack was the predominant factor in the coupled motion. The static forces and moments deduced from the flight data were in good agreement with estimates from wind-tunnel tests (ref. 10). A second model was flown on May 25, 1959,

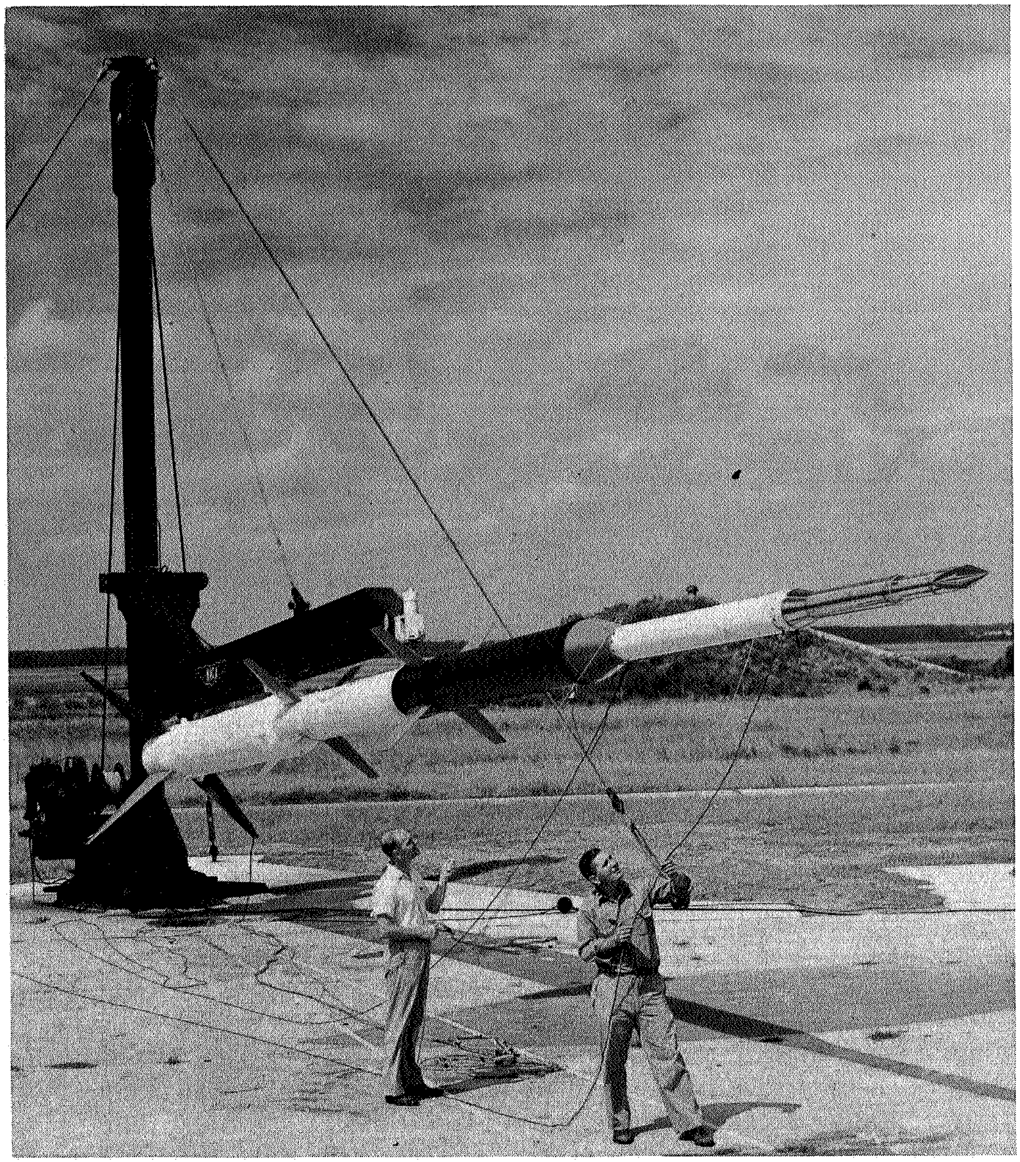


FIGURE 373. Engineer J. R. Hall and technician George Cutler check wiring to five-stage Honest John test vehicle. Vehicle is shown with simulated glide-rocket model on the nose, October 8, 1957.

with vertical fins added to the wing tips to increase the directional stability and thereby improve the flight behavior. This model, shown in figure 375, was boosted to a Mach number of 4.4 by an Honest John-Nike-Nike booster. The same separation and disturbing systems were used. This model experienced the same type of coupling motion as the first, indicating little improvement by the addition of the fins at the wing tips (ref. 11).

The structural design of glide rockets, particularly that part exposed to the aerodynamic heating environment, presented probably the largest problem facing the designer. Several aircraft manufacturers had been awarded study contracts for this phase of the vehicle. As mentioned earlier in this section, these contracts were in support of several proposed projects such as Brass Bell, Robo, and Dyna-Soar. Among the contractors were Bell Aircraft Corporation, Glenn L. Martin Company, and Boeing Airplane Company.

A favored solution to the problem was to use a double-wall construction, wherein the inner wall was the load-carrying member and the outer wall dissipated the aerodynamic heat input through radiation, at the same time protecting the inner wall from high temperatures. Typically, the outer wall would

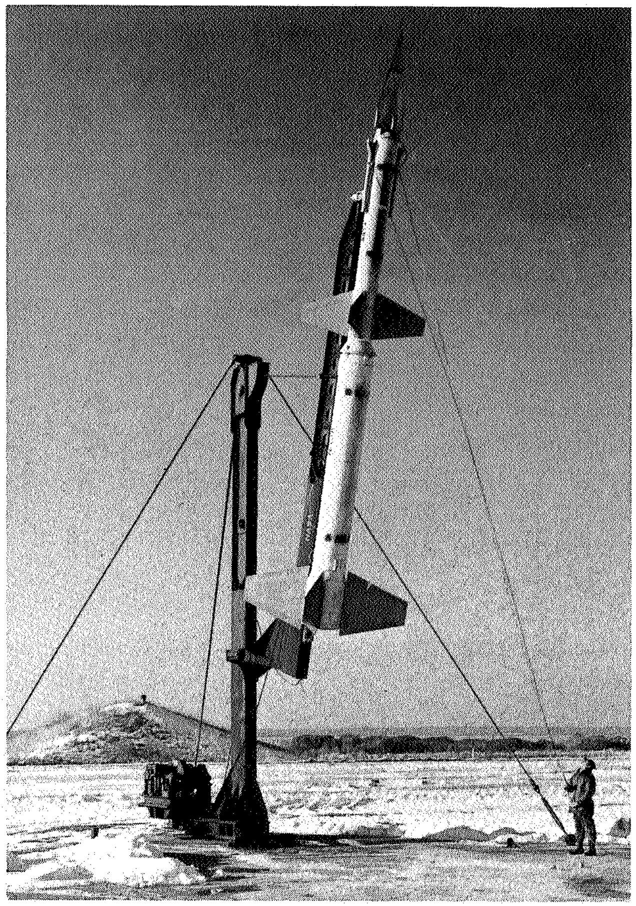


FIGURE 374. Technician George Cutler checks power cable to glide-rocket model with clipped delta wing. View shows model on Honest John-Nike booster, December 17, 1958.

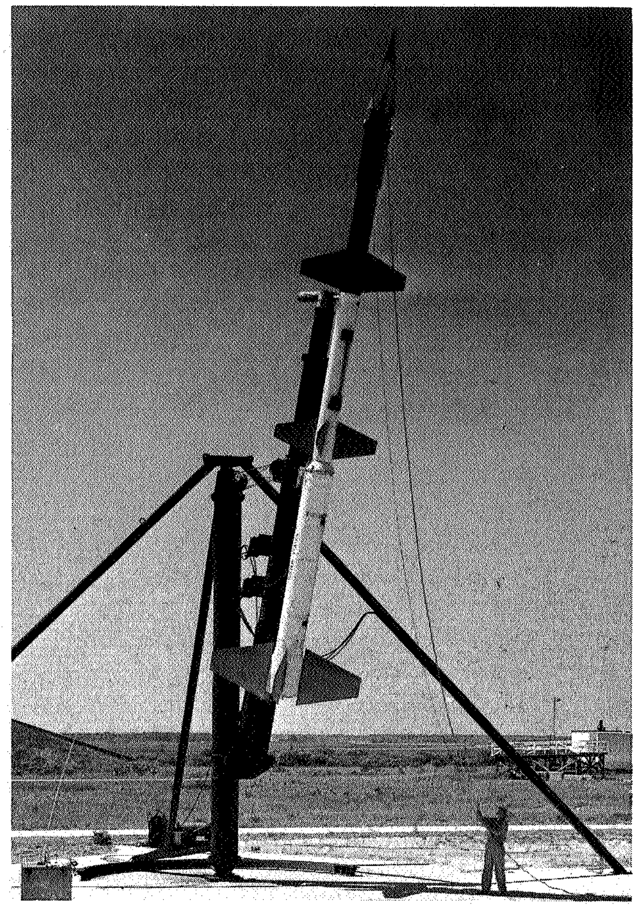


FIGURE 375. Technician F. E. Weatherman prepares to pull external-power cable to glide-rocket model with tip fins. Model is shown on Honest John-Nike-Nike booster, May 25, 1959.

reach a temperature of 2,000°F or more while being both attached to and insulated from the inner wall and other areas of the structure, whose temperatures were kept below 500°F, approximately. This difference in temperature created strains and stresses leading to buckling that compounded the problem of mere survival at the high temperature. In addition, since the outer wall was added to the main structure, it was imperative that it be of minimum-weight construction. Because of the expansion of the outer wall, the general plan was to construct it in small panels, providing room for movement at the edges either by leaving a small gap between panels or by overlapping them.

While much was learned from tests of typical panels placed in a radiant heater, the Ethylene Jet at Wallops was favored for such tests because of its ability to provide high-density airflow as well as high temperatures. A general research program on protective heat shield panels was initiated in 1958 and conducted through 1960. Three different types of panels were tested. The first was made of 0.20-inch-thick graphite in a 6-inch by 6-inch panel fastened to and separated from the base plate representing the primary structure. The panel was secured by steel bolts within zirconium dioxide fasteners at each corner and in the center of the panel, or by stainless steel fasteners of the same size. Thermal expansion was allowed through use of oversize holes and a gap around the outer edge. In the first test, the zirconium dioxide fasteners spalled away at the surface, and the graphite plate fluttered and broke up. With stainless steel fasteners, no trouble was experienced and a temperature of 1,700°F was measured on the graphite surface after a 30-second test.

A lighter heat shield, made of 2-inch by 2-inch tiles of stainless steel 0.15-inch thick, survived the test but experienced extensive distortion and flutter under the measured temperature of 1,500°F.

The third heat shield was supported by a multipost arrangement proposed by M. A. Faget. It consisted of two sheets of stainless steel 0.0075-inch thick spaced apart 0.37 inch by a multitude of

0.035-inch-diameter stainless steel posts placed every 0.25 inch. The posts were welded to both plates. The primary structure used in this test was of corrugated sandwich construction and was insulated from the heat shield panel. This heat shield survived the test in the Ethylene Jet and appeared to be a promising design. Although the outer panel reached a temperature of 1,600°F, the inner panel reached only 800°F, and the insulated primary structure reached a temperature of less than 200°F (ref. 12).

Some panels were also tested for the Air Force in connection with the study contract with Bell Aircraft for the Brass Bell hypersonic glider program. Bell had proposed early in 1956 that the load-carrying structure be protected from direct aerodynamic heating by a large number of small, thin-skin, insulated panels. A typical panel would be 8 inches by 12 inches with an outer skin made of 0.005-inch-thick inconel. This skin was stiffened by a corrugated member and insulated from the main structure by either bulk insulation or reflective insulation. In use, the outer skin would reach an equilibrium temperature consistent with a balance between radiative losses and aerodynamic heat input. This temperature would be below the dangerous temperature for the outer skin but considerably above a safe temperature for the main structure. With proper insulation and additional cooling as needed, it would be possible to use a more or less conventional basic structure under conditions of hypersonic flight with its high potential heating. Eleven different panel assemblies were supplied by Bell Aircraft. Four of these were tested in the Preflight Jet during July 1956, with supplementary heating supplied by an exterior quartz-tube radiant heater. The Mach 1.4 12-inch jet was used at Wallops, as shown in figure 376. Subsequent to the tests in the jet, some of the test panels were subjected to the radiant heater without airflow in the Structures Research Laboratory at Langley, at temperatures up to 1,500°F.

The effectiveness of the insulation was determined from the static tests, in which it was found that the bulk insulation was more effective than the reflective insulation although it was heavier and thicker. In the jet tests, some of the thin skins fluttered and failed although some control of this was possible by changing the edge support. Because of the large thermal expansion at the high temperatures, it was necessary to use small panels separated by a gap. The tests clearly indicated the need for more research before this type of structure was to become a reality (ref. 13).

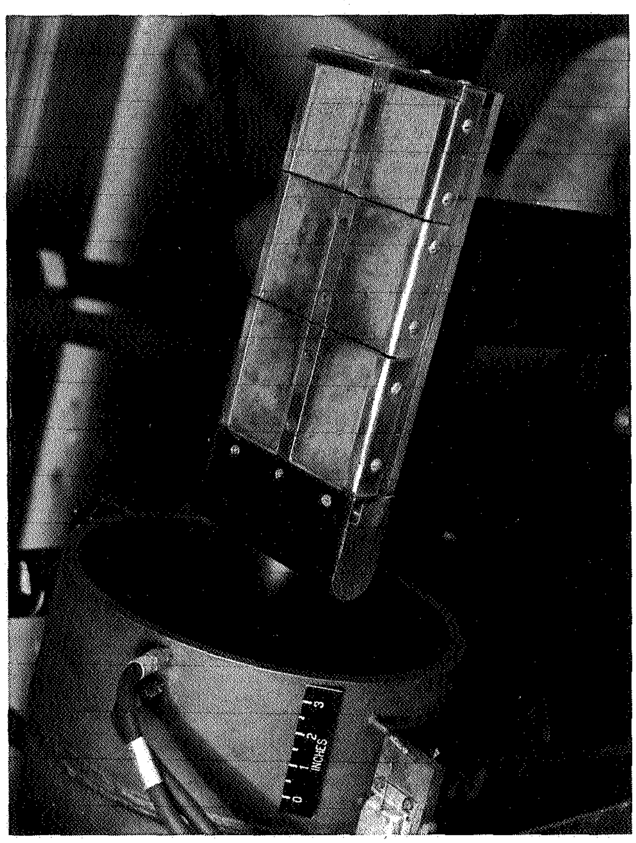


FIGURE 376. Bell Aircraft Corporation honeycomb panels in Ethylene Jet for heating test, August 1957.

A blunt, flat-top, lifting body proposed for a glide rocket, is shown in figure 377. It was flight tested on October 11, 1960, by a new technique wherein the test model, plus a companion dummy model on the opposite side, were mounted at the rear of a Nike motor. The two models plus their pylon supports provided stability. An Honest John booster completed the propulsion system. After maximum speed was reached, the test model was separated from its pylon, with the hope that it could avoid striking the rocket case. Although the test appeared to be a success, the data were never published.

LOCKHEED POLARIS BALLISTIC MISSILE REENTRY BODY

The Lockheed Polaris submarine-launched intermediate-range ballistic missile (IRBM) was the Navy's first ballistic missile. It was developed later than the Jupiter and Thor missiles and was the first IRBM to have solid-rocket motors. The Air Force had developed the Atlas ICBM, and the Army had its short-range Redstone ballistic missile. On November 8, 1955, the Secretary of Defense approved the development of two IRBM's—Thor, by the Air Force, and Jupiter, by the Army. On February 1, 1956, the Army activated the Army Ballistic Missile Agency (ABMA) at Redstone Arsenal to develop Jupiter. At this time, Jupiter was to be a missile suitable for both the Army and the Navy. ABMA initiated development of large solid-rocket motors at Aerojet for possible use in the Navy version of Jupiter. This development program led to the Jupiter Junior and Jupiter Senior rocket motors at Aerojet. Both motors were to see service in later NASA flight programs at Wallops.

In December 1956, DOD directed a reorientation of the Fleet Ballistic Missile program, the Navy's IRBM, from the liquid-propellant Jupiter (under development by the Army) to the solid-propellant Polaris, a Navy development, which could be launched from a submerged submarine. Development of Polaris was assigned to the Navy Special Projects Office, Rear Admiral W. F. Raborn, Director, as the Navy's project of highest priority. Raborn organized the Polaris-Submarine Special Task Group to advise the Project Officer in this development. The Special Task Group consisted of a Steering Committee and six subcommittees with membership from the aeronautical, naval, and missile communities, as well as the military. The NACA was invited to recommend a member for the Reentry Body Subcommittee. In January 1957, the NACA selected PARD Branch Heads M. A. Faget and P. E. Purser as member and alternate, respectively.[5] The function of the Special Task Group was to recommend an optimum weapons system and monitor the development program. In July 1958, C. L. Gillis replaced Purser as an alternate to Faget, and shortly after this time both Faget and Purser terminated their activity on the Polaris project in favor of participation in the Mercury manned satellite project and the Space Task Group. On December 17, 1956, the Navy authorized Lockheed to proceed with the development of Polaris.

The first meeting of the Special Task Group was held on January 7, 1957. As a member of the Reentry Body Subcommittee, Faget contributed directly to the recommendations regarding the shape of the reentry body as well as its aerodynamics and structural protection for reentry survival.

At the request of BuOrd on December 21, 1956, the NACA issued RA A73L226 to cover supporting analyses at PARD for reentry body design as a part of the contribution of Faget to the Polaris project. The favorable findings in the research already conducted at Wallops in the Preflight Jet and in flight with flared cylinders influenced the selection of the shape of the reentry body. The aerodynamic heating data, obtained in flight to Mach 15 at Wallops as well as in the Lockheed X-17 flight tests at Cape Canaveral, provided data directly applicable to the design. The study of Hall and Garland discussed in Chapter 14, indicated that it would be feasible to use a flared cylinder with either a subsonic-impact shape with a copper heat shield, or a supersonic shape with a graphite shield (ref. 14). The study was initiated at PARD by Faget with the needs of Polaris in mind.

The Polaris missile was designed to be carried in vertical tubes aboard submarines and to be launched while submerged. It was 28 feet long, had a diameter of 4.5 feet, and weighed about 30,000 pounds. It consisted of a two-stage solid-propellant booster plus a reentry body.

5. Letter from H. L. Dryden, NACA Director, to Chief of BuOrd, Jan. 3, 1957, regarding nominations for Polaris Special Task Group.

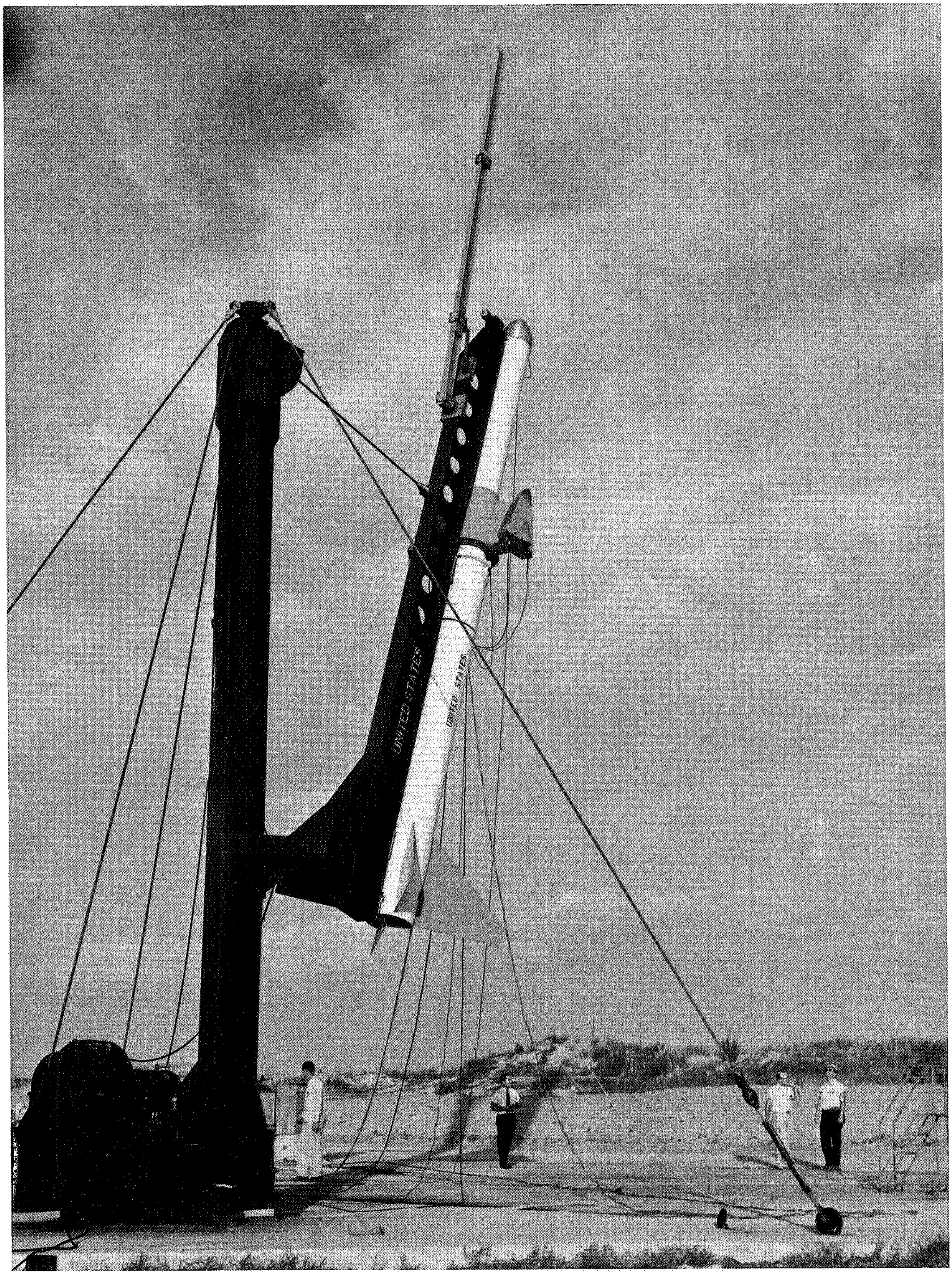


FIGURE 377. Glide-rocket model, shown on pylon at base of Nike rocket motor used with Honest John booster, October 11, 1960.

Three separate rocket-model flight projects were conducted at Wallops in response to Lockheed and Navy requests for direct support of Polaris. The first of the projects was to provide total drag data on the reentry body, which were needed to compute accurate trajectories. The Lockheed contact for these tests was former PARD engineer R. L. Nelson. Nelson made numerous telephone calls and visits to PARD between June and October, 1957, to get the program under way. The drag models were flown in two groups and provided data on stability as well as drag. Supplemental tests of smaller models in the Helium Gun were also made. The second series of rocket models was flown to support development of the fuzing system for the missile, with emphasis on base-pressure measurements. The third series of rocket models was flown to provide heat transfer to Mach 10 on the reentry body.

In addition, a few tests were made in the Ethylene Jet at Wallops and the ceramic-heated air jet at Langley, of various ablation materials suitable for protection of the nose of the reentry body. All of these tests were conducted concurrently under different sections of PARD but will be discussed in detail by series. They were given high priority at Langley and Wallops in keeping with the priority of the full-scale missile. Full-scale development firings of Polaris were under way before the Wallops tests were all completed. Between March 1958 and August 1959, 15 rocket models and 9 Helium Gun models were tested.

The first drag and stability models were round-nose cylinders about 6 inches in diameter and 19 inches in length, with a 16.5-degree flare at the base. A single Recruit booster was used in the first test, as shown in figure 378. An explosive bolt held the reentry body to the booster prior to burnout. The first attempted flight, on March 28, 1958, resulted in a freak accident, as was discussed earlier in Chapter 8, when the explosive bolt was energized before the Recruit ignited, and the reentry body fell

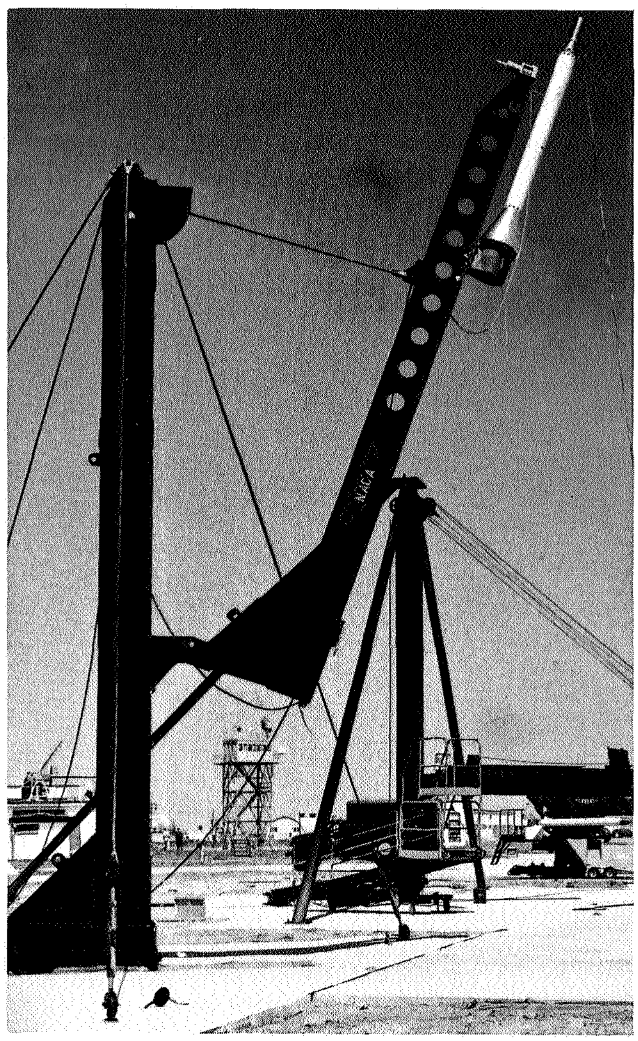


FIGURE 378. Test model of Polaris nose cone, shown on Recruit booster with flared base, April 14, 1958.

to the ground just before the Recruit booster took off as a riderless vehicle. The recovered model was fitted to a second booster and was flown successfully on April 14, 1958. A second model was also flown for more accurate determination of average drag. Both models provided data to a Mach number of 2.84 (ref. 15). A third model provided data on a flare having a lower angle but greater length. Data to a Mach number of 4.3 were provided by a fourth model propelled by a Nike-Recruit booster (ref. 16). Despite the symmetry of these models, high roll rates were experienced in flight, initiated by misaligned fins on the first stage. In some cases, this roll aggravated the natural oscillatory motion of the model as it slowed to transonic speeds.

The second series of rocket models, to provide data on the fuzing system, was requested by NOL representatives in a visit to Langley in August 1957 (ref. 17). The Navy representatives requested flight tests in which the base pressure would be measured under the same conditions of altitude and velocity to be experienced by the full-scale reentry body. PARD proposed instead that base pressure coefficients be determined for a range of flight conditions from which pressures for particular flight conditions could be calculated. Six models were flown in this series, and data on drag and stability were also provided to supplement the earlier data.

In the base-pressure tests, the model had a diameter of 9.12 inches and a length of 28.38 inches. A single Cajun booster was used in the first test, as shown in figure 379. A Mach number of 1.22 was reached in this test. The second model was flown with a Nike-Cajun booster, and a Mach number of 1.9 was reached. The first model oscillated over a wide pitch and yaw range at a Mach number of 0.98. The large angles, about 24 degrees, were explained by tests at Ames that showed a hysteresis loop in the pitching moment curve plotted against angle of attack. The center of gravity was moved forward on the second model, and the oscillations were reduced to about 2 degrees (ref. 18). One model was flown with a Nike-Cajun booster on a special trajectory, to verify calculations of the fuse setting as determined from the generalized pressure tests. An actual pressure switch, set for the desired condition, was also on board in this test. The model was flown on September 18, 1958, along a trajectory that duplicated the actual reentry conditions of velocity, altitude, and deceleration in the terminal phase. To obtain this trajectory, the Nike was fired at an elevation angle of 75 degrees, and after separation the Cajun and the model coasted over the top at an altitude of 28,000 feet. The Cajun was then fired on a downward trajectory and accelerated the model to a Mach number of 2.0. The reentry angle and weight of the

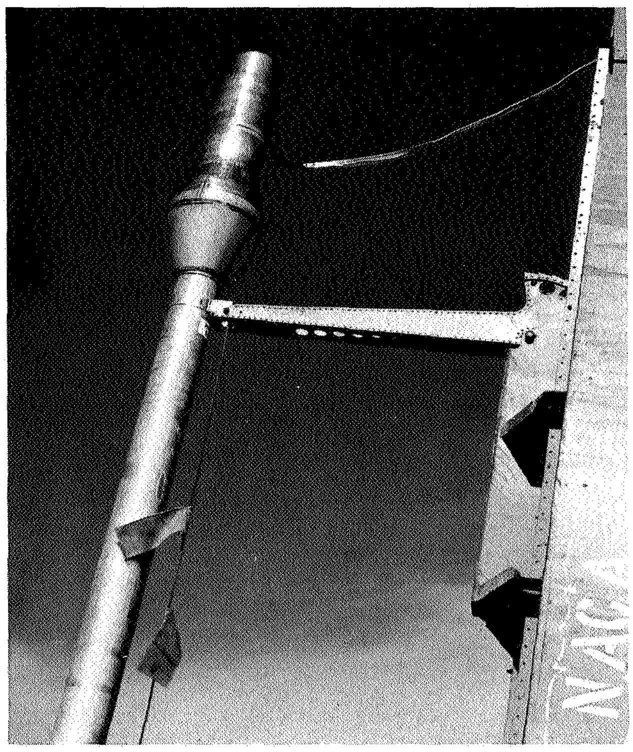


FIGURE 379. Model of Polaris nose cone on Cajun booster for pressure measurements in flight, February 11, 1958.

model were selected to duplicate a full-scale reentry. At the desired altitude and speed, the pressure switch closed as planned and verified the design method (ref. 19).

In the third series of rocket models, devoted to measurements of heat transfer to Mach 10, three models were flown between October 1958 and March 1959. These models were flown after abandonment of a plan to test full-scale reentry bodies at Cape Canaveral on a special vehicle. In June 1957, representatives of the Navy Special Projects Office visited PARD and stated that plans had been made to measure heat transfer on five 1/2-scale reentry bodies on X-17 vehicles, with the flights to be followed by tests of full-scale bodies on a new three-Sergeant (cluster)-Sergeant launch vehicle (ref. 20). In November 1957, Faget visited the Special Projects Office and learned that the development of Polaris had been accelerated and that plans for the new Sergeant test vehicle had been canceled. L. L. Luccini, another former Langley employee, now in the Special Projects Office, mentioned that the Sergeants left over from this canceled vehicle might be transferred to PARD. In December 1957, Faget was contacted by Lockheed about tests at Wallops with a series of three rocket models to determine heat transfer, using the first four stages of the five-stage Honest John system (ref. 21). BuOrd officially requested such tests on January 14, 1958, and NACA Headquarters issued RA A13L137 on March 7, 1959, to cover the project. The NACA agreed to furnish the 12 rocket motors required for the three vehicles, provided the Navy would give PARD three Sergeant motors in exchange (ref. 22). J. R. Hall was the project engineer for these heat transfer tests.

The models of the reentry body used in the heat transfer tests had a diameter of 7.3 inches and a length of about 22 inches. The first test was made on October 6, 1958, with the model shown in figure 380. The four booster stages were Honest John-Nike-Nike-Recruit. The first two stages were

FIGURE 380. Model of Polaris nose cone, shown on four-stage Honest John booster for heat-transfer test to Mach 10, October 6, 1958.

fired at low altitude and then, after separation, the upper stages were allowed to coast over the top at an altitude of 85,000 feet. The Nike-Recruit stages were then fired in rapid succession on a downward trajectory of 10 degrees to a Mach number of 10.15 at an altitude of 78,500 feet. A gas-operated piston forced the model ahead of the booster, which was then kicked to one side by six pulse rockets to increase the drag and thus the separation of the booster from the model. After separation, the model was disturbed in pitch by a pulse rocket to an angle of 20 degrees. The nose of the model was made of copper, nickel plated and polished to a 2-microinch finish. Two models were flown successfully; a third did not reach the desired maximum speed because the third stage did not fire. In the tests, laminar flow was indicated back to the flare, and the heating rate agreed well with Van Driest's theory. Although the model was oscillating in pitch and had some rolling velocity, the heating appeared to be uniform around the cylinder (ref. 23).

The overall Wallops support program in the development of Polaris was considered quite successful and was another example of good working relations between the NACA and the military, this time Navy BuOrd. In a letter to Dr. Hugh L. Dryden, Director of the NACA, Admiral Raborn commended the NACA for the support provided in development of Polaris through July 1958. He stated, in part:

> The significant contributions of the NACA to the Polaris reentry body aerodynamic program are greatly appreciated. The interest, initiative and cooperation displayed have provided a stimulus for the program which must not pass unrecognized. The NACA and the individuals concerned are again commended for the valuable assistance to the Fleet Ballistic Missile Program. It is hoped that the excellent relationship already established will continue to be as rewarding in the future as it has to date.[6]

TEMCO CORVUS GUIDED MISSILE

The Navy Corvus air-to-surface guided missile (XASM-N-8) was developed by Temco Aircraft Corporation. As a supersonic missile designed for use against ships, it had a diameter of 19 inches and a length of 14.7 feet. It had a clipped 62.1-degree delta wing on the bottom of the fuselage and four stabilizing fins interdigitated with respect to the wing. The total weight was 1,368 pounds. After extensive ground tests at Temco and the Pacific Missile Range, the first air launch was made on July 18, 1959, from a Douglas A4D Skyhawk airplane (ref. 24).

Prior to the first test of the prototype missile, a parachute recovery system was developed to allow retesting and thereby reduce the number of missiles required for the program. The recovery system was developed under a subcontract held by Talco Engineering. As a part of the development of the recovery system, flight tests under full-scale conditions were desired. On August 25, 1958, representatives from Temco and Talco visited PARD to learn whether such flight tests could be made at Wallops Island. The Navy insisted that Temco prove compliance with the specifications for the recovery system by achieving three out of four successful recoveries at Mach 1.7. Temco proposed the use of a single external booster with dummy full-size missiles in the proof tests. PARD estimated that an Honest John rocket motor would provide the desired condition of Mach 1.7 at an altitude of 8,000 feet (ref. 25).

PARD expressed an interest in conducting the proposed tests, and eventually eight flights were made—five at Wallops and three at White Sands Proving Ground. Talco constructed the dummy models, while the Navy provided the Honest John rocket motors. Since the models were expected to be recovered, onboard recording instrumentation was used. Wallops participated in the assembly, launching, photography, tracking, and recovery operations.[7] BuAer officially requested NASA to provide this assistance. Five Honest John motors and three dummy models were to be provided, with the expectation of reusing at least one of the models. The request of BuAer was approved on November 18, 1958. The PARD identification number was E130.

The first launching at Wallops was on November 6, 1958, without success. Figure 381 shows one of the models with its Honest John booster. The dummy models were equipped with an additional large vertical fin for directional stability required in the absence of the missile's automatic control system. The recovery system consisted of two parts: a drogue parachute for operation from Mach 1.43 down to 0.28,

6. Letter from Rear Admiral W. F. Raborn, Director, Special Projects, to Dr. Hugh Dryden, Director NACA, July 23, 1958, commending the NACA for support of Polaris reentry body development.
7. The NACA became NASA on October 1, 1958.

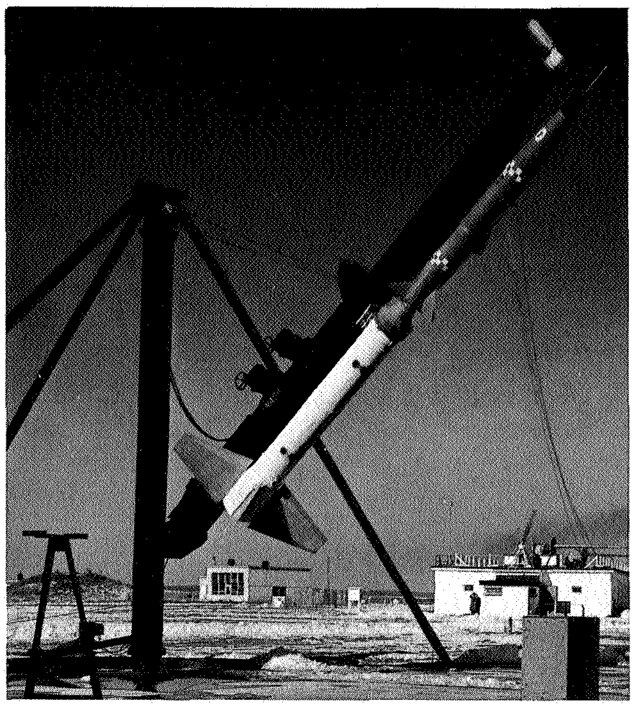


FIGURE 381. Temco Corvus guided missile ready for flight test at Wallops with Honest John booster, December 18, 1958.

to open in two stages; and a main parachute arranged by reefing to open in three stages. The drogue chute had a flat diameter of 5.4 feet, while the main chute had a diameter of 37.1 feet.

In the first flight test, several things went wrong with the various ejection mechanisms. First, the additional fin was ejected prematurely by explosive bolts at Honest John ignition, leaving the missile directionally unstable after it separated from the booster. In addition, the hatch cover tore loose and released the drogue chute prematurely. The chute was then torn from the missile.

The second launching at Wallops was on December 18, 1958. This time the parachutes tore loose from the missile and no recovery was made. No premature firings of explosive devices were noted during the flight, although during preliminary tests in the shop at Wallops one system fired accidentally, as has been discussed in Chapter 8. In the third test, on February 5, 1959, although larger drogue chute attachment lines were used, the drogue chute was ejected prematurely and tore off. Later, when the main chute opened, it also tore off.

Following the third failure, Temco took over the project from Talco and constructed additional models. With these, a telemeter was to be used to ensure receiving data in case of failure of the recovery system. Temco provided the telemeter receiver at Wallops. An energy-absorbing system was added to the drogue chute (ref. 26).

The fourth launching at Wallops was on May 27, 1959. Again, the main chute tore off, apparently because of premature release of the drogue chute before the model had slowed down. Following this failure, the launch site was moved to White Sands to allow recovery of components in case of failure. The first launch was made there on July 31, 1959, with some success in that the parachutes did not break loose and the model was recovered intact; but the main chute was torn and did not decelerate the model as much as expected (ref. 27). A second test at White Sands on August 18, 1959, was quite successful. Changes in the suspension lines of both the drogue and main chutes had been made (ref. 28). Among other things, the single steel cable holding the drogue chute was changed to two nylon lines. The seventh model in the program was then moved back to Wallops to verify the operation of the complete system for ocean recovery. This launching, on September 2, 1959, the fifth at Wallops, was another failure. This time, the main chute opened early and became entangled in the drogue chute, tearing it off.

The eighth and final test of the series was made on October 22, 1959, at White Sands. In this test, the drogue chute performed well and no further modifications were considered necessary; but the main chute did not fill as much as desired while in a reefed condition. Consequently, when the chute opened fully it did so at a velocity higher than expected, which caused higher than expected loads in the attachment lines. The need for further development was indicated (ref. 29).

While the parachute recovery system for Corvus was not fully developed in these tests at Wallops and at White Sands, the experience gained with the system was beneficial to PARD and Wallops personnel in connection with later recovery projects, particularly the Mercury capsule launched by the Little Joe launch vehicle.

USE OF NIKE MISSILE IN FLIGHT EVALUATION OF A RESEARCH CONTROL SYSTEM

A complete Nike ground-to-air guided missile was launched at Wallops on June 5, 1958. A standard Nike missile mobile launcher was used, as shown in figure 382, and an Army crew fueled the liquid-rocket motor within the missile itself. The missile as flown was different from the standard Nike in that it had an entirely different control system. The automatic control people at PARD and IRD had conducted considerable research in the laboratory with different control and guidance systems and had applied some of their findings to the D4 general research PARD missile, as has been discussed earlier in this history. Both the NACA Subcommittee on Stability and Control and the NACA High-Speed Aerodynamics Subcommittee early in 1954 had recommended that the NACA accelerate efforts in the automatic control and guidance field. One method for doing this, recommended by R. A. Gardiner, head of Automatic Control Dynamics section of PARD, was to use existing Nike missiles as a flight test bed for some of the control systems already developed in the laboratory at Langley.

On November 10, 1954, a request was made to NACA Headquarters that four such missiles be obtained from the Army for this purpose.[8] NACA Headquarters asked the Chief of Army Ordnance to supply four missiles for research use, stating that the warheads and radar equipment would not be needed.[9] The control system within the missile was to be modified by the NACA to simulate different promising new systems that might be of benefit to the Army in future development programs.

Four Nike missiles were assigned to Langley by the Army at no cost to the NACA. Only one of these was ever used in the flight program, but much use was made of the components of the others in laboratory research. The unused missiles were eventually returned to the Army.

The initial plan for the Nike missiles was to flight test some of the simplified control systems studied at Langley, to improve reliability. As time went by, however, interest in these systems diminished, and the single Nike missile tested was modified to flight test a Langley-developed system that had shown promise of minimizing the effects of altitude and Mach number in the control system while at the same time providing "exceptionally favorable static and dynamic characteristics" (ref. 30). The project engineer for the flight test was C. L. Robins, Jr., and the project designation was D117 (ref. 31).

The flight test covered a Mach number range of 1.18 to 2.63 and an altitude range of 14,700 feet to 67,600 feet. The flight results were compared with the earlier theoretical study and with simulator results. Programmed commands for changes in flight path were given the control system at the rate of one every 6.5 seconds. The response characteristics were then evaluated from data transmitted to the ground station through a 10-channel telemeter. Although a Nike missile was used, only the system supplying the power to move the controls was retained from the standard Nike. In the modified control system, a torque servo that gave control deflection proportional to the opposing aerodynamic moment was used, plus a control-surface-position feedback. The results agreed fairly well with the theoretical analysis and verified this method for minimizing the effects of Mach number and altitude on response.

THIOKOL TART MISSILE

The Tart missile was developed by Thiokol Chemical Corporation for the Air Force for use as an electronic-countermeasure missile for bomber defense. It was designed to be launched from a tube and

8. Letter from Langley to NACA Headquarters, Nov. 10, 1954, recommending procurement of Nike missiles.
9. Letter from the NACA to Chief, Ordnance Research and Development Division, Department of the Army, Dec. 6, 1954, regarding use of Nike missiles in flight research.

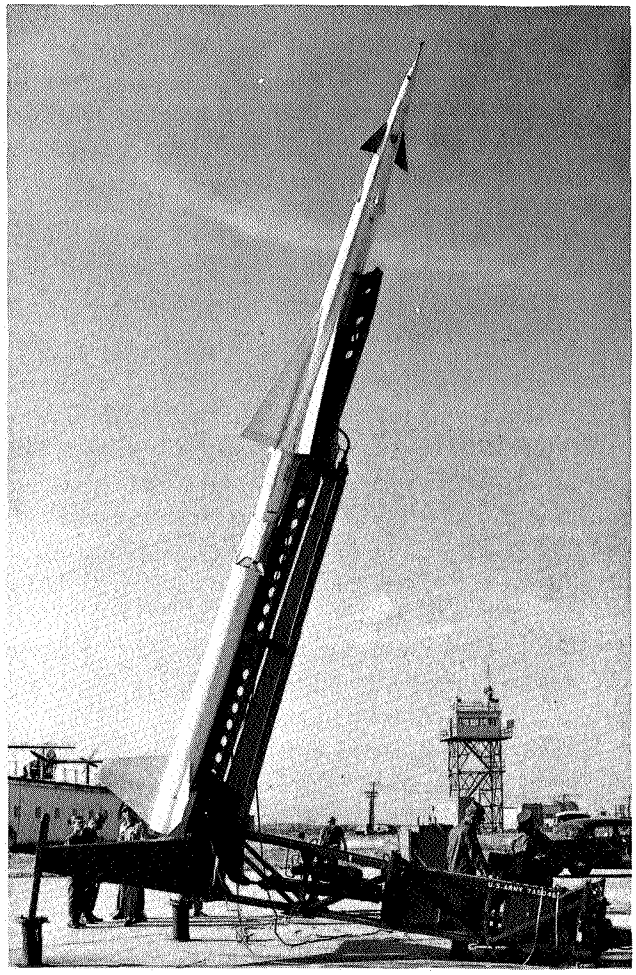


FIGURE 382. Nike guided missile being prepared for launching by Army crew, June 5, 1958. Flight was made to conduct control system research.

was propelled by an internal solid-rocket motor that provided an incremental speed of about Mach 1.0. It was an ogive-cylinder about 2.7 inches in diameter and 43 inches in length. The main problem in the development related to the stabilizing fins. When short, stubby fins did not provide adequate stability, Thiokol turned to a folding-fin arrangement consisting of four tangential, high-aspect-ratio fins that lay along the body when folded and rotated approximately 90 degrees about a pivot in the fin. Following a visit by Thiokol representatives to Langley in January 1957, a series of free-to-roll tests was made in the Langley high-speed 7-foot by 10-foot tunnel, to a Mach number of 0.95, in April 1957. The objective was to measure the roll rate resulting from any misalignment of the fins.

On March 18, 1958, Thiokol representatives visited PARD to propose a few flight tests of the Tart missile and some tests in the Preflight Jet to study the opening characteristics of the fins. Four flight tests and six runs in the Jet were proposed (ref. 32). The Air Force officially requested these tests on April 17, 1958, and NACA Headquarters approved the program on May 20, 1958, with the issuance of RA A73L270.

For the flight tests at Wallops, a Thiokol T58 rocket motor was used as a booster to propel the Tart and its launch tube as a unit to Mach 1.5, to simulate a full-scale launch condition from an airplane at Mach 1.5. At burnout of the booster, the Tart was ignited and was expected to emerge from the tube and unfold its fins. Two firings were made at Wallops on May 8, 1958. One of the missiles is shown in figures 383 and 384. R. R. Lundstrom, PARD project engineer for these tests, described the results as follows:

> On the first launching the Tart fired as planned but immediately after it was free of the launching tube it yawed very sharply to the right. On the second launch, motion pictures showed that a burst of smoke came from the end of the launching tube at about booster burnout but the Tart did not leave the launching tube.

FIGURE 383. Technicians Ed Matthews and Roy Hindle connect firing leads to Thiokol Tart missile at Wallops, May 8, 1958.

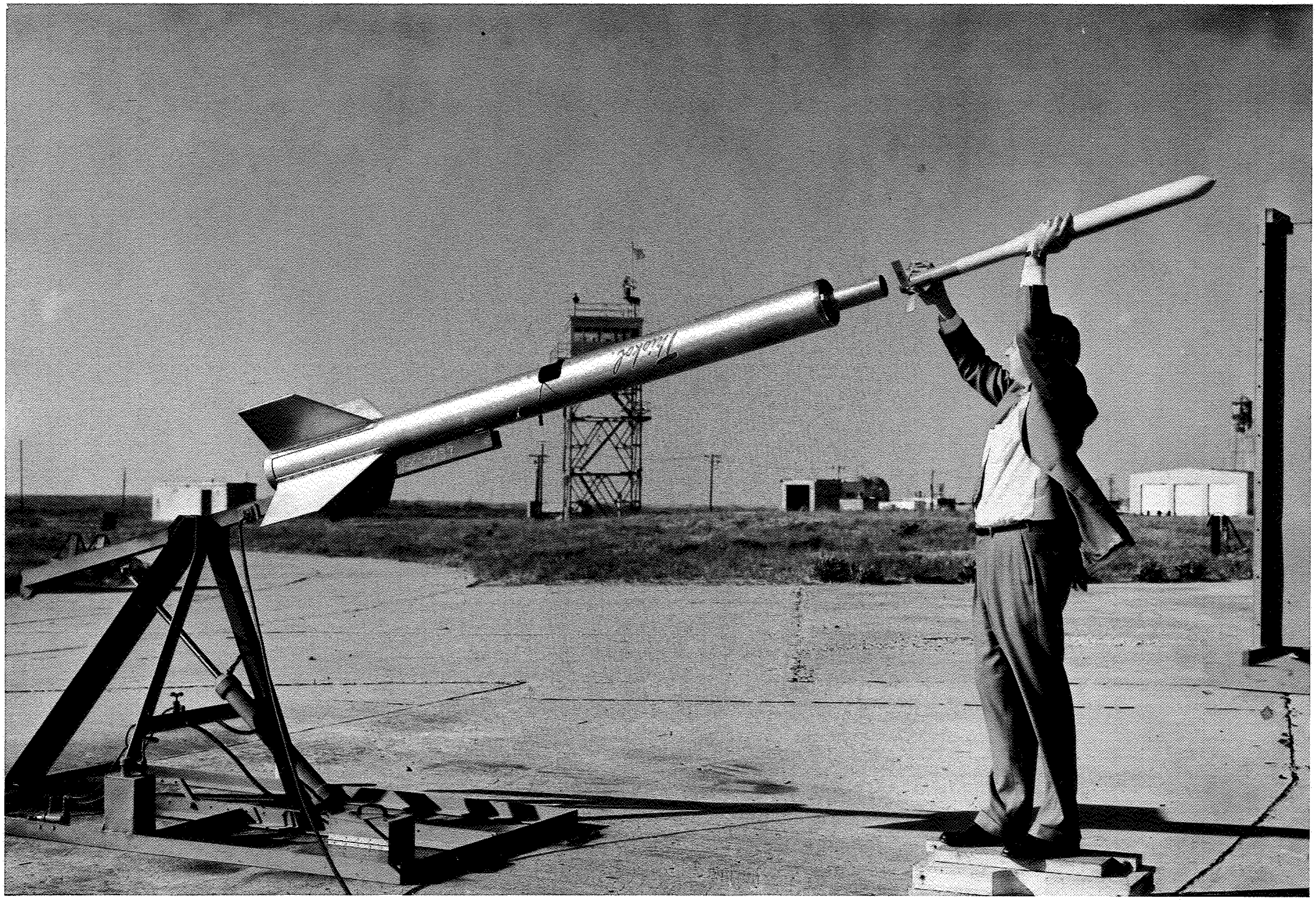


FIGURE 384. Thiokol Tart missile with folding fins, shown as it is being inserted in rocket launcher used for flight test at Wallops, May 8, 1958.

In July 1958, tests were made in the Preflight Jet of the opening characteristics of the fins. Four tests were made on July 22 in the 27-inch Mach 1.4 nozzle, with apparently satisfactory results. On July 23, two tests were made in the Mach 2.0 nozzle, and the fins broke off at the hinge point in both tests.

GENERAL ELECTRIC ICBM ABLATIVE NOSE CONE

Chapter 14 has discussed initiation of the first of a series of test programs conducted for the Air Force and General Electric Company in regard to development of the ICBM nose cone for Atlas. Although the first GE nose cones had copper heat shields, by late 1957 GE was developing an advanced nose cone that utilized an ablative shield. In November 1957, H. H. Jackson of GE visited PARD and proposed that three five-stage models be flown at Wallops to investigate different ablation materials on a model of the advanced nose cone design. He proposed that GE furnish the test models and all hardware needed, and that Langley instrument the models, conduct the flight tests, and analyze the data. The Air Force would supply the rocket motors (ref. 33).

PARD was also interested in ablative heat shields and recommended cooperation. The Air Force (Western Development Division) (WDD) sent an official request through WADC to the NACA on January 14, 1958. The first test was expedited by borrowing rocket motors and hardware from another Honest John five-stage project, and took place on April 24, 1958. The model is shown in figure 385. Because of the general interest in the program, the models were given an H50 designation, which covered general flight rocket models in cooling research under the High-Temperature Branch of PARD. The flight was a failure because the telemeter went out upon ignition of the Recruit stage. A second model, launched June 27, 1958, suffered the same fate. This was exasperating as well as surprising inasmuch as seven Honest John five-stage systems had been flown successfully in a row prior to these two.

Extensive research was conducted on the telemeter and its support system, and special measurements were made of the shock loads of the Recruit motor at ignition. After shock loads as high as 200 g were measured, the test models were subjected to more severe drop tests. A free drop of 9 feet into a shallow box of sand was found to duplicate the shock loads from the Recruit. The telemeter was redesigned to survive this experience, and on November 20, 1958, a special flight was conducted with a five-stage model containing two improved pressurized telemeters. In this flight, data were transmitted until splash. The test was only partially successful, however, because the third stage failed to fire although the fourth and fifth stages did. The model withstood the acceleration loads from the Recruit, although not under as severe a condition of dynamic pressure. This flight, nevertheless, inspired a third attempt to obtain ablation data on the GE nose cone. The third flight was made on March 17, 1959. This time the model broke apart at ignition of the Recruit motor. It was determined that several design changes had been made to various parts of the last stage, one of which evidently had created a weak spot. A redesigned and strengthened version was successfully flown on July 12, 1959, but this was too late for the GE ablation program.

DEVELOPMENT OF MACH 18 SERGEANT FIVE-STAGE LAUNCH VEHICLE

Chapter 13 has discussed the conferences with Air Force BMD in the spring of 1955 that led to the Air Force's giving Langley 24 Recruit motors and 2 Sergeant motors. These motors were to be used in multistage rocket vehicles at Wallops to provide heat-transfer data of interest to the ICBM program. Word was received in June 1955 that the motors would be delivered to Wallops in January 1956. The Recruit motors were used in the Honest John five-stage system and the Nike-Recruit vehicles almost immediately upon receipt, the first use at Wallops being on August 24, 1956. The Sergeant motor, on the other hand, was larger than any motor previously used there and required a completely new design, not only of the launch vehicle but of a suitable launcher.

The Sergeant motor was 31 inches in diameter and 230 inches in length. It weighed 8,185 pounds with 7,033 pounds of propellant, for a high propellant-mass fraction of 0.86. It was made by Thiokol with polysulfide-ammonium perchlorate propellant, and produced 50,000 pounds of thrust for 27.5

FIGURE 385. Representatives of PARD and GE examine ablative nose cone ready for flight test with five-stage Honest John booster, April 24, 1958.

seconds. To make the best use of this motor, it was desired to have equally efficient motors in all stages. The Recruit and T55 motors used in the fourth and fifth stages of the Honest John five-stage system were suitable, but the Nike motor used in the second and third stages was too ancient. Preliminary calculations indicated that a maximum Mach number of 15.8 could be attained with Nike motors in the system, only a small improvement over the Honest John five-stage system. A new motor of less weight and more impulse was located in November 1955 at Grand Central Rocket Company. The motor had been developed for use in ground-launching of the Lockheed X-7 ramjet flight test vehicle. It was identified as "XM-25" and "Lance," but at first PARD referred to it as the X-7 motor, from its first application. The Lance had a diameter of 15 inches, a length of 163 inches, and a weight of 1,651 pounds with 1,190 pounds of propellant. The propellant-mass fraction of 0.73 placed it in about the same category as the Cajun. The thrust was 51,000 pounds for 5.3 seconds. With two of these motors substituted for the two Nike stages, the maximum Mach number was calculated to be about 18.

Further calculations indicated that the Mach number could be increased to 19.5 if, in addition to the Lance motors, a somewhat larger, high-performance motor were developed to replace the T55 motor in the final stage. Langley informed NACA Headquarters of this possibility and requested that the Air Force be asked to assist in procurement of Lance motors and development of the new last stage motor (ref. 34).[10] The new motor proposed for the last stage was later to be named Cherokee and was to be essentially a scaled-down Recruit motor. The proposed motor had a diameter of 5 inches, a length of 65 inches, a thrust of 11,500 pounds for 1-second burning time, and a total weight of 70 pounds with 53 pounds of propellant.

Despite repeated efforts by NACA Headquarters to obtain the aid of BMD in obtaining Lance rocket motors and developing the new Cherokee motor during the spring and summer of 1956, no assistance was forthcoming. The Recruit and Sergeant motors were supplied to the NACA as an extension of the Lockheed X-17 flight project. The Lance motors, on the other hand, did not come under the jurisdiction of BMD. To procure these motors, as well as to develop a new motor, would require the establishment of an entirely new flight project which BMD was reluctant to do at this stage in the ICBM development. The NACA, therefore, was obliged to finance the rockets itself. Some Lance rockets were purchased for the Sergeant system in late 1956, but development of the Cherokee was delayed until later. It was eventually developed under a contract with Thiokol Chemical Corporation, but it came too late and was never to be used at Wallops.

The Sergeant five-stage vehicle was made up of a Sergeant motor as the first stage, two Lance motors in tandem as the second and third stages, a Recruit as the fourth stage, and a T55 in the fifth or model stage. The vehicle was unguided, but all stages were aerodynamically stabilized to follow a zero-lift trajectory. The overall length was about 68 feet and the weight was 13,727 pounds. Calculations indicated that the 2.5-g acceleration at launch provided by the Sergeant motor alone would cause serious tipoff problems and would be vulnerable to any gusty wind condition. To offset this possibility, two Recruit motors were strapped to the sides of the Sergeant, and the takeoff acceleration was thereby increased to 7.4 g. The nozzles on the Recruits were canted so that their thrust would pass through the center of gravity of the total vehicle at launch. The two Recruit motors were arranged to be fired by means of pull-away clips when the vehicle began to move after ignition of the Sergeant. This arrangement prevented premature ignition of the Recruits. The complete vehicle, ready for launch, is shown in figure 386. It was launched from the new tubular launcher developed especially for this vehicle (see description in Chapter 14).

The first launch of a Sergeant five-stage vehicle was made on June 27, 1958. It was a successful flight and reached a maximum Mach number of 17.8 although the telemeter failed before peak Mach number and limited the data obtained to a Mach number of 15.1. In the flight, the Sergeant with the two Recruits accelerated the vehicle to Mach 3.1, after which explosive bolts were fired, releasing a locking band that had attached the front end of the Sergeant to the next stage. The Sergeant drag-separated from the vehicle, which then coasted to a peak altitude of 112,000 feet. After the vehicle went over the top and was on a slightly downward trajectory, the remaining four stages were fired in rapid succession. The critical ignition was that of the second stage. Because of wind effects, it was not deemed wise to depend on a timer for this purpose as had been used in Honest John five-stage vehicles.

10. Letter from Langley to NACA Headquarters, Feb. 20, 1956, requesting assistance in procurement of new rockets.

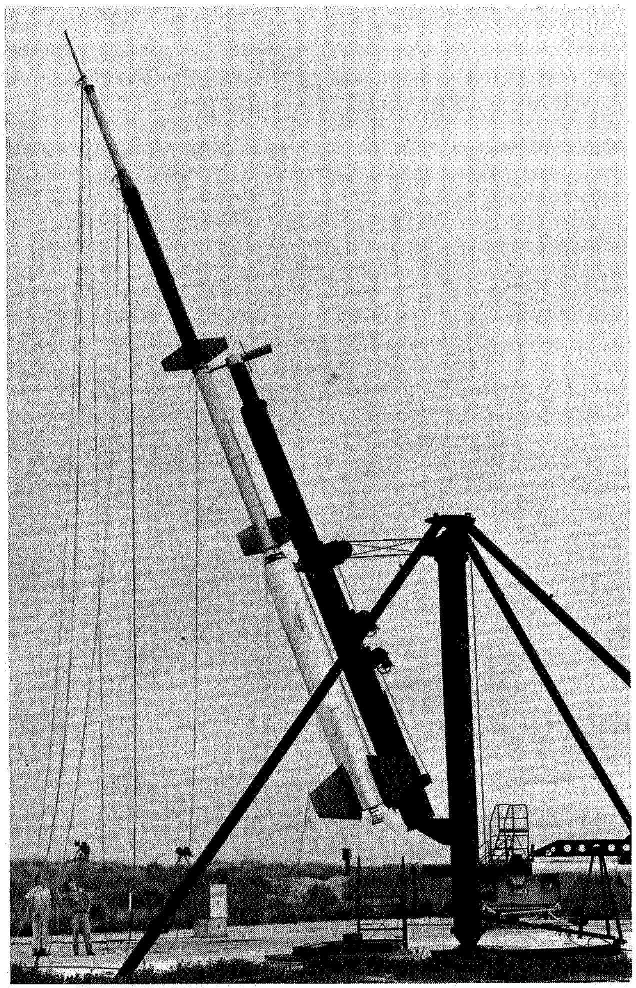


FIGURE 386. First five-stage Sergeant vehicle ready for launch in test of heat transfer to blunt cylinder at Mach 18. Test took place on June 27, 1958.

Instead, a ground-command system was used, that operated in conjunction with the DPN/19 beacon carried in the third stage as a tracking aid to the Reeves Mod II radar. In operation, the actual trajectory of the vehicle was followed on the radar plot board and a command signal to fire was sent when the trajectory reached the desired downward angle. For safety, a mechanical timer was also used, which would have fired the second stage at a somewhat later time in case of failure of the radar beacon system. The same timer also prevented the command system from firing the rocket early in the flight because of vibrations or other reasons. Firing was prevented by keeping the system unarmed until the proper time. The actual settings were 76 seconds after takeoff for arming, and 120 seconds for backup firing. The command system was actuated at 97.5 seconds and provided a trajectory very close to that desired. After the command system ignited the second stage, the successive stages were ignited automatically at burnout of previous stages by means of pressure switches cocked and tripped by the rise and fall, respectively, of the chamber pressure of the motor of the previous stage. Each of the stages was connected by a blowout diaphragm that collapsed upon ignition. At burnout of the fifth stage, the altitude was 94,000 feet.

The distance from Wallops to the model during the end of the test period was in excess of 50 miles. Because of this situation, arrangements were made with the Navy in Norfolk, Virginia, to station a ship about 35 miles from shore and allow the NACA to put a telemeter-receiving station on board. Arrangements for the ship were made by R. L. Krieger, F. B. Smith, and H. Kyle during a visit to CINCLANT in Norfolk on November 26, 1957 (ref. 35). NACA Headquarters formalized the request by contacting CNO in Washington, D. C.[11]

11. Letter from J. W. Crowley to Deputy Chief of Operations (Air), Dec. 19, 1957, regarding approval to place a telemeter receiving station aboard a Navy ship offshore from Wallops.

As was the case in previous initial hypersonic flights, the test model was designed for aerodynamic heat transfer measurements. The forward section of the model was a 5.2-inch-diameter cylinder made of 0.05-inch inconel with a blunt copper spherical-segment nose having a radius of 11.7 inches. Such a shape had been found earlier to provide an almost constant heating rate across the face, and was similar to the shape to be selected for the bottom of the Mercury capsule in its original design. The forward copper face was 0.50-inch thick and was welded to the inconel cylinder behind it. The face and a part of the cylinder were equipped with chrome-alumel thermocouples. The telemeter was located just behind the nose and was protected from the hot shell by an insulating shield. The model stage was stabilized by a 10-degree flare that extended back as far as the rocket nozzle.

The flight results for heating rate at the stagnation point of the nose were in fair agreement with the theory of Fay and Riddell, which takes into account equilibrium-dissociated air. Flow over the face itself appeared to be laminar, but it was not as uniform as had been predicted by simplified theory. The heating rate along the cylindrical sides was roughly 10 percent of the stagnation-point rate (ref. 36).

The second Sergeant motor, supplied by the Air Force BMD, was used in the second Sergeant five-stage vehicle, which was flown on November 20, 1958. Structurally, it was identical with the first vehicle except for some strengthening of the structure at the antenna insulating ring. The nose was different in that a flat nose was used and special instrumentation was installed to measure radiative heating from the very hot boundary layer behind the shock. Unfortunately, through an error in wiring, the third stage, instead of the second stage, fired when the command was given, and although the remaining stages fired in order, the maximum Mach number was only 14.5 instead of 18. The data from this flight were never reported because the amount of radiative heating was quite small.

AERODYNAMIC STABILIZATION OF SLENDER MISSILES

The aerodynamic stabilization of missiles usually meant the addition of fins that extended out from the body as much as the width of one diameter. This could be tolerated for ground-launched missiles or for externally carried air-launched missiles. With internally carried missiles, however, stowage space was at a premium, and efforts were made to keep the span of the fins low. This usually resulted in the use of low-aspect-ratio fins. In some cases, the fins were folded while stowed and were opened at release. This arrangement complicated the missile design but did allow the use of the more efficient high-aspect-ratio fins. The Army became interested in fin-stabilized ammunition in its efforts to increase the velocity of its rounds. Here again, the fin size was limited, this time by the bore of the gun barrel. Several rocket flights were made to provide data needed for the design of this general class of slender or small-diameter missile.

A summary of available data on the lift and stability of a wide range of combinations of wings, tails, and bodies of interest for fin-stabilized ammunition was prepared for the Army by P. E. Purser and E. M. Fields. The summary included a list of 179 reports that covered theoretical aspects as well as experimental measurements from rocket models and wind tunnels (ref. 37).

Hemispherical noses and cylindrical bodies of fineness ratio 20 were used on the first two general research rocket models to provide data on high-aspect fins that might be used for a folding-fin missile. Both models had four rectangular tail fins with an overall aspect ratio of 5; and one model had four rectangular fins located forward of the center of gravity as control fins. This second set of fins had an aspect ratio of 3.4. The models were launched by a double Deacon booster and were then propelled to a Mach number of 2.5 by an HVAR rocket motor mounted internally. While they were rolling at a rather fast rate, the models were disturbed in pitch by pulse rockets. The data were analyzed by the method of R. L. Nelson (NACA TN 3737). Rather poor agreement was obtained with theory, partially because of the thick boundary layer or separated flow present on these extra-long bodies (ref. 38).

One method of reducing the span of the stabilizing fins was to use fins of very low aspect ratio and to employ six fins instead of four. There was some indication that such an arrangement might also have less induced roll than a four-fin body. To evaluate these effects, two rocket models having fineness ratios of 12 and 18, respectively, were flown with six fins of very low aspect ratio for stabilization. The models were propelled by a single Nike booster to a Mach number of about 3.2. Again, Nelson's method of analyzing rolling symmetrical missiles was used. The results indicated little induced roll resulting from combined pitch and yaw motions. Both models were stable and had constant center-of-pressure locations over the Mach number range (ref. 39).

The last rocket model in the slender missile series had a flared skirt for stabilization instead of fins. Such a system had been used with considerable success on the final stage of the hypersonic heat-transfer models. The model was an ogive-cylinder of fineness ratio 11.5, with a 10-degree flare at the base. It was accelerated to a Mach number of 3.2 by a Nike booster, as shown in figure 387. After separation, induced by firing a small rocket motor in the base of the model, pulse rockets were used to provide a disturbance in pitch. Despite the apparent symmetry of this configuration, a rolling motion developed during the burning of the separation rocket and persisted throughout the flight. At Mach numbers near 3.0, the rolling motion appeared to increase, indicating some induced-roll effects, but at Mach numbers below 2.0 (approximately), the roll subsided somewhat. The absense of appreciable damping-in-roll apparently contributed to the maintenance of roll in the flight. The center of pressure was located near the midlength of the body (ref. 40).

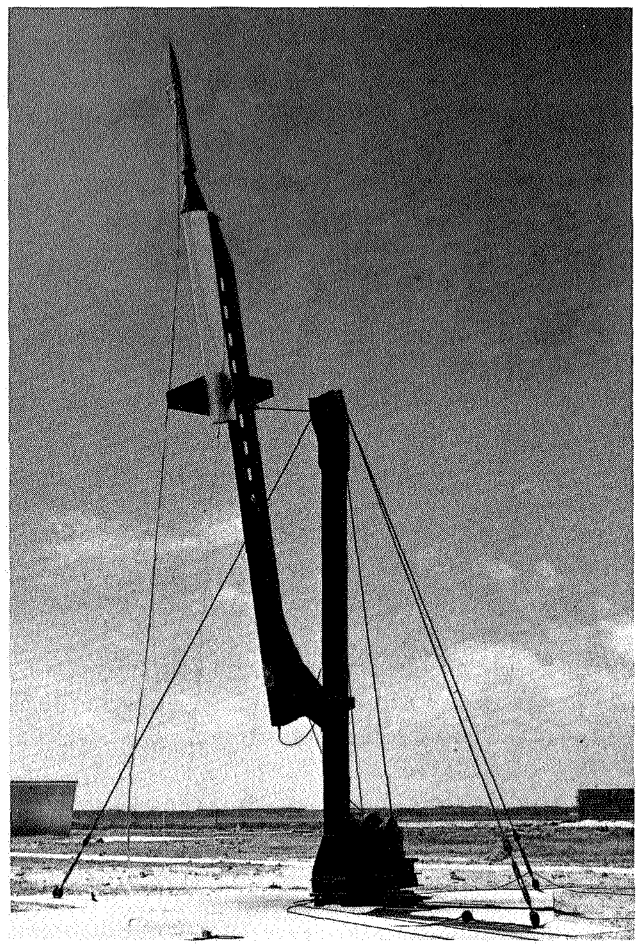


FIGURE 387. Ogive-cylinder-flare missile ready for flight stability test with a Nike booster, May 2, 1957.

UNIVERSITY OF TEXAS DRAG BALANCE ON RM−10 MISSILE

The Defense Research Laboratory of the University of Texas had developed an acceleration-insensitive drag balance for Johns Hopkins Applied Physics Laboratory (APL), to be used in measuring skin friction on missiles in flight (ref. 41). It had been flown successfully on an Aerobee-Hi sounding rocket and then on a Viking (ref. 42). On July 31, 1957, representatives from Texas visited Langley and proposed that skin friction on a section of an RM-10 missile be measured with one of these balances.

The test was desired for correlation with the extensive amount of data accumulated on this general research model, and to obtain data at a high Reynolds number. With the support of APL, Texas offered to install the balance on a section of an RM-10 if the NACA would furnish the RM-10, instrument it, and flight test it. The Texas system made use of a patch of skin two inches in diameter contoured to match the surface of the missile (ref. 43). On September 26, 1957, NACA Headquarters accepted the offer of the University of Texas and APL.[12] The forward skin of the RM-10 missile to be used was sent to Texas for installation of the patch and internal balance. The critical part of this balance was the method for canceling acceleration forces. After several months of work, a new design under development persisted in being responsive to inertia loads, and it became necessary to revert to the original design used in the Viking.[13] Work on the RM-10 at Langley was also delayed, so the launch date was moved from the original date of October 1958 to the early 1959. The model was flown successfully on February 18, 1959. A T40 rocket motor, mounted internally, was also used to provide a maximum Mach number of 3.35. The data were transmitted to Texas in May 1959.[14]

The drag balance readings appeared to be affected by rapid changes in acceleration at rocket ignition and cutoff, but further analysis was required to determine whether any error persisted during steady conditions. In addition to the drag-balance readings, a number of other measurements were forwarded to Texas for further analysis under terms of the University's contract with APL. The data included measurements of skin temperature, total pressure, and acceleration, as well as velocity and trajectory as determined by NACA instruments. Also supplied to the University were measurements of total pressure in the boundary layer at the same distance from the nose as the skin-friction balance. The measurements were obtained with a small pressure probe. The analysis by Texas produced the following statement: "After a considerable study of these flight results it was concluded that the skin friction balance was extremely sensitive to large rates of change of acceleration" (ref. 44). It appeared that the high inertia loading produced a permanent deformation of the balance structure. Nevertheless, the measured data were only about 20 percent greater than calculations according to turbulent theory. The results deduced from the pressure probe data were in closer agreement with theory, although some effects of heating were indicated. The probe was, therefore, recommended as the preferred device. This was the device that PARD had been using all along.

AIR FORCE JASON PROJECT

The JASON Project was the part of the ARGUS Program concerned with data gathering by high-altitude sounding rockets. The ARGUS Program was established to study the behavior of artificial radiation generated by a nuclear explosion in space. It was carried out by the Air Force Special Weapons Center (AFSWC) for the Advanced Research Projects Agency (ARPA) of the Department of Defense. The program had its origin in the postulation of N. C. Christofilos of the University of California, Livermore, in October 1957, that such radiation would be trapped by the earth's magnetic field and remain a hazard to space flight for an extended period. With the successful launching of the unmanned satellite, *Sputnik I*, by Russia on October 4, 1957, and the imminence of manned space flight, a positive evaluation of this effect was imperative.

In the ARGUS Program, small A-bombs were exploded above the atmosphere in the South Atlantic on August 27, August 28, and September 6, 1958. Radiation was measured by sounding rockets launched before, during, and after these bursts from Wallops Island, Virginia, Cape Canaveral, Florida, and Ramey Air Force Base, Puerto Rico. Radiation measurements were also made by the *Explorer IV* satellite. The A-bombs were carried aloft to an altitude of 300 miles by modified Lockheed X-17 rocket vehicles launched from the rocketship Norton Sound. At the explosion of one of the A-bombs it was noted that "The initial flash was followed by an auroral luminescence extending upward

12. Letter from Ira H. Abbott to F. W. Fenter, Sept. 26, 1957, regarding offer to furnish drag balance for test on RM-10.
13. Letter from M. J. Thompson, DRL, to H. J. E. Reid, Sept. 10, 1958, regarding RM-10 missile test with University of Texas skin-friction balance.
14. Letter from Langley to University of Texas, May 29, 1959, transmitting results of RM-10 flight test with University of Texas drag balance.

and downward along the magnetic lines where the burst occurred" (ref. 45). The measurements by the JASON sounding rockets contributed to the understanding of this behavior.

The first contact between AFSWC and Langley in this program was on May 6, 1958, when Captain John J. Buckley, Project Officer of the JASON Project, visited Langley to enlist aid in converting the PARD Honest John five-stage launch vehicle into a high-altitude sounding rocket. He explained that a rocket was needed to carry a 30-pound payload to an altitude of at least 300 miles, and that, "after examining all existing rocket vehicles, the Air Force had concluded that this five-stage system was, by far, the most feasible and economical for the job" (ref. 46). The most difficult part of the project was the tight schedule. Approximately 21 vehicles had to be launched before September 1958, when the moratorium on nuclear air bursts was to go into effect. AFSWC planned to procure the necessary rocket motors and to contract with Aerolab Development Company for the construction, assembly, and launch of the sounding rockets. The original plan was to make the necessary developmental firings at Wallops, but to make the operational launches from Cape Canaveral and two other sites outside the continental limits of the United States. Although the launch crew at Wallops could handle the assembly and launch there, new crews would have to be trained for the other sites. Aerolab had done an excellent job of constructing many different types of rocket models and launch-vehicle components for PARD and had launched some small rocket models at White Sands, but this new undertaking was by far the most ambitious one. Nevertheless, Shortal and other Langley representatives agreed with the choice of Aerolab. Later, Aerolab was to produce a series of sounding rockets for general use, based in part on this and other PARD vehicles. The later series would be identified by the name "Argo."

Lockheed Aircraft Corporation was assigned responsibility for the instrument package and the telemeter for the JASON Project, in addition to the X-17 launch vehicle for the A-bomb. Their experience with the earlier X-17 heat-transfer program at Cape Canaveral made them well qualified for this task.

Langley was asked to assist Aerolab and Lockheed as needed, and to launch two of the test vehicles to check out the system and to train other crews in assembly and firing techniques. Langley was also to supply consultation services, including, possibly, technical representatives at the launchsites during the tests. AFSWC agreed to supply the necessary travel funds. In view of the national importance of this project, approval of the request was recommended to NACA Headquarters. On May 13, 1958, AFSWC sent through a formal request to NACA Headquarters, which approved it on May 19, 1958, and issued RA A73L271 to cover the work.

On May 19, 1958, representatives from AFSWC, Lockheed, and Aerolab visited Langley and reached agreement on several details of the project. Aerolab was to build everything back of the instrument package, which was to be the responsibility of Lockheed. The instrument package was to have the same diameter as the last stage of the launch vehicle (6.2 inches) and to be 44 inches in length. It was to be a hemisphere-cylinder and would weigh 58 pounds. PARD calculated that such a package could be lifted to an altitude of 400 miles with the five-stage vehicle. The instrument package was to contain an FM/FM telemeter of sufficient power for this distance, and would include instruments to measure accelerations as well as radiation. Lockheed was to provide the telemeter receivers. Three models were planned for launch at Wallops, the first on July 3, 1958. All flights were to be completed by August 1, 1958 (ref. 47).

Not an unimportant phase of the project was construction of a launcher and rocket-storage facility at each of the launchsites. Langley supplied AFSWC with drawings of the wire-braced launcher constructed at Wallops for the Honest John five-stage vehicle discussed earlier.

On June 11, 1958, AFSWC informed the NACA of a change in plans and stated that, scientifically, Wallops Island was a very desirable site for launchings during the actual experiment. Accordingly, AFSWC asked approval for the launching of five vehicles during August, in addition to the checkout vehicles agreed to earlier. Now the launchsites were to be Wallops, Cape Canaveral, and Puerto Rico. This change in plans simplified the job because now only one entirely new launch complex would be required, that at Puerto Rico. NACA personnel and facilities could be used at Wallops and Air Force personnel and facilities could be used at the Cape. At Puerto Rico, a location near Ramey Air Force Base was selected, and some assistance was expected from the Air Force personnel there. Three launchers were constructed at the Cape and two at Ramey.

Now that Wallops was to be one of the actual test sites, an additional launcher was required there, plus a ready booster storage facility. To meet the need, construction of a duplicate of the cable-braced launcher was expedited at the north end of the launch area. For the storage facility, a shedlike building, about 27 feet by 172 feet was constructed behind the Assembly Shop. It fronted on the new roadway connecting with the launch area, as shown in figure 388. For easy access, the building was left open on the long side facing the Assembly Shop. Funds for the launcher and storage facility were furnished by AFSWC.

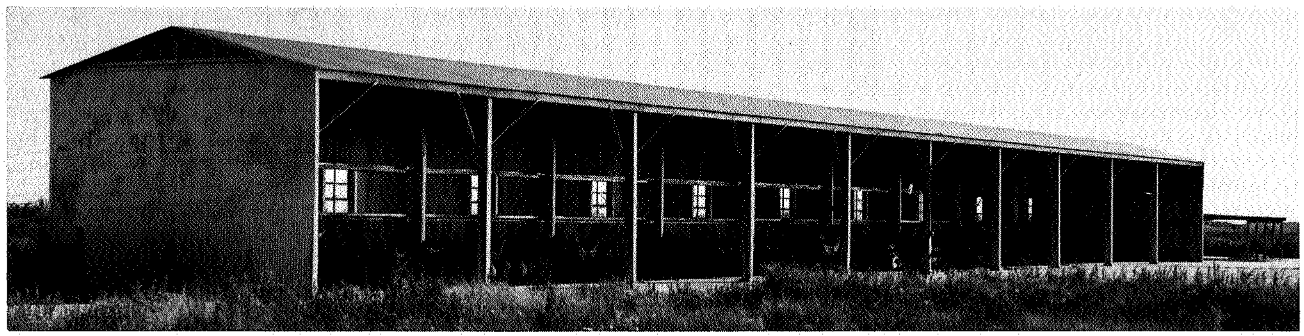


FIGURE 388. Ready booster storage building erected behind Assembly Shop for Project JASON, September 1958.

The entire ARGUS Program was probably the most ambitious rocket-vehicle program ever undertaken with such a short time schedule. The fact that neither the Lockheed X-17 nor the Honest John five-stage system had been launched before as a sounding rocket introduced some questions into the program. New payload packages for both vehicles had to be designed, constructed, and instrumented. In addition, all the rocket motors and components had to be procured. Each of the 3 X-17 vehicles required a Sergeant motor and four Recruits, while each of the 23 Honest John vehicles required one Honest John, two Nikes, one Recruit, and one T55 motor. In the meantime, the launchsites had to be prepared and crews obtained for training. Less than 2 months were available to accomplish this! All rocket motors and components had to be transported by Air Force airplane. Of course the program had the highest priority of DOD, but that did not ensure meeting the schedule. Wallops personnel took the job in stride as just another rocket project. While the components for JASON were arriving, the Wallops crew was busy assembling and launching four other multistage vehicles, the largest of which was the first Sergeant five-stage system, launched on June 27, 1958.

The first JASON vehicle was launched at Wallops on July 11, 1958, to check out the system. The fifth stage broke away during burning of the third stage, and gloom settled over the island. It was found that a shear flange had been overlooked in converting the PARD design to JASON. This was quickly added to the next vehicle, which was launched on July 17th. This time the third stage did not ignite. Now the experts from Langley and Wallops went over all the Aerolab components. Because of the number of vehicles and the fact that other ranges were to be used, Wallops had departed from its usual system of making up all electrical wiring to the rocket igniters on the job. In this case, Aerolab technicians had performed the task. After detailed examination of all systems, the igniter assembly for the third stage was changed and the instrument package was strengthened. In addition, examination of the wiring showed that the crimping method used in making electrical connections did not ensure a tight joint, and the possibility existed of an open circuit's developing during accelerated flight. Langley and Wallops propulsion technicians then remade all the firing leads with solder joints, as had been the practice before. This remade vehicle, shown in figure 389, was launched on August 1, 1958, with complete success. This was indeed fortunate, because only three vehicles had been allotted to the development program.

The aim of the program was to reach an altitude of at least 300 miles. The first successful flight exceeded this by a large margin. Because the vehicle had neither a guidance nor destruct system, the elevation angle for the launch was set at 80 degrees for range safety, although this reduced the possible altitude. Since the Wallops radars could not track such a vehicle to its peak altitude, the Millstone Hill radar of the MIT Lincoln Laboratory near Boston, Massachusetts, was called upon for assistance.

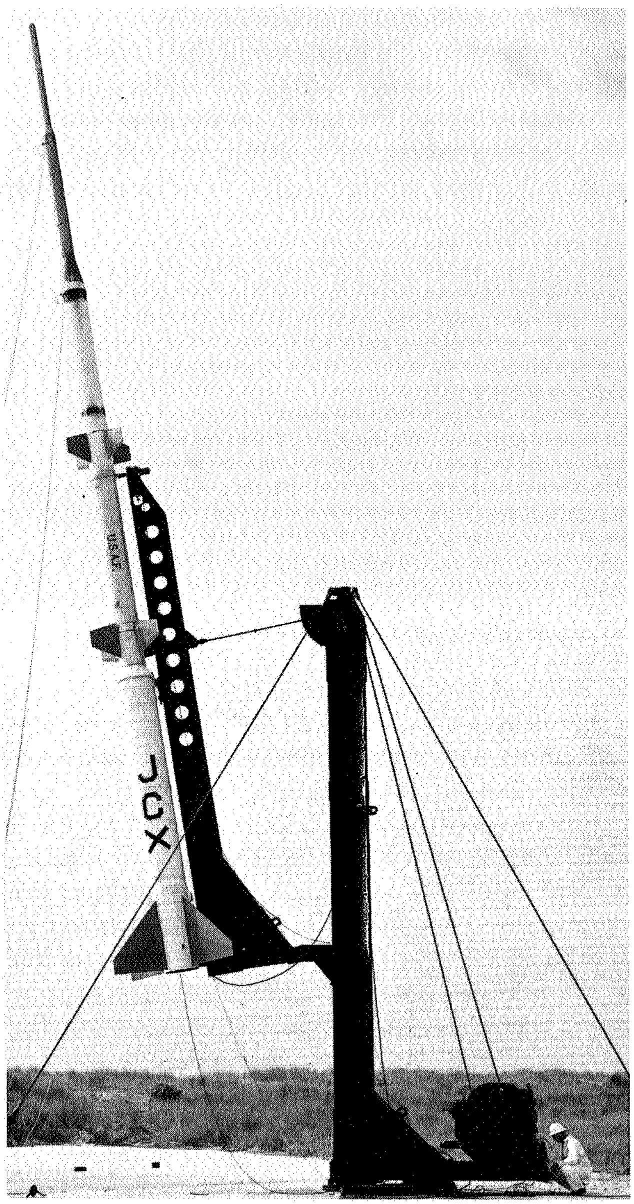


FIGURE 389. The first successful JASON vehicle launched at Wallops, August 1, 1958.

Millstone personnel reported that on August 1 they tracked an object to an altitude of 470 miles and indicated an impact point at latitude 36.2° North and longitude 65.5° West. This placed impact about 570 miles from Wallops on a bearing of 103 degrees true azimuth and about 270 miles north of Bermuda.

The JASON vehicle was basically the same as the earlier Honest John vehicles except for the payload package and the firing sequence. As mentioned earlier, the payload extended about 45 inches ahead of the T55 motor in the fifth stage. The entire last stage was a 6.2-inch-diameter cylinder 82.5 inches long, with a hemispherical nose and a 10-degree stability flare at the base. The skin of the nose and instrument package was made of titanium, while the flare and the protective shell around the T55 motor were made of inconel. The payload weighed 49 pounds. The total vehicle was 57.3 feet long and weighed 7,100 pounds.

The first three stages had tapered, unswept fins for stabilization, while the fourth and fifth stages had flared skirts. The stages were connected in the same manner as that used previously.
The plug adapter connecting the first and second stages did not have a locking device and merely slid away from the second stage after burnout of the Honest John stage. A delay igniter, activated at launch, ignited the second stage about 5 seconds after this separation. Near burnout of the second-stage motor, another delay squib, also activated at launch, fired and withdrew a pin locking the second and third

stages together. After burnout of the second stage, it was then free to drag separate. The last three stages then coasted about 20 seconds. This coast period was a compromise between a desire to fire the upper stages at high altitude, where the drag would be lower, and a need to fire these stages at a low enough altitude to ensure aerodynamic stability. The third stage was fired at an altitude of about 65,000 feet, by means of a mechanical timer which also energized a delay squib that was to ignite the fourth stage shortly after third-stage burnout. The fourth stage was attached to the third by a disc designed to collapse under pressure at firing of the fourth-stage motor. The fifth stage was connected to the fourth by the same type of disc and was ignited by operation of a pressure switch that was cocked when the fourth stage was fired and then closed when the pressure decreased at burnout of the fourth-stage motor. Burnout of the fifth stage occurred at an altitude of about 115,000 feet and a velocity of 13,000 feet per second.

In the flight on August 1, 1958, the Lockheed telemeter in the fifth-stage instrument package performed well and provided data on accelerations from which the performance of the vehicle was determined in support of the radar measurements. In a later flight, telemeter data were received at Cape Canaveral with the aid of a 60-foot antenna. Andrew G. Swanson analyzed the performance of the first successful vehicle and that of a vehicle under various assumed payload weights and wind conditions (ref. 48).

Following the successful launching of August 1, 1958, the remaining JASON vehicles and the other components of the entire ARGUS Program were rushed to completion, and final plans for the actual A-bomb experiment were finalized. A large number of Aerolab and Air Force personnel were at Wallops for observation and training. The Project Officer for AFSWC at Wallops was Major F. W. Korbitz, Jr., shown in figure 390. After the firing on August 1, the two crews being trained at Wallops went to their stations at Cape Canaveral and Puerto Rico. When Langley was asked to supply a technical representative to assist the crew at Puerto Rico, J. T. Markley, a member of the Heat Transfer Section of PARD, was given the assignment. He not only provided the required assistance there but also participated in negotiations with the CAA in connection with interference problems that arose between air traffic control and the JASON flight vehicles. He demonstrated so much initiative and operational capacity in this type of assignment that, at its completion, he was transferred to the branch headed by Krieger, to assist him in operational analyses for other projects involving rocket flights that were to cross established air routes.

The first JASON firing at Wallops as a part of the actual ARGUS experiment was performed on August 25, 1958, to obtain base-point readings of radiation existing prior to the A-bomb explosion. This flight was only partially successful, because the telemeter did not function properly. The Millstone Hill radar was not available for the operational launches. Instead, altitude of each launch at the three stations was estimated from the length of time a telemeter signal was received, and also from "look" angles of the large telemeter antenna at Cape Canaveral, which was able to receive signals from vehicles launched from all three stations. The weather at the time of the August 25 launch at Wallops would have been considered unsuitable for normal Wallops launches because of rain and overcast skies. Prior to launch, lightning caused ignition of a black powder charge in a bolt-retracting mechanism, but it was replaced in time for the launch.[15]

The next launch, at 2:27 a.m., August 27, 1958, coincided with the first A-bomb explosion in the South Atlantic. Everything worked as planned, and a telemeter signal was received for over 16 minutes. Then followed three flights during the night of August 29–30. These were at 10:46 p.m. on the 29th and at 12:16 a.m. and 2:19 a.m. on the 30th. In figure 391, the three vehicles are shown at Wallops, ready to go. These three flights were before, during, and after the second nuclear burst. All flights were successful. Another launching was made at 5:00 p.m. on the 30th to obtain more information on decay rates. While these four vehicles were being launched at Wallops, three were launched at Cape Canaveral and two at Puerto Rico, for a total of nine launchings between 10:46 p.m. on August 29 and 7:01 p.m. on August 30. The operational launches from Wallops were made on an azimuth of 165 degrees, while those from Puerto Rico were on an azimuth of 330 degrees, and those from Cape Ca-

15. As discussed earlier in this chapter, part of the bad weather was associated with hurricane Daisy as it passed along the east coast Aug. 28–29, 1958.

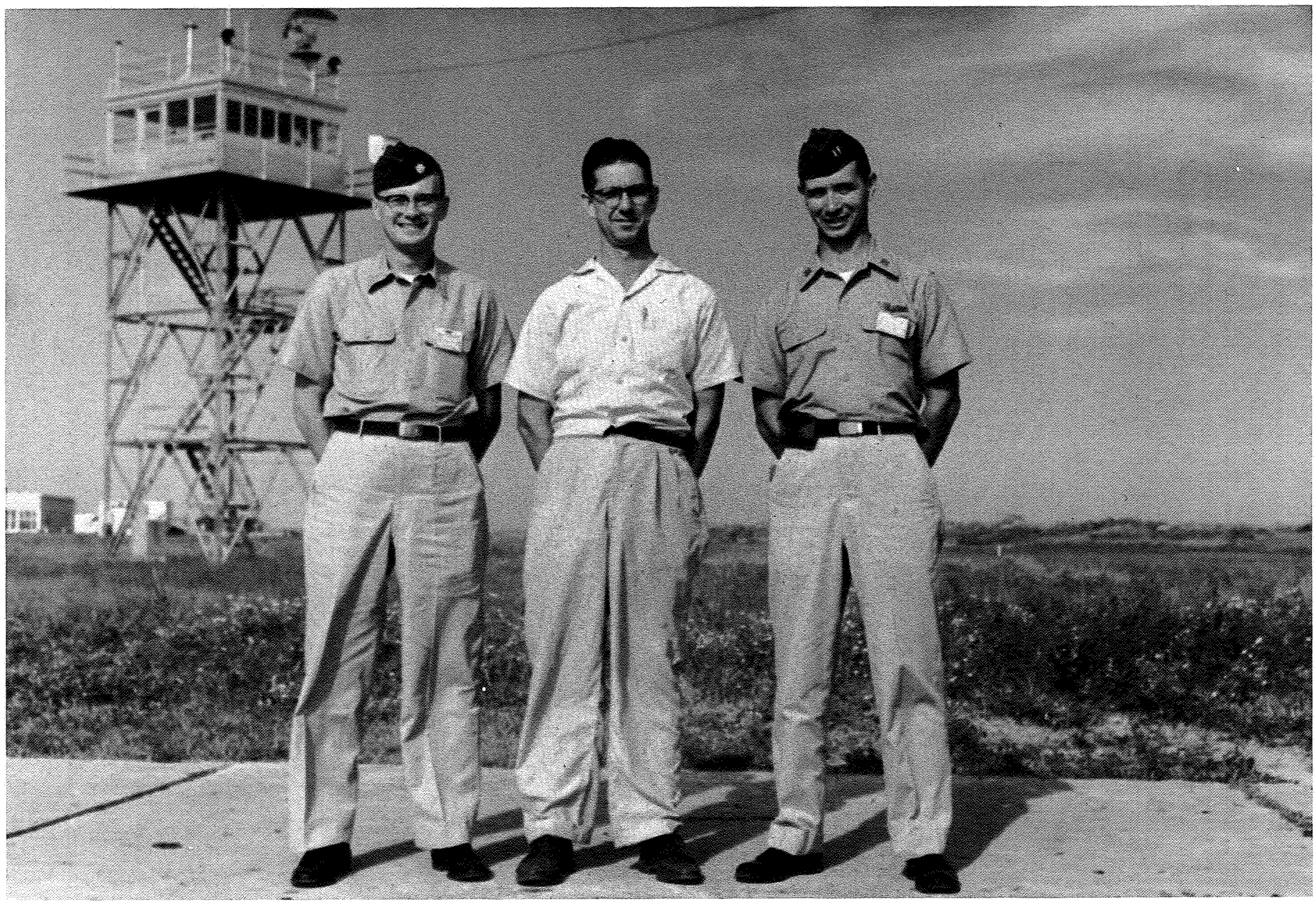


FIGURE 390. Engineer J. C. Palmer (center) with AFSWC project officers F. W. Korbitz, Jr., and R. G. Dingman (left and right) at Wallops for JASON launchings.

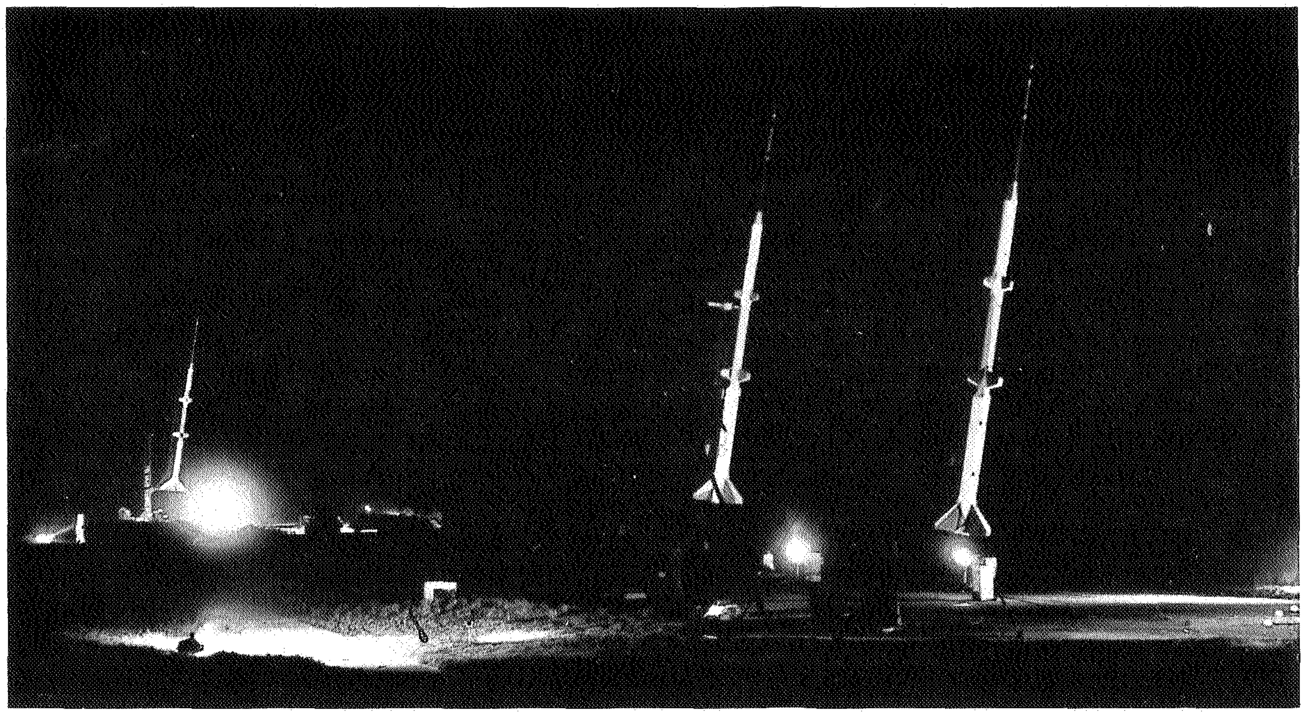


FIGURE 391. Three JASON vehicles ready for launch at Wallops on the night of August 29, 1958.

naveral, at 85 degrees. Thus the firings from Wallops and Puerto Rico were almost in line and diametrically opposed, while the Cape launchings crossed this path at right angles. The last launch at Wallops was on September 2, 1958, at 3:00 p.m., as shown in figure 392. This flight also was successful.

In all, 10 flights were made at Wallops, 3 of which were developmental. Six operational flights were made from each of the other sites. Data were also obtained from the Explorer IV satellite. In fact, the air bursts were timed to enable this satellite to be of the greatest use. In the final nuclear explosion on September 6, 1958, only Explorer IV was available. As it turned out, the data from Wallops were the most useful because of the path taken by the radiation from the burst.

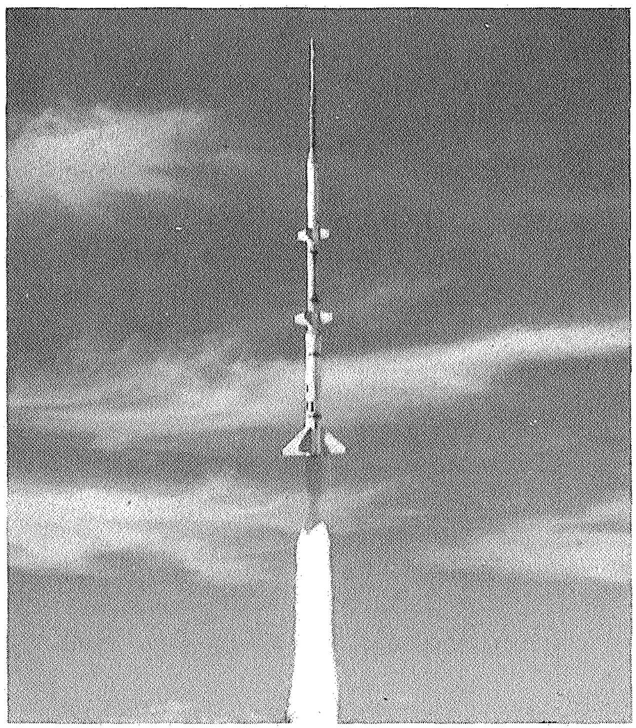


FIGURE 392. Final launch of the JASON series at Wallops, September 2, 1958.

AFSWC was very much impressed by the performance of the JASON vehicle, and on September 15, 1958, the Commander sent a letter of thanks to the Director of the NACA, with an endorsement by the Commander of the Air Research and Development Command. Major General W. M. Canterbury, AFSWC Commander, stated, "I am delighted to report that its demonstrated reliability (JASON) during the critical period of the project was 100 percent. This remarkable record, of which I am justifiably proud, was achieved—and could not have been otherwise—with the wholehearted, enthusiastic and expert assistance of the NACA." He commented on the direct contributions of Palmer, Krieger, Markley, and Swanson, and stated further that "My people were strongly impressed by the obvious high morale and esprit demonstrated by the Wallops Island crew and by the pleasant attitude of informality surrounding its operations—an attitude which proved to be of tremendous value in getting the job done well, done right, and done in a hurry." The letter did not reach NACA Headquarters until October 2, 1958, one day after the NACA became NASA, and the new Administrator, T. Keith Glennan, forwarded the letter to PARD with his own personal thanks, as one of his first official acts of commendation.

The president of Aerolab Development Company, E. G. Crofut, expressed his thanks to PARD saying, "I know I'm speaking for all personnel at Aerolab who are just 'busting with pride' when I say that it would not have been possible without your help."[16]

The responsibility for Project JASON lay with AFSWC, and decisions regarding such things as time of firing and range clearance were theirs. One decision was to backfire on Wallops later. The path of the various stages of the JASON vehicle between Wallops and the impact point west of Bermuda crossed several major oceanic airways. AFSWC decided to avoid the interference problem by rerouting all commercial air traffic in the area during the time of the experiments. This was accomplished through an official request of Roy W. Johnson, Director of ARPA, to James T. Pyle, CAA Administrator.[17] Johnson requested that CAA control centers arrange to reroute air traffic in an area extending 700 miles seaward from the three launchsites—Wallops, Cape Canaveral, and Ramey Air Force Base. When this was done during the actual experiments, the pilots and the airlines "raised the roof." Disruption of air traffic was intense, and afterward, everyone said "Never again!" Although ARPA obtained the approval for rerouting the airlines, Wallops was blamed for that part of the disruption associated with launchings from Wallops. Later, the CAA even suggested that Wallops be prohibited from launching long-range vehicles in the future. It was several months before this problem was finally settled, as will be discussed later in this chapter.

The ARGUS experiment, itself, was a complete success. The theory of Christofilos was completely borne out, and the ability of an atomic explosion in space to create a region of intense radiation with a long decay time was demonstrated. The free electrons apparently were trapped by the earth's magnetic field in a process much the same as that evidenced in the Van Allen radiation belt. Such radiation could be a hazard for long-term exposure of men and would require consideration in space station design.

UNIVERSITY OF MICHIGAN EXOS SOUNDING ROCKET

Early in 1957, the Air Force became interested in a sounding rocket that could take a 50-pound payload to an altitude of 300 miles. The interest stemmed from a need of WDD for data on air density to this altitude in support of a "high altitude reconnaissance aircraft, believed to be a satellite vehicle." WDD arranged with the Air Force Cambridge Research Center (AFCRC) to handle development of the required sounding rocket as they had done for the Nike-Cajun vehicle. AFCRC, in turn, contracted with the University of Michigan's Aeronautical Engineering Department under the direction of L. M. Jones, who was assisted by W. H. Hansen, F. F. Fischbach, and others. Jones and Hansen had worked with PARD in development of the Nike-Deacon and the Nike-Cajun sounding rockets.

16. Letter from E. G. Crofut to NACA-PARD, attention of Joseph Shortal, Sept. 19, 1958, regarding successful JASON Project.
17. Letter from Roy W. Johnson, Director, ARPA, Aug. 4, 1958, to James T. Pyle, Administrator, CAA, regarding arrangements to reroute air traffic during JASON rocket launchings.

Jones and Hansen visited Langley on March 20, 1957, and discussed the need for the new vehicle. They requested the technical assistance of PARD in the development and the assistance of Wallops in the initial test firings. They also asked for advice on rocket motors to use for this new mission. They had considered the new Arcon and Iris motors under development by Atlantic Research Corporation. PARD representatives pointed out that a number of different combinations of motors could do the job, but recommended a combination of Honest John-Nike-Recruit for the new vehicle, to be named "Exos" (ref. 49). With regard to test firing such a system at Wallops, it was pointed out that a range in excess of 400 miles would be expected for Exos, and PARD experience had indicated such firings were not feasible at Wallops. The PARD experience referred to was launching of the F40 four-stage heat-transfer vehicle, which had been modified to an over-the-top trajectory primarily to avoid range conflicts.

AFCRC made an official request to NACA Headquarters on May 7, 1957, and Headquarters replied that technical help would be supplied, but that the firings from Wallops did not appear feasible.[18]

The University of Michigan went ahead with the design and construction of three Exos vehicles and gave consideration to test firings at Cape Canaveral, Eglin Air Force Base, and Point Mugu, while at the same time hoping that something would turn up that would allow the firings to be made at Wallops. This looked-for something turned out to be the incipient conversion of the NACA to NASA, and thence to a space agency in the spring of 1958, and the direct interest in making Wallops a full-fledged sounding-rocket range. During a visit of Jones to Langley on March 21, 1958, the tenor of the discussion was considerably different from that of the discussion during his visit a year earlier. Now PARD said "Maybe" instead of "No" with regard to firings at Wallops. In fact, a 5-year plan of firings at Wallops had been prepared by PARD on the assumption that the NACA would get the space assignment. Many sounding rockets were in the program, and there was a feeling that if Exos were developed there might be a place for it in the program. In an attempt to encourage PARD in launching the Exos, Jones indicated that in order to get an earlier start on the expanded space program, it might be possible for PARD to borrow the second and third vehicles, provided they were replaced later. Jones also discussed a system for measuring air density at altitudes up to 200 miles by supplementing his accelerometer, as used with the Nike-Cajun vehicle, with lightweight inflatable spheres. He was seeking a sponsor for this system and asked if PARD would be so interested. In response, PARD asked Jones to submit a proposal (ref. 50).[19] At this time, it was not clear what the role of PARD would be in the space program and whether it would have the responsibility for supporting outside contractors, including universities, in space research. This facet of the creation of NASA will be discussed in more detail later in this chapter. This was but one of many proposals to be received from interested contractors.

An affirmative decision to launch the experimental Exos sounding rockets at Wallops was made a few months later. AFCRC repeated the request for such firings on June 5, 1958, and ARDC added its endorsement and plea for assistance on August 12, 1958. On August 28, 1958, NACA Headquarters officially approved the request and issued RA A74L285 for the project. The rocket was ready before that, however, and the first firing was made at Wallops on June 26, 1958, without waiting for the paperwork to catch up with verbal arrangements. The second vehicle was launched on September 25, 1958. Only two of the three vehicles were launched because after both were highly successful, the third was held for a later firing with a different payload. It was to be launched from Eglin Air Force Base, Florida.

The first Exos rocket is shown in figure 393. The launcher supplied by Michigan was obtained as surplus from White Sands Proving Ground where it had been used in the initial flight tests of the Honest John missile. By this time, Wallops had had experience with the JASON Project, and again the MIT Millstone Hill radar staff was asked to assist in determining the trajectory of this new system. The first vehicle, launched at an elevation angle of 75 degrees, reached an altitude of 200 nautical miles,

18. Letter from J. W. Crowley to Commander, AFCRC, May 28, 1957, regarding assistance to the Air Force in development of upper atmosphere research rocket system.
19. Letter from W. H. Hansen and L. M. Jones to J. A. Shortal, Mar. 25, 1958, regarding discussions held at PARD on Mar. 21, 1958, in connection with Exos and the space research program.

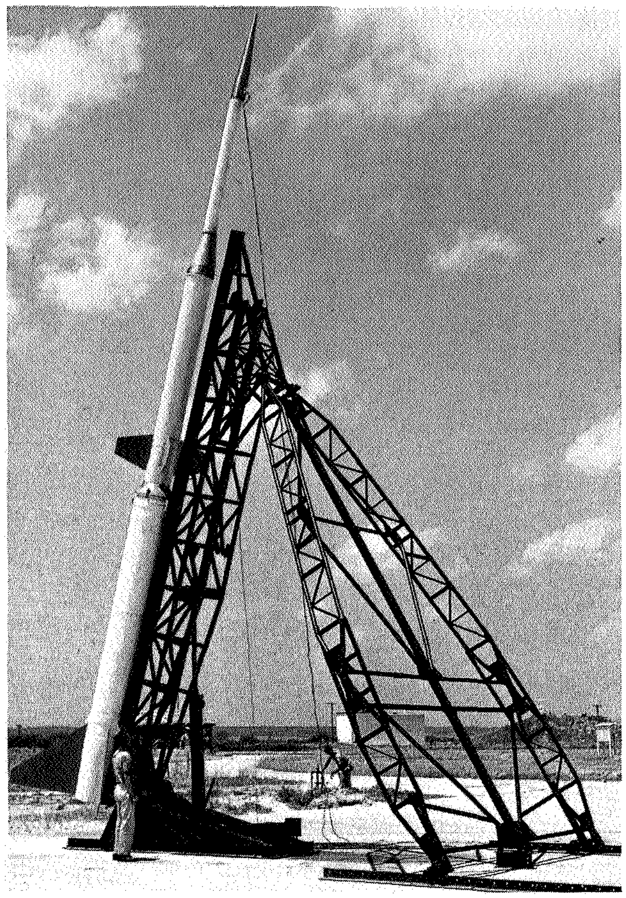


FIGURE 393. University of Michigan Exos sounding rocket, shown on special launcher at Wallops, June 26, 1958.

while the second vehicle, launched at 80 degrees, reached 250 nautical miles, as determined by the Millstone Hill radar. The payload in both cases weighed about 80 pounds. The payload, as well as the basic sounding rocket components, was constructed by the University of Michigan. The telemeter and instrumentation it contained to measure accelerations and skin temperature had been prepared by AFCRC. University of Michigan personnel participated directly in activities at Wallops during the launch.

The three-stage Exos used three of the rocket motors used in the five-stage Honest John vehicle and in JASON, and the corresponding fins and adapters. The Honest John stage drag-separated from the remainder of the vehicle after burnout. The second stage was ignited by means of a delay squib about 25 seconds after this separation. The third stage, connected to the second by a collapsible diaphragm, was fired by means of a switch activated by pressure in the second stage. The range of both vehicles was estimated to have been about 400 miles. The vehicles were about 42.5 feet long and weighed 5,778 pounds. The nose cones were truncated 4.3-degree half-angle cones with 9-inch cylindrical afterbodies. All components except the nose cone were based on proven designs—a fact that no doubt contributed to the success of the program. It was concluded that the Exos was ready for use as a sounding rocket without any change (refs. 51 and 52).

UNIVERSITY OF MARYLAND ORIOLE SOUNDING ROCKET

Assistance provided the University of Maryland by the NACA in connection with developmental firings of the Terrapin sounding rocket in September 1956 has been discussed in Chapter 13. Professor S. F. Singer of Maryland maintained his interest in upper atmosphere research and continued his search for a small, inexpensive system that could be easily transported and launched. He was anxious to involve his students in space research with rocket vehicles.

On March 25, 1958, Singer and graduate student R. T. Bettinger visited NACA Headquarters to describe a small, new sounding rocket and to enlist NACA support in launching some of these from Wallops Island. The rocket system consisted of a Loki solid motor with a pencil-shaped dart 7/8-inch in diameter attached to the front end. Singer called this system "Oriole" but later it was to be identified by others as "Loki-Dart." In operation, the dart would separate from the Loki immediately after burnout of the motor and was calculated to coast to an altitude of 100 miles. Singer planned to launch his first research series of Orioles from Canada but wanted to make preliminary test firings from Wallops before this. His only requirement was for a launch pad, electric power, and radar tracking.

NACA Headquarters indicated that PARD would probably provide the assistance required but that he should contact PARD regarding the details. Singer indicated a need for a rocket range for use by interested universities. He was told that consideration was being given to expanding Wallops for space activities but it was not clear at the time just "what could be done to make it more available to universities" (ref. 53). Later, under NASA, the Wallops range was to be made available to many outside users, including universities, but Wallops would maintain control over all range activities because of safety considerations.

Singer wrote a letter to NACA Headquarters on June 3, 1958, in which he proposed a series of 60 Oriole rocket launchings for space research and asked the NACA's support. W. J. O'Sullivan, Jr., of PARD recommended to NACA Headquarters that the proposed research be sponsored by the NACA (ref. 54). Singer proposed (a) studying the behavior of various gases, including sodium and barium, after release at high altitudes, and (b) firing shaped charges at high altitude. Langley proposed an RA to cover this support and NACA Headquarters approved it as RA 023L19 on August 27, 1958. By this date, some preliminary tests at Wallops had been made.

Bettinger visited PARD on July 29, 1958, and discussed the initial phases of the program. It was agreed that some preliminary tests would be made on August 15 to determine structural integrity of the Oriole, and that tests with instrumented rockets would follow in mid-September. A miniaturized instrument package, less than an inch in diameter, was displayed by Bettinger as a prototype of those to be flown in September. Under the agreement, Maryland was to furnish the launcher, the airborne instrumentation, and ground receiver. The NACA was to furnish the Loki rocket motors and ground support at Wallops (ref. 55). PARD assigned the designation E129 to the Oriole project.

The first firings of the Oriole rocket at Wallops took place on August 14, 1958. One of the rockets is shown in figure 394. Three firings were made, but poor visibility made tracking difficult, and the tests were postponed until the following day. Tracking was especially difficult because of the high acceleration of the Loki motor. On August 15, three more Oriole rockets were launched, and radar tracking was fairly successful. Apparently the Oriole rocket was structurally sound, but the maximum altitude appeared to be lower than predicted.

The experience with the University of Maryland team convinced Wallops personnel that they would have to take direct responsibility for safety in all launchings from Wallops. The earlier idea of Singer that university personnel could be allowed freedom to launch rockets did not prove to be workable. One trouble was that the launcher brought to Wallops was excessively corroded and had to be reworked by Wallops personnel. More serious, however, was the fact that, without prior notice, E. Hinnov of Maryland arrived with two smoke rockets. It would not have come to light that these models contained smoke if Hinnov had not set one off inadvertently in the test area. It was then learned that Bettinger planned six Oriole launchings and Hinnov planned to use four smoke rockets, in addition, to be fired during twilight hours. PARD project engineer C. C. Shufflebarger insisted that the firings be formalized—at least to the point of describing each model and listing the launch angle and the range to be expected—so that Wallops would have the information prior to the tests. In addition, no smoke models were to be assembled at Wallops without Wallops clearance (ref. 56).

Phase II of the Oriole firings at Wallops was conducted on September 22 and 25, 1958. Four models with telemeters and two with smoke were planned. On the 22nd, only one telemeter was functioning properly after assembly, and even it stopped working during launch. Two smoke models were launched at twilight, but no smoke was seen by anyone. On the 25th, a second telemetered model was launched with good success. A signal was received for 150 seconds, estimated as the time to splash. A

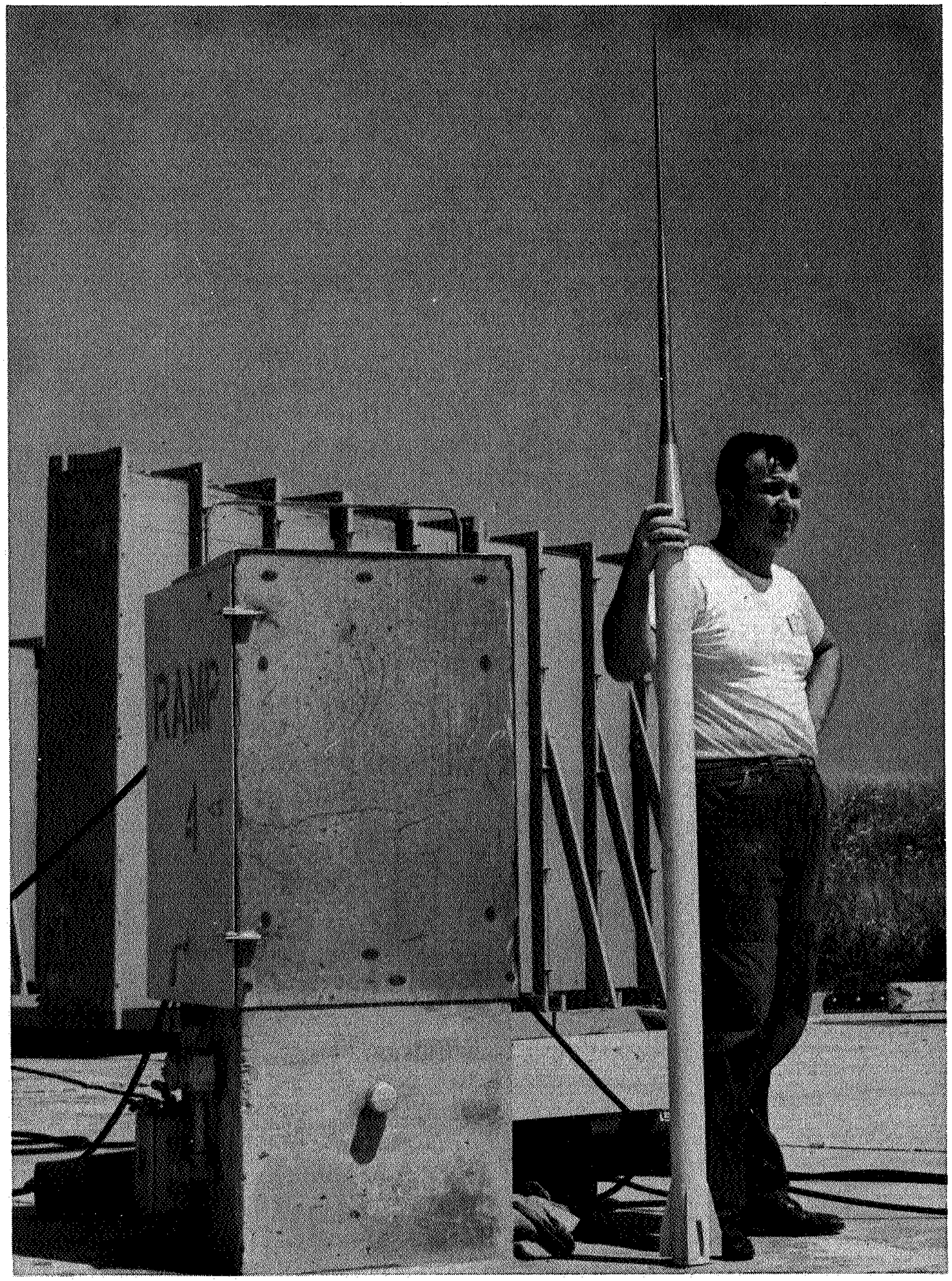


FIGURE 394. R. T. Bettinger of the University of Maryland, photographed at Wallops with Oriole sounding rocket, August 14, 1958.

third smoke model was prepared with some modifications, in view of the negative results on the 22nd. At launch, this rocket became entangled with its launcher and after flying an erratic path when it became free, landed back on the launch pad (ref. 57). This ended the Oriole project as far as Wallops was concerned.

NAVAL RESEARCH LABORATORY ARCON SOUNDING ROCKET

The Arcon sounding rocket was a development of Atlantic Research Corporation (ARC), supported by the Naval Research Laboratory. ARC, under a contract with Army Ordnance, had developed a means of increasing the burning rate of its Arcite plastisol propellant to as much as 7.5 inches per second by the addition of small lengthwise metallic filaments. With this high burning rate, ARC now calculated that it would be possible to build a slender rocket motor the size of the Deacon, with an end-burning grain, and to produce a thrust of 1,430 pounds with a burning time of 24 seconds, for a total impulse of 34,000 pound-seconds. In comparison, the improved Deacon, under development by the NACA as the Cajun, produced 8,300 pounds of thrust for 3 seconds, for a total impulse of 24,900 pound-seconds. The increase for the Arcon resulted from a propellant of greater impulse and higher density, and a greater loading density due to absence of the internal cavity used in the Deacon and Cajun. ARC also calculated that the long-burning motor would reach a higher altitude as a sounding rocket because the thrusting period covered a range of higher altitudes with lower drag losses. Some of these advantages over the Cajun would be offset by the need for a heavier insulating liner to protect the motor case from the hot flames of the burning propellant. The amount of insulation required had not been determined.

At a meeting of Army Ordnance, BuOrd, NRL, Air Force, and NACA representatives on October 20, 1955, ARC made a proposal for development of such a sounding rocket (ref. 58). ARC calculated that the rocket could reach an altitude of 325,000 feet with a payload of 20 pounds, when launched at sea level. Similar calculations for a Deacon indicated an altitude of only 36,000 feet. The Army Ordnance and Air Force representatives expressed an interest in procuring such a sounding rocket but were not interested in financing its development. NACA representative, W. J. O'Sullivan, Jr., stated that the NACA had no immediate need for such a rocket. The NRL representative, John W. Townsend, and BuOrd representative, Elliot Mitchell, were more interested in the proposal. Later in the year, NRL and BuOrd jointly undertook development of two sounding rockets of this type, one the size of the Deacon, named "Arcon," and a larger rocket named "Iris."

While the Arcon sounding rocket was being developed by ARC, NRL developed a highly mobile transporter and launcher, which would allow launching from most anywhere on land or ship. This equipment was designed to handle either the Arcon or Iris (ref. 59).

On May 29, 1958, NRL representatives visited Langley and described the Arcon and its special mobile launch complex as well as its planned use in physical research at high altitudes. NRL asked for permission to use the facilities at Wallops to fire three models as proof tests of the rocket and the launch equipment (ref. 60). On June 4, 1958, a formal request was made by the Director of NRL to the Director of the NACA for permission to launch three Arcon rockets at Wallops. John W. Townsend, Jr., was listed as scientific officer in charge of the operations for NRL. J. W. Crowley, Associate Director for Research at NACA Headquarters, replied on June 11, 1958, that "NACA has a deep interest in upper atmosphere research and therefore will be glad to assist in the development of the Arcon research rocket by firing three of the rockets as requested."[20] RA A73L282 was issued to cover the NACA work.

The three Arcon rockets were fired at Wallops on July 16, 21, and 22, 1958. One of the rockets with its special mobile launcher is shown in figure 395. The Arcon had a diameter of 6.1 inches and an overall length of 133.8 inches. It weighed 239.5 pounds, including its 27-pound booster. A short-burning booster (3,000 pounds of thrust for 0.4 second) was used to initiate the launch and get the Arcon up to a stable speed by the time its own motor had developed enough thrust to provide acceleration. These Arcon rockets were given the designation E128 by PARD. All three firings were failures. In the first test, the rocket broke up at burnout of the motor. In the second test, "the model-booster combination left the launcher normally. However, the side of the rocket motor case burned through shortly after it separated from the booster, very close to the Arcon fins" (ref. 61). Thrust ceased at this point, and the Arcon splashed a few hundred feet offshore. The third rocket changed azimuth about 60 degrees shortly after launch. Near burnout, it started corkscrewing and then suddenly veered upward nearly 90 degrees and broke up. Pitch-roll coupling was suspected in this case.

NRL continued its interest in the Arcon, and after the NACA was converted to NASA, effecitve October 1, 1958, and the NRL upper atmosphere people, including Townsend, were transferred to NASA, Arcon went with them. By March 1959, Townsend was ready to launch additional Arcons at Wallops. The organization of NASA and the change in functions and responsibilities of the various units will be discussed in detail later in this chapter. Under NASA, Townsend was Chief, Space Sciences Division, Goddard Space Flight Center, under Abe Silverstein, Director of Space Flight Development at

20. Letter from the NACA to NRL, June 11, 1958, regarding firing of three Arcon rockets at Wallops Island.

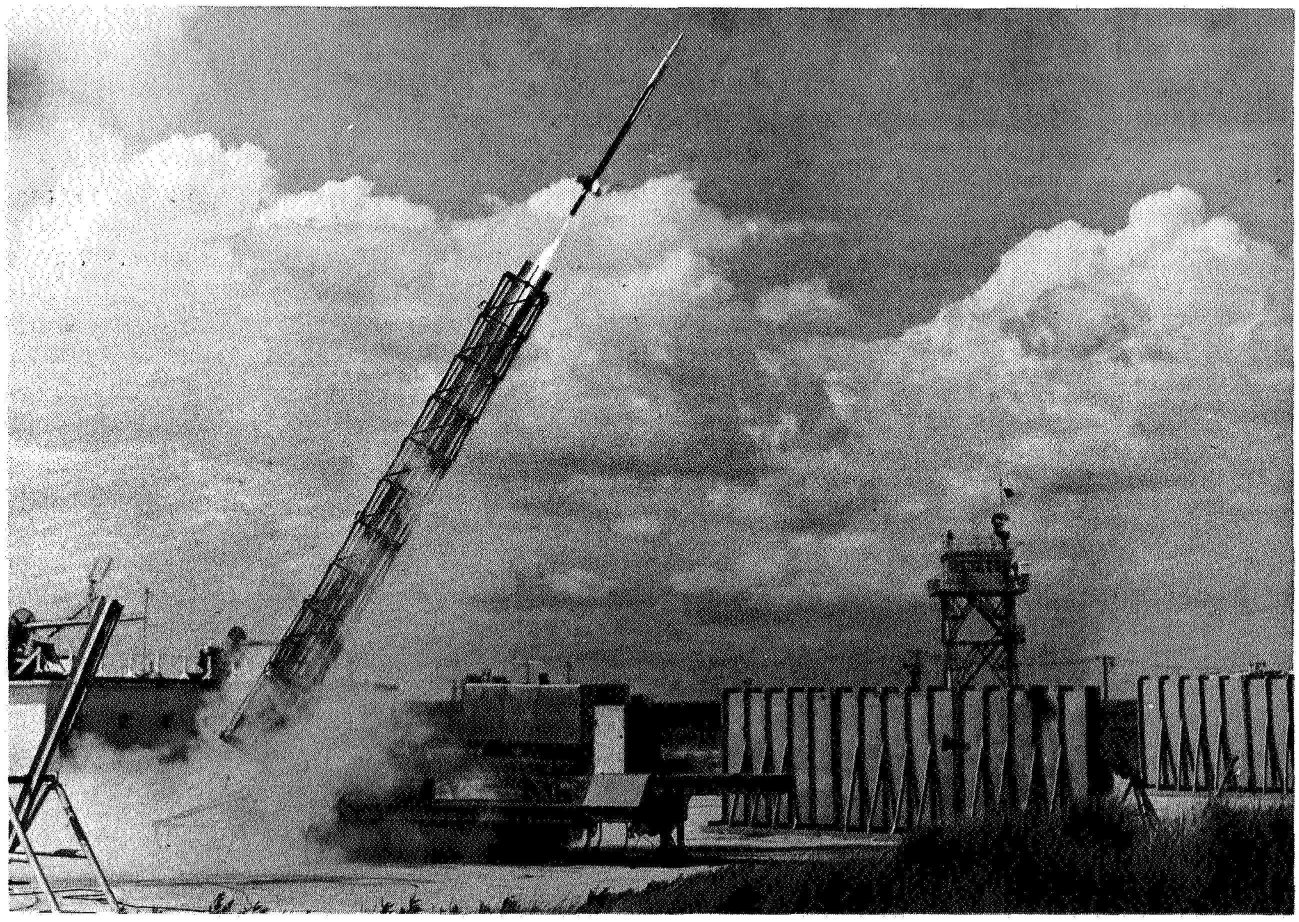


FIGURE 395. Launch of the first Arcon sounding rocket at Wallops, July 16, 1958. As shown, a special transportable launcher was used.

NASA Headquarters. Wallops was officially a part of Goddard, then nonexistent, but operationally still very much a part of Langley and PARD. Now Townsend did not need to ask permission of Langley to launch rockets at Wallops, but he did need to ask Langley to evaluate the radar and Rawinsonde data from the flights. In this connection, Townsend asked M. B. Ames, Jr., in NASA Headquarters, for Langley assistance (ref. 62). Crowley, now Director of Aeronautical and Space Research, replied officially in a letter to Silverstein that the assistance would be provided by Langley[21], and then told Langley to charge this work to the earlier NACA RA approved for the first three Arcon firings.[22]

The new firings of Arcon rockets were made in two stages. Three were fired in May 1959, and three more in August. These rockets were identified by Wallops as G2 plus a serial number, and by Goddard as the 2.00 series. By this time, Wallops had instituted a tighter control over prelaunch prediction of impact point, and the Goddard personnel had engaged a group from the State University of New Mexico to perform the necessary wind-weighing calculations for the flights. The first launching, May 14, 1959, was a complete success and was tracked all the way by Wallops FPS-16 radar. A peak altitude of 74,000 yards and an impact range of 42.5 nautical miles were indicated. The predicted impact point was 30 nautical miles. The flight azimuth was 112 degrees, quite close to the predicted value of 110 degrees. The altitude reached, however, was only about two-thirds of the expected value. The second flight gave about the same results. In the third flight, the Arcon motor blew open at the nozzle upon ignition, the fins were torn off, and the launcher was damaged. Splash point for the damaged Arcon was about 100 feet from shore.

21. Letter from J. W. Crowley to Abe Silverstein, Mar. 12, 1959, regarding Langley assistance in Arcon firings.
22. Letter from NASA to Langley, Mar. 12, 1959, regarding PARD assistance to Space Flight Development in firing three Arcon rockets.

In the second series of three rockets, launched August 7, 1959, the payload had been reduced to 20 pounds to reach a higher peak altitude. The first and third vehicles broke up at a time corresponding to motor burnout, while the second model appeared to be a success and reached an altitude of 320,000 feet, quite close to the original ARC estimate. By this time, however, Goddard was interested in much higher altitudes and did not feel that further development was warranted.

RANGE CLEARANCE AND CONFLICT WITH THE CAA

Some of the problems of obtaining clearance from the Navy for long-range rocket launchings from Wallops have been discussed earlier, and a workable arrangement, mutually satisfactory to the NACA and the Navy was finally agreed upon on July 6, 1953, as has been mentioned in Chapter 10. The normal procedure was to work cooperatively with the Navy and use the Navy fleet training areas for impact. For short-range rockets, under 25 miles, such cooperation involved only the Navy unit at Chincoteague. A search radar atop the Observation Tower at Wallops was used to assure that no ships were in the way within this range. For ranges beyond 25 miles, the firings were coordinated with the Fleet Training Group, Chesapeake Bay; and, in addition, the Navy provided an airplane for surveillance of the impact area. Use of the training area gave Wallops a range of about 100 miles without any conflict with commercial aviation and the CAA.

For ranges greater than 100 miles, there was some question about the necessity for sea search. At Cape Canaveral, the Air Force Missile Test Center (AFMTC) utilized airborne radar for sea search out to 150 miles, in much the same way as did Wallops, but beyond this distance they depended on a "one chance in one hundred thousand" or less probability of hitting a vessel. This meant, in general, that unless there was an abnormal concentration of vessels in a particular area, no search was required beyond 150 miles. In March 1957, AFMTC queried the NACA about clearance philosophy. Langley replied that despite launching 6,000 test vehicles[23] in the past 12 years, no report had been received of a ship's being hit. The system of sea search used at Wallops was explained with the comment that firings were delayed until a clear area along the expected flight path was shown by the search radar. The calculation was made by plotting hourly positions of any ship in the area and then projecting its position at the desired launch time. If necessary, the launch azimuth was changed to ensure a safe area.

The first conflict with the CAA resulted from a plan in August 1957 to eliminate part of Restricted Area R-45, covering Wallops Island and Chincoteague, and to establish a dual very high frequency omnidirectional range (VOR) airway from Cape Charles, Virginia, to Coyle, New Jersey, the eastern edge of which would pass over Wallops Island. Commander John F. Betak, Navy member of the New York Regional Airspace Subcommittee, who also represented the NACA's interests as well as the Navy's, informed Langley of the plan and suggested that the NACA appear at the next meeting to protect its interest.

At the meeting on August 11, 1957, identified as Meeting No. 114, Krieger represented Langley and Wallops, while J. A. Hootman represented NACA Headquarters. Navy men also were there from Chincoteague and Norfolk. After solid opposition by NACA, Navy, and Air Force representatives, CAA representatives withdrew their plan and the matter appeared to be ended (ref. 63). In the discussion at this meeting, it was learned that what was really needed was a dual airway all the way from Maine to Florida, but this was outside the jurisdiction of the New York Subcommittee. In January 1958, Commander Betak informed the NACA that a proposal for a dual airway from Boston to Miami would be discussed at Meeting No. 118 on January 28, 1958.

The two proposed routes were parallel from Boston, across the eastern end of Long Island, and thence down the coast to Salisbury, Maryland. From Salisbury, Route I crossed Cheaspeake Bay to Hopewell, Virginia, and then continued south through Rocky Mount, North Carolina. Route II from Salisbury passed directly over Wallops to Norfolk and then continued to Wilmington, North Carolina,

23. This figure was larger than other figures quoted because it also included the small test rockets fired for calibration of range instrumentation.

and on south to Miami. It was seen that the proposal for Route II was identical with the earlier one, as far as Wallops was concerned, and Krieger prepared a memorandum reiterating the earlier objections and pointing out that rocket flights of direct benefit to "ballistic missiles, anti-ballistic weapons, rocket gliders and other space vehicles," and of interest to the Air Force and the Navy, were being conducted at Wallops. He therefore requested that the military members of the Subcommittee protect the NACA's interests (ref. 64).

The Subcommittee met on January 28, 1958, and this time the Air Force member made a strong plea not to interfere with the NACA's operations at Wallops because of its direct benefit to the Air Force and the Navy. In addition, the Air Force member stated that the proposed Route II would pass over Suffolk AFB, McGuire AFB, and Dover AFB and hamper their operations. Objection also was made to closing part of training area W-107. He stated in summary:

> Basically, in times of world tension and chaos, it is inconceivable that the Department of the Air Force be expected to favorably accept a proposed airway structure that will reduce operational effectiveness and defense capability.

The Navy member reinforced the objection of the Air Force with statements that the proposed new routes "would adversely affect air operations at virtually every Navy and Marine air installation along the Atlantic Seaboard from Boston, Massachusetts, to and including Norfolk, Virginia." When the various parts of the proposal were put to a vote, the Air Force, Navy, and Army members voted as a unit and defeated the proposal (ref. 65). The situation was to remain in this condition, as far as an airway over Wallops was concerned.

By April 1958, plans were well along for development of a multistage, solid-rocket launch vehicle, for use at Wallops, that would have upper stages with impact points far beyond the Navy training areas. Flights would cross international airways under control of the New York Oceanic Control Center. This vehicle was later to be named "Scout." The Navy representative on the Airspace Subcommittee, Commander Betak, was contacted by Krieger on April 3, 1958, and was asked to make inquiry of New York Oceanic Control regarding necessary clearance arrangements for flights across the airways. A formal letter asking for this assistance followed the initial request.[24]

An overall assessment of range safety procedures connected with such long-range flights was made by Krieger, and an operation plan was prepared (ref. 66). As before, a Navy airplane would search the range for ships out to a distance of 100 miles, but beyond 100 miles no sea search would be conducted because Krieger's analysis, based on information obtained from Navy officials in Norfolk, Virginia, indicated that the probability of hitting a ship in the North Atlantic was less than one chance in five million. This conclusion was based on an average of 2,500 ships evenly distributed over the area. An average ship 60 feet by 600 feet was assumed. The air space beyond the Navy training area presented a different picture. Although the chance of hitting a commercial airliner was far less than that of hitting a ship, the consequences would be so much more serious that a different approach was required. Contacts with the New York Oceanic Control Center indicated that it would be feasible to launch the rocket from Wallops at a time when the flight path of the vehicle would be clear of airplanes. This would be accomplished through close coordination with New York Oceanic Control, which maintained a continual record of location of all aircraft within its area. Later, additional Oceanic Control Centers had to be contacted as well.

Because of the JASON Project, discussed earlier in this chapter, this operation plan had to be put into effect long before the Scout vehicle was launched. In the preliminary JASON firings, the exact time was not critical, and the coordination with Oceanic Control was effected as planned, for the firings on July 11 and 17 and August 1, 1958. For the firings during the actual ARGUS A-bomb experiment, however, timing was critical, and the JASON launchings could not be delayed by aircraft in its flight path. As was discussed earlier in the JASON section of this chapter, ARPA was able to request rerouting of all oceanic air traffic in the path of JASON during the experiment. Rerouting of some traffic in the Cape Canaveral area during regular launchings there had been a practice for some time without opposi-

24. Letter from H. J. E. Reid to Commander John F. Betak, Apr. 4, 1958, requesting assistance in arranging for clearance with New York Oceanic Control Center.

tion. The JASON launchings covered such a large area, however, that the disruption of air traffic between the West Indies and northward was extensive. In some cases, airplanes while en route were ordered to change their flight plans to such an extent that it was questioned whether there was enough fuel aboard to reach their destination. During this period, Wallops personnel monitored many radio conversations between aircraft crews and ground controllers that clearly indicated their unhappiness with the event.

In order to placate the CAA and the New York Oceanic Control Center as well as the airlines involved in the disruption of air traffic during the JASON firings, Krieger instituted an educational program to acquaint the appropriate officials with the operations at Wallops. The objective was to work out a satisfactory operational plan for the future. J. T. Markley was placed in charge of the program at PARD, under Krieger. Markley had had many contacts with CAA personnel during his stay at Puerto Rico at the time of the JASON firings, and he was not at all hesitant to explore the problem with CAA authorities in New York and Washington, D. C. From data obtained through personal contact, Markley prepared charts to show the density of airplanes along the airways seaward of Wallops; and, in addition, he prepared graphs to show the density of airplanes at different times of the day along the major airway, Oscar, that ran from New York to Puerto Rico. A pronounced lull in air traffic was found to exist in the early daylight hours. He made arrangements for 12 men from the CAA, including Administrator J. T. Pyle, to visit Wallops on November 20, 1958, to witness two five-stage rocket launchings. An acceptable plan was finally agreed upon for future flights over airways (ref. 67).

During the JASON operations, control of civil aviation was changed by Congress with the establishment of the Federal Aeronautics Administration (FAA) to take over the duties of the CAA, effective January 1, 1959. Early in December 1958, the NACA had to placate the new FAA Administrator, Elwood Quesada, a retired Lt. General of the Air Force. Quesada's first suggestion, upon learning of the airway interference problem at Wallops, was that all long-range firings be conducted at Cape Canaveral instead of Wallops. In addition, he questioned the wisdom of the proposed extensive expansion of Wallops by NASA.

On December 8, 1958, E. C. Buckley and Markley briefed Quesada and his staff, as well as a representative from the Bureau of the Budget, on plans for future operations at Wallops. Quesada was told that the only trouble encountered in coordination of firings with the CAA had occurred during the JASON firings, and that in the future NASA would not relinquish responsibility to anyone for coordination of firings, as it had during JASON. At this time, Quesada agreed not to object to the proposed expansion at Wallops, and wondered if he had any basis for objecting to the long-range firings at Wallops, anyway, since the conflicts with airways occurred beyond the 12-mile limit (ref. 68). During the discussion that followed the briefing, it was obvious that the CAA officials were now on the side of NASA as far as Wallops was concerned; and they told Quesada that moving all of the civilian space-program firings to Cape Canaveral would create greater problems than if the load were divided between Wallops and the Cape. Quesada withdrew his objections, and the way was now cleared for NASA's continued use of Wallops Island as a rocket range.

NASA Headquarters sent Quesada a letter on February 12, 1959, confirming the information presented at the meeting on December 8. Quesada was assured that large rockets in the space program would not be launched at Wallops, and all firings at Wallops would be on a noninterference basis, in accordance with controlled firing concepts established by the FAA. A formal agreement between the FAA and Wallops, effective March 1, 1959, was signed by Krieger for NASA and by L. V. Reynolds, Chief Controller, New York Center.[25] The agreement provided that NASA would conduct firings so as to ensure safety for nonparticipating aircraft. This would be achieved by NASA surveillance of the area, plus information provided by the New York Center. Close contact between New York and Wallops would be maintained during each long-range firing.

Despite this agreement, Quesada wrote Glennan on June 12, 1959, that he still recommended that NASA limit its firings at Wallops to a range of 800 miles, pending a review of airspace requirements for all missile ranges. This was strongly protested by J. A. Shortal in a memo sent to NASA Headquarters (ref. 69), and nothing further was heard either way.

25. Letter of Agreement, New York Air Route Traffic Control Center and NASA Wallops Station, effective Mar. 1, 1959, regarding rocket and missile test operations.

The Navy, likewise, became concerned about the effects of an expanded rocket program at Wallops under NASA, particularly in regard to the possibilities of conflict in use of the Fleet training areas. Although a good working arrangement had been in existence since 1953, the Chief of Naval Operations felt that a conference should be held to discuss future plans under NASA.[26] A meeting for this purpose was scheduled in Norfolk, Virginia, on September 24, 1958. Krieger and Markley represented Langley at the meeting. The Commander of the Eastern Sea Frontier was also represented at the meeting because this group had cognizance over Navy activities beyond the training area. One outcome of the meeting was that the Navy agreed to limit its jurisdiction within the Navy training areas to an altitude of 75,000 feet, and a request was made to the CAA to effect this change.[27] With this change, firings from Wallops could penetrate altitudes above 75,000 feet without reference to Navy operations, and clearances were required only for impact areas and altitudes below 75,000 feet.

In order to acquaint the Navy people with Wallops operations, a group was invited to the island on November 5, 1958. The group consisted of two Navy members of the Airspace Subcommittee, including Commander Betak, two officers on the staff of CNO, and a representative of CINCLANT-FLT, Norfolk. NASA submitted a proposed working procedure which the Navy accepted for the calendar year 1959. The Virginia Capes Operating Area Coordinator was designated as liaison officer for such operations.[28] The working procedure agreed to was essentially the one prepared in connection with the overall study made of the problem of conflict with the CAA and the Navy over airspace utilization at Wallops (ref. 70). Two months' notice was now generally required for reservation of a Navy training area.

Another change in procedure was made, which would affect flight operations from Wallops in the years ahead. Now, instead of reserving a pie-shaped area, bounded by azimuth rays about 10 degrees apart, probable impact areas of each stage were computed for each launching. The calculation of these impact areas required such detailed considerations as vehicle stability, thrust misalignment, stage tip-off at separation, and wind effects—all of which added a new complication to the launchings. Nevertheless, it placed the firings on a sounder basis and reduced the area required for clearance to particular impact areas.

In February 1959, in anticipation of the closing of the Navy station at Chincoteague, NAOTS informed other Navy units that after March 15, 1959, there would be no further requirement for the use and control of Vacapes Operating Area 6, offshore from Wallops. Control was reassigned to the Commander, Operational Development Force, U. S. Atlantic Fleet, with scheduling authority.[29]

SPACE FLIGHT PLANS AND CONVERSION TO NASA

The successful orbiting of *Sputnik I* by Russia on October 4, 1957, was not only a major milestone in man's conquest of space, but was also the first in a chain of events that led to the conversion of the NACA to NASA and to a change in the functions and responsibilities of Wallops as well, eventuating in a greatly enlarged physical plant and a fourfold increase in personnel. The public interpreted *Sputnik I* as an indication of this nation's lag in the missile race as well as an indication of a space gap—and rightly so, for by this time, despite the accelerated pace of the development of two ICBM's, Atlas and Titan, and two IRBM's, Thor and Jupiter, none were operational. Only the Army's Redstone 200-mile ballistic missile was ready for use. No Titan had been flown, and of the two Atlas missiles launched, both were failures. The success with IRBM's was somewhat better, with two successful Jupiter firings out of four and one succesful Thor out of five.

26. Letter from NACA Headquarters to Langley, Sept. 2, 1958, regarding avoidance of conflicts with Navy in utilization of airspace in vicinity of Wallops.
27. Letter from COMSERVLANT to Navy Regional Airspace Officer, CAA First Region, Nov. 5, 1958, regarding request for change in effective altitude of warning areas.
28. Letter from CINCLANT to Director, NASA Langley, Nov. 24, 1958, regarding coordination procedures for rocket firings from Wallops Island for calendar year 1959.
29. Letter from COMSERVLANT to COMOPDEVFOR, Mar. 12, 1959, regarding reassignment of scheduling authority for Vacapes Area 6.

Wernher von Braun at ABMA, sensing the deficiency in missile capability, had developed a vehicle, with the assistance of JPL, that could reach orbital speed by the addition of a three-stage cluster of small solid-rocket motors to the top of a lengthened Redstone missile. The small rocket motors in the cluster were JPL Baby Sergeants, somewhat larger than T55 motors used at Wallops in multistage vehicles, but otherwise generally similar. The cluster of Baby Sergeants was mounted in a spinning tub on top of the Redstone and was fired in three stages. The Redstone control system provided the desired attitude at firing of the cluster, while the spinning motion maintained this attitude. The main cluster contained 14 rocket motors, fired in two stages, first 11 and then 3. The third stage was a single motor mounted on top of the three second-stage motors. The payload was mounted on top of this last motor (ref. 71). Von Braun called the combined vehicle "Jupiter C." Despite a successful launch of a Jupiter C in a reentry test on September 20, 1956, Von Braun had been turned down in his request to convert it into a satellite vehicle, as Project Orbiter. He had placed a couple of the vehicles in storage, however, and bided his time.

The American Rocket Society and the National Academy of Sciences were among the first to propose the creation of a National Space Establishment to counter the Russian threat. After the Russians launched an even larger satellite, *Sputnik II*, on November 5, 1957, President Eisenhower tried to reassure the nation with three announcements on November 7, 1957: (1) the successful reentry and recovery of an ablation nose cone that had attained ICBM speeds with a Jupiter C missile, (2) the appointment of James R. Killian as Special Assistant to the President for Science and Technology, and (3) the reactivation of the President's Scientific Advisory Committee with Killian as chairman. These announcements were followed by a directive from Secretary of Defense Neil McElroy to the Army on the following day, to attempt to launch two satellites by March 1958. This was to provide a backup to the Vanguard satellite launch vehicle which the Navy's NRL had been working on since 1955, as a part of IGY. When the first complete Vanguard launch on December 6, 1957, turned out to be a dismal failure, the wisdom of providing a backup was clearly indicated. The first attempt by the Army, on January 31, 1958, to launch a satellite with a Jupiter C, was successful and did mollify the critics of the U. S. space efforts somewhat, although the small size of this satellite, *Explorer I*, in comparison with Russia's 1,100-pound *Sputnik II*, only served to emphasize the space gap.

The NACA realized the impact of *Sputniks I* and *II*, and on November 21, 1957, it established a Special Committee on Space Technology. This committee was activated in January 1958 with H. Guyford Stever, chairman, and members from Government and industry, including Von Braun, W. H. Pickering of JPL, and J. A. Van Allen of the State University of Iowa. The NACA laboratories were represented by R. R. Gilruth (Langley), H. J. Allen (Ames), and A. Silverstein (Lewis).

This special committee organized Working Groups on the following subjects:

- Space Research Objectives
- Vehicular Program
- Reentry
- Range, Launch, and Tracking Facilities
- Instrumentation
- Space Surveillance
- Human Factors and Training

Each Working Group was composed of 8 to 12 specialists in the corresponding fields, drawn from throughout the nation.[30] Figure 396 shows the Special Committee on Space Technology at its visit to Wallops on October 28, 1958.

The establishment of such a large committee by the NACA was an indication of its plan to pursue space research with vigor, yet under the same type of committee system already in use in aeronautical research. On February 26, 1958, the four original technical committees were renamed to reflect their cognizance over missiles and spacecraft as well as aircraft. For example, the Committee on Aerodynamics was renamed the Committee on Aircraft, Missile, and Spacecraft Aerodynamics.

One of the important actions of NACA Headquarters that contributed to its getting the national space assignment was a request to Langley on December 19, 1957, to prepare a document for

30. For a complete list of members of the Special Committee as well as its Working Groups, see the 44th *Annual Report of the National Advisory Committee for Aeronautics, 1958,* GPO 1959.

FIGURE 396. NASA Special Committee on Space Technology assembles behind test model of multistage hypersonic rocket vehicle at Wallops. Photograph was taken prior to meeting on October 28, 1958. Left to right: W. L. Alford, Langley; J. C. Palmer, Wallops; M. N. Gough, Langley; Colonel N. C. Appold, Air Force; J. B. Whitten, Langley; B. Myers, NASA Hq.; M. U. Clauser, Ramo-Woolridge; S. K. Hoffman, North American Aviation; C. B. Palmer, NASA Hq.; J. R. Dempsey, Convair; J. A. Shortal, Langley; H. G. Stever, MIT, Chairman; H. J. Allen, Ames; R. R. Gilruth, Langley; H. W. Bode, Bell Telephone Laboratories; A. Hyatt, BuAer; and R. L. Krieger, Wallops.

presentation to the Killian committee, describing NACA research applicable to space. The resulting document, containing some 70 pages of text and photographs, was prepared and presented in a matter of only a few days, and described the many space-related facilities and projects in the various NACA laboratories (ref. 72). Space-related research was considered to mean research whose results were applicable to vehicles designed to travel in space during at least part of their journey. Such vehicles included not only spacecraft, such as the inflatable spheres under development at Langley and the X-15 research airplane, but also hypersonic gliders, ballistic missiles, and antiballistic missiles. All of the hypersonic heat-transfer research at Wallops was applicable, as well as the reentry materials research in the Ethylene Jet, research on advanced rocket motors such as the spherical motor, and investigation of the dynamic stability of reentry nose cones. A survey indicated that approximately 50 percent of the overall NACA research was space-related, while the activities of PARD and Wallops were 90 percent related to space.

NACA Headquarters, in a staff study dated January 14, 1958, made a counter proposal to those calling for a new National Space Establishment. The view was that, in recognition of the extensive activities in space-related research of the NACA and its laboratories, the scientific research required for manned or unmanned flight should be the responsibility of the NACA. It recognized that the military had the responsibility for military space activities, but that the NACA was in a better position to develop the technology, as it had done for airplanes. The plan was that the NACA should conduct space flight operations for space science, with the experiments coming under the cognizance of the National Academy of Sciences and the National Science Foundation. For manned space flight, a continuation of the joint NACA-DOD pattern, as used with the X-15 and other research airplanes, was proposed. To carry out these additional responsibilities, a rapid expansion of personnel and facilities was recommended. In addition, the need for making space flights for research purposes was recognized, with the accompanying requirement for a launching site and an appropriate network of observation stations (ref. 73). On January 16, 1958, the NACA passed a resolution endorsing this overall plan, and directed its newly formed Special Committee on Space Technology "to review the needed research and development in light of the guidelines given above."

The release of the staff study and of the resolution of the NACA were timed to coincide with an address by H. L. Dryden, scheduled for delivery to the Institute of Aeronautical Sciences in New York on January 27, 1958. In his paper, read by NACA Executive Secretary J. F. Victory, the plan referred to above was described; but, in addition, Dryden interjected some of his own thoughts. For example, "In my opinion, the goal of the program should be the development of manned satellites and the travel of man to the moon and nearby planets." He pointed out that "NACA had been increasingly in research applicable to the problems of space flight" and cited the X-15 research airplane as a vehicle "to explore problems of manned flight into space." He recommended a cautious step-by-step approach to the eventual goal of manned exploration of our solar system, making the statement, "I personally am unwilling to be a party to trying to put a brave young pioneer into orbit until his demonstrated chance of successful return is much better than 50 percent" (ref. 74).

The next step in implementing the NACA plan for greater participation in the space program was to prepare in detail a listing of the actual facilities, additional personnel, and funds required for presentation to Congress. This time, the NACA Lewis Laboratory was selected as the site for preparation of this joint staff study. Each of the laboratories submitted its needs and sent representatives to work directly with the group at Lewis. PARD Branch Head Paul E. Purser represented Langley, while R. L. Zavasky, Technical Staff Assistant at Langley, coordinated the Langley inputs and kept Purser informed of Langley's desires during the period of the study. The study began in late January 1958 and was completed February 10, 1958, with publication of "A Program For Expansion of NACA Research in Space Flight Technology With Estimates of Staff and Facilities Required." In submitting material from Langley, the various divisions took this opportunity to press for extensive new facilities for research at extreme temperatures and velocities. The total cost of such facilities, as proposed by Langley, was estimated to be $123 million over a 5-year period. A significant part of the proposal was $23.4 million for the expansion of Wallops Island facilities.[31]

31. Letter from Langley to Lewis (attention, Paul Purser), Jan. 29, 1958, regarding contemplated expansion of Langley and Wallops Island facilities related to space flight research programs.

The items proposed for Wallops are shown in the following table:

Item	Estimated Cost (millions of dollars)
1. Increase in range of existing radar	1.5
2. Telemeter system with 1,500-mile range	.6
3. Tracking radar with 1,500-mile range	10.5
4. Space flight reentry instrumentation	.4
5. Shipborne tracking and instrumentation facility	5.5
6. Expansion of photographic and optical systems	.6
7. Expansion of rocket and launch facilities	.5
8. Facilities for handling and launching large vehicles	2.5
9. Electronic guidance and control equipment	.8
10. Expansion of shop, administrative, and dormitory facilities	.5
Total	23.4

Increases in professional personnel and operating costs to go with this expansion of facilities were given Purser by telephone on January 30. For Wallops, the items amounted to an additional 64 professionals and $2.15 million in expenditures. This was a vast increase in professionals, considering that Wallops had only about six assigned there at that time.

The Congress was also awake to the increased urgency and need for expansion of space exploration. On February 6, 1958, the Senate appointed a Special Committee on Space and Astronautics, with Lyndon B. Johnson as Chairman. The House, not to be outdone, appointed a Select Committee on Astronautics and Space Exploration and named Speaker J. W. McCormick, Jr., Chairman. The Department of Defense established the Advanced Research Projects Agency (ARPA) with Roy Johnson, Director. The agency's province was not only space satellites and probes but also antimissile development. By the end of March, ARPA had solidified a quite ambitious space flight program, including a manned space flight project. The activities of ARPA in the JASON Project have already been discussed. President Eisenhower assigned his Special Assistant for Space Technology, J. R. Killian, the task of recommending a plan to cover all U. S. space activities. On March 5, 1958, Killian recommended to the President that the NACA be given jurisdiction over the civilian space program, and cited the NACA's resolution and the expansion plan of February 10 as evidence of NACA ability to move forward in space. Killian recommended that the NACA be renamed National Aeronautical and Space Agency (NASA) and that the head be appointed by the President. In addition, the new agency was to have jurisdiction over civilian space flight as well as over space research. The President approved the recommendation and made plans for congressional approval.

During the next month, the plans for NASA were solidified and legislation, as well as a budget for fiscal 1959, was prepared. The Killian Committee (PSAC), Bureau of the Budget, and NACA Headquarters worked closely in this preparation for congressional action. On March 7, 1958, Robert O. Piland, Head of PARD's Heat-Transfer Section and leader in multistage rocket vehicles, was temporarily assigned to Killian's executive staff in Washington, D.C. Appointment was made of W. E. Stoney, Jr., as acting section head during Piland's absence. Dryden moved Silverstein to NACA Headquarters in March to assist in preparation of a space flight development program.

Near the end of March 1958, J. W. Crowley asked Langley to prepare a NASA Space Technology Program for budget purposes, in light of the latest developments, to supersede the plan of February 10. A Working Group was assembled at Langley on March 31, 1958, for this purpose. While most of the members were from Langley, representatives from Lewis and Ames also participated. The members of this Working Group are listed below:

Bruce Lundin, Lewis
Walter Olson, Lewis
W. J. O'Sullivan, Jr.
P. E. Purser
J. A. Shortal
J. G. Thibodaux
F. L. Thompson
J. W. Crowley, NACA Headquarters
R. L. Zavasky, Secretary
Clinton E. Brown
E. C. Buckley
Robert Crane, Ames
M. A. Faget
R. L. Krieger

Crowley addressed the group at its opening meeting and stated that he needed an itemized space program in a hurry, for budget and congressional purposes. He stated the total figure should be at least $150 million. He also indicated that he was thinking of about $20 million for Wallops. The group considered all facets of the new space assignment to be given to the NACA.

The discussions of the Working Group covered six general areas. First, it was agreed that a vigorous space science program was needed, with the support of the universities and other IGY participants. This called for sounding rockets, probes, and satellite launch vehicles. Second, development of larger rocket motors, new high-energy motors, and larger launch vehicles was required. Third, development of a vigorous manned space flight program was needed. The four-stage solid-fuel rocket orbiter (Scout) was considered a test vehicle for scaled models in the manned staellite program. Fourth, it was unanimously agreed that Wallops should be enlarged to become a major launchsite and should be provided the capability for launching vehicles as large as the Thor. To accomplish this, a blockhouse and launcher for Thor missiles were specified; and, for safety, it was proposed to move all supporting activities to a new area on the mainland and construct a causeway connecting the new area with the island. Expanded range instrumentation was also considered essential, and the acquisition of Assawaman Island (the small, unpopulated, barrier island immediately south of Wallops) was advocated for possible location of new instrumentation. The dredging of a boat basin and channel leading to the ocean was also discussed for docking of the recommended instrumented ship for downrange operations. Fifth, for eventual flights to the moon and the planets, a launchsite near the equator was felt to be needed, to place a spacecraft in the plane of the ecliptic without a plane change after launch. Sixth, an increase in personnel and operating funds was recommended. Of special interest was the strong feeling that ample travel funds should be itemized because, under the NACA, travel had been severely limited. A million-dollar item for travel was therefore inserted.

A tentative program was prepared on March 31, 1958, and transmitted to NACA Headquarters the following day.[32] Crowley left early in the afternoon and took rough notes back to Washington with him. The initial program merely listed areas of activity with approximate costs for fiscal 1959.

A summary of this March 31 program, with particular emphasis on Wallops facilities, is given in the following table:

	Area of Activity	*Approximate Cost (millions of dollars)*	
I.	Scientific Program Unmanned satellites, sounding rockets, and lunar probes		103.0
II.	New Vehicles and Techniques Million-pound-thrust rocket motor, high-energy rocket motors, and new test vehicles		47.0
III.	Manned Space Flight		
	a. Small-scale recoverable orbiter	4.0	
	b. Vertical flight and reentry vehicles	14.5	
	c. Manned orbital and reentry vehicles	12.5	31.0
IV.	Equipment and Facilities		
	a. Contract for research and development services for electronics and computers	20.00	
	b. Hypervelocity particle and magnetodynamics laboratory	8.65	
	c. Downrange tracking ship	7.00	
	d. Adaptation of Wallops Island range for handling Thor vehicles	7.25	
	e. Wallops Island instrumentation	4.70	
	f. High-energy fuel research facility (Lewis)	5.00	
	g. High-energy fuel test stands (Edwards)	10.00	62.6
V.	New Space Launching Site		1.0
VI.	Personnel and Operating Costs		8.5
		Total	253.1

32. Letter from Langley to the NACA, Apr. 1, 1958, transmitting NASA Space Technology Program.

This total of $253 million was only slightly greater than the amount finally received, when transfers of funds from the military were included for fiscal 1959 ($238 million), although there were many changes in distribution of the funding. The total of $18.95 million shown for Wallops expansion was somewhat less than the figure of $23.4 million proposed by Langley in January.

The details of the program were modified in the weeks ahead, and by May 15, 1958, a rather large brochure had been prepared. The revised program was called "NASA Space Flight Program" and called for a total funding of $259 million for fiscal 1959. The Wallops part of this new plan had been increased to $24 million as follows:

Item	*Cost (millions of dollars)*	
1. Tracking Systems (including "Millstone Hill" radar and optical systems)		12.0
2. Adaptation of Wallops Island for handling large liquid-fuel rocket motors		
a. Mainland Facility	3.90	
b. Causeway	2.40	
c. New Launch Area	1.25	
d. Launch Facilities	3.85	
e. Land Acquisition (mainland area, marsh, and Assawaman Island)	0.60	12.0
Total		24.0

Note that a causeway was now itemized, as well as purchase of Assawaman Island.

The revised program also included funds for a Space Flight Research Center to be located at an existing NACA laboratory. It also spelled out the complete program in detail. For example, a complete range of geophysical probes and satellites was described as well as programs for weather reconnaissance, communications by satellites, and astronomical observations. A fixed-position satellite at an altitude of 22,000 miles was envisioned for communications. The basic sounding rocket specified was the three-stage Exos, described earlier in this chapter. A minimum capability of an altitude of 300 miles was desired.[33] This 61-page document, prepared through the persistent efforts of the secretary of the Working Group, R. L. Zavasky at Langley, was to be used as the reference planning document for the NASA space program in the months ahead.

The legistation authorizing the conversion of the NACA to NASA was passed by the Congress and signed by the President on July 29, 1958. It was known as the Space Act, PL 85-568. "NASA" now stood for National Aeronautics and Space Administration. On August 8, 1958, President Eisenhower appointed T. K. Glennan to be the first Administrator, and H. L. Dryden, the Deputy Administrator. They were confirmed by the Senate on August 15 and sworn in on August 19. NASA was officially in being on October 1, 1958, in accordance with an official pronouncement of readiness by the Administrator on September 25, 1958. The existing NACA laboratories were renamed Research Centers.

Between April 2, 1958, the time President Eisenhower announced that he was proposing that the space program be given to an expanded NACA, and October 1, 1958, the time NASA was open for business, there were many meetings between the NACA and military representatives to discuss the implementation of the President's directive that transferred to the new agency many of the space projects in being under the military. This phase of the history of NASA is amply covered in other histories such as that of Rosholt and the history of the Mercury Project (ref. 75). Of greater importance to the Wallops history is the decision affecting the location of Wallops on the NASA organizational chart, and the new responsibilities to be assigned it. The impact of the space program on the older NACA laboratories is also of interest.

33. Letter from Langley to the NACA, June 5, 1958, transmitting revised staff study, "NASA Space Flight Program," dated May 15, 1958.

In May 1958, Dryden appointed I. H. Abbott chairman of an Ad Hoc Committee on NASA Organization, made up entirely of NACA Headquarters people. This committee recommended the establishment of four main offices in Headquarters: (1) Management, (2) Aeronautical and Space Research, (3) Space Flight Programs, and (4) Space Science. The Space Flight Office was made separate but equal to the Aeronautics and Space Research Office under a directive from Dryden that development projects be kept apart from research activities. The final chart of the Abbott committee, dated August 11, 1958, recommended, in addition, that the four NACA laboratories, Langley, Ames, Lewis, and Edwards be under the cognizance of the Aeronautical and Space Research Office, that the new Space Flight Research Center report to Space Flight Programs Office, and that Wallops (Pilotless Aircraft Research Station), report to the new Space Center.

On August 1, 1958, the location of the new space center was announced as Beltsville, Maryland. On August 19, 1958, Glennan met with NACA Headquarters officials and reviewed the recommendations of the Abbott committee. As an outcome of this review, the Space Science Office was deleted, but the location of the field centers on the organizational chart was kept the same. The Space Flight Research Center was now called Space Projects Center, and the name "Wallops Station" appeared for the first time, still under that center.[34] The first official NASA organization chart, marked "tentative," October 24, 1958, showed this same organization except that a Space Sciences Office had been reinstated. It had been placed under the Space Flight Development Office, however. The three main offices and their directors now were:

Business Administration	A. F. Siepert
Aeronautics and Space Research	J. W. Crowley, Jr.
Space Flight Development	A. Silverstein

This tentative movement of Wallops from the responsibility of Langley to the Space Projects Center had no immediate effect because the Space Projects Center was not really in existence, and no director had been appointed. Operations continued as before, with the full support of Langley. Krieger was still located at PARD, and Wallops launch operations continued as before under the cognizance of PARD.

The first contract signed by NASA Headquarters was with McKinsey and Company, to study and make recommendations on the NASA organization. After the McKinsey report was received in December 1958, the first official NASA organizational chart was released, with the date of January 27, 1959. Now the Space Projects Center was called Beltsville Space Center, but Wallops was still shown under it as one of several space project centers. JPL was also shown but in a parallel position with Beltsville, both reporting to Silverstein. When Glennan released the January 1959 chart, he attached a memo to it in which he stated that the chart "establishes the lines of authority and responsibility to be observed by NASA employees." Despite this directive, the relation between Wallops and Langley continued as before and was to do so until Krieger moved his office to Wallops late in July 1959. The next organization chart, dated March 23, 1959, listed Krieger as head of "Wallops Station." A major change in the organization was indicated on the chart dated May 1, 1959. Now four separate space flight centers were shown, each reporting to Silverstein. These were the newly named Goddard Space Flight Center, JPL, Wallops Station, and NASA-AMR Operations Office.

The change from the NACA to NASA on October 1, 1958, was followed by some severe changes in Langley management personnel. M. N. Gough, Chief of the Flight Research Division, was moved to Cape Canaveral to head the NASA office there. He sent for his Assistant Chief, John W. Bailey, to join him shortly afterward. Gough was replaced by Philip Donely as Chief of Flight Research (ref. 76). E. C. Buckley, Chief of the Instrument Research Division, was moved to NASA Headquarters to take charge of all range operations. His Assistant Chief, M. Stoller, transferred to the Office of Space Flight Development. Buckley was replaced at IRD by Paul F. Fuhrmeister, and Stoller by Howard B. Edwards (ref. 77). A change in personnel of even greater significance to Wallops operations was the establishment of the Space Task Group (STG) at Langley to develop the Mercury manned satellite, with R. R.

34. The name "Wallops Station" was changed to "Wallops Flight Center" on April 26, 1974.

Gilruth, Assistant Director of Langley, named the Project Manager and C. J. Donlan, the Assistant Project Manager (ref. 78). Gilruth was replaced as Assistant Director by E. C. Draley, whose position as Chief of the Full-Scale Research Division was assigned to Mark R. Nichols (ref. 76).

The STG, although located at Langley Field for a long period, was not a part of the Langley Research Center but reported directly to the Office of Space Flight Development in NASA Headquarters. Later it was to be shown temporarily on organization charts as a part of the Goddard Space Flight Center before it finally was moved to Houston, Texas, as the Manned Spacecraft Center. The initial transfer of personnel from Langley to STG on November 5, 1958, consisted of 35 people, 14 of whom were from PARD. These included two branch heads, P. E. Purser and M. A. Faget, and one section head, A. C. Bond. C. H. Zimmerman, Assistant Chief of the Stability Research Division, was transferred to STG as head of contract management. Following this initial transfer of 35 people, an almost continuous stream of staff members left Langley to join STG to participate directly in the manned satellite project. At PARD, Carl A. Sandahl replaced Faget as Head of the Performance Aerodynamics Branch, and J. G. Thibodaux replaced Purser as Head of the High-Temperature Branch. Don D. Davis, Jr., was transferred from the Full-Scale Research Division to PARD as Assistant Head of the High-Temperature Branch. All sections of this branch were disbanded (ref. 79).

The only deterrent to an even greater number of transfers from Langley to STG was the statement by Langley management that all research, including tests at Wallops in support of Mercury, would be conducted by Langley, while STG would supervise development work by its contractors. In contrast, the people at Lewis were told that anyone wanting to do any rocket-model testing must leave Lewis. Practically all of John Disher's team, which had conducted the air-launched rocket-model program at Wallops, transferred from Lewis to STG. The men under W. K. Ritter, who had initiated a hydrogen-fluorine engine flight project with testing planned for Wallops, moved as a group to Goddard. As far as Wallops was concerned, however, a rocket firing was the same whether it was called research or development, or whether it was for Langley or STG.

The 1959 budget for NASA was divided into three categories: Salaries and Expenses (S & E), Research and Development (R & D), and Construction and Equipment (C & E). The new category, R & D, contained funds for direct procurement or development by contract of expendible items such as rocket motors, space vehicles, and instrumentation. Funds for S & E covered NASA employee salaries and direct support expenses. The C & E funds covered new facility construction as before, under the NACA. The funds for fiscal 1959 for NASA came from the earlier 1959 funds for the NACA, transfer of funds from DOD for support of transferred space projects, and new supplemental appropriations for NASA. The breakdown is shown in the following table:

Source	*Funding (millions of dollars)*	*Category*	*Funding (millions of dollars)*
NACA 1959 funds	101.1	S & E	86.3
DOD transfer	154.6	R & D	204.6
NASA supplemental, August 1958	80.0	C & E	48.0
NASA supplemental, May 1959	3.2		
	338.9		338.9

The $48-million C & E category contained $24.5 million for Wallops expansion, practically the same sum as that proposed by Langley in January 1958. The expansion of Wallops, to be discussed in detail in the next chapter, was carried out in the same manner as had been earlier C & E projects at Wallops. That is, Langley Engineering Division was responsible for preparation of drawings and specifications, selection of contractors, and inspection of contract work, under the general direction of Krieger. The other supporting services provided by Langley likewise continued to be provided by Langley until Wallops had expanded sufficiently to take these over.

Although the NASA organization charts indicated that the old NACA laboratories were under an Office of Aeronautical and Space Research, this was generally interpreted as "aeronautical" research only, for all "space" research funds under R & D were allotted to the Office of Space Flight Development. This meant that the funds for any space research projects at Langley had to be obtained from

Silverstein rather than directly from Crowley. The change affected such projects as O'Sullivan's inflatable spheres, the Scout launch vehicle, and rocket model tests in support of Mercury, all to be discussed later in this history. At first, Silverstein tried to control all the space funds at Langley through his Space Task Group, but this proved to be too much for STG, and eventually direct transfer of space funds for Langley contracts was made.

The titles of the major offices in NASA Headquarters were changed on December 29, 1959. The title of Silverstein's office was changed from Space Flight Development to Space Flight Programs, a modification that removed the limitation of "development." The Office of Aeronautical and Space Research, now under I. H. Abbott, following the retirement of Crowley, became the Office of Advanced Research Programs. The change here was the removal of specific reference to "space research." The fields of endeavor of this office, as denoted by the titles of the Assistant Directors under Abbott, were as follows:

Aerodynamics and Flight Mechanics
Structures and Materials, and Operating Problems
Powerplants

These titles were carried over from the NACA and corresponded to the various NACA committees. No recognition was given to the new Special Committee on Space Technology. The research centers under Abbott were not expected to engage in space flight activities but were to have only a supporting role. The intent was that all space flights would be the responsibility of Goddard Space Flight Center. The change in the name of Wallops from Pilotless Aircraft Research Station (PARS) to Wallops Station was noted earlier when it was shown apart from Langley on the NASA organization charts. The name of the Pilotless Aircraft Research Division (PARD) at Langley was changed to Applied Materials and Physics Division (AMPD) in December 1959 (ref. 80) to eliminate any implication that Langley had responsibility for rocket flight tests. The transfer of this responsibility to an expanded Wallops Flight Center will be discussed in Chapter 16.

DEVELOPMENT OF INFLATABLE SPHERES FOR SPACE RESEARCH

The most famous unmanned satellite to be launched by NASA was undoubtedly Echo, the 100-foot, inflatable, spherical, passive, communications balloon. Following launch from Cape Canaveral, August 12, 1960, it was to remain in orbit and visible in the night sky for more than 8 years. While not launched from Wallops, Echo was a PARD project, and several developmental firings were made from Wallops in the Shotput project, to be discussed in the next chapter. Less known were the smaller inflatable spheres developed as forerunners to Echo and designed for determination of air density at satellite altitudes. In diameter, the spheres measured 20 inches, 30 inches, and 12 feet, respectively. The developmental spheres, as well as the 100-foot Echo, were the brainchildren of PARD's scientific wizard, W. J. O'Sullivan, Jr.

The first in the series of inflatable spheres for space research had a diameter of 20 inches. This diameter was chosen to be the same as that of the Vanguard spherical satellite with which it was proposed as a subsatellite. The proposal, made by O'Sullivan at the January 1956 meeting of the UARRP (ref. 81), was to eject a lightweight inflatable sphere having the same size as that of the heavier Vanguard spherical satellite, and to determine air density from the relative deceleration of the two spheres. Up to the time of this meeting, the UARRP had assumed responsibility for selection of satellite experiments, along with the IGY Technical Panel on Rocketry. O'Sullivan was a member of both groups. At this January meeting, responsibility for satellite experiments was transferred to a newly formed IGY Technical Panel on the Earth Satellite Project (TPESP). O'Sullivan's proposal was made as an alternative to a proposal that air density be determined with a large inflatable sphere containing a more sensitive version of the omnidirectional accelerometer developed by the University of Michigan team for use in the Nike-Cajun sounding rocket program. The simplicity of O'Sullivan's proposal appealed to the Satellite Panel, and action was initiated to redesign the Michigan proposal accordingly. Apparently, the Michigan team did not concur but continued work on the accelerometer proposal. When no progress in the development of an inflatable satellite was evident by June 1956, O'Sullivan proposed to NACA management that the NACA undertake the required development (ref. 82).

Although O'Sullivan specifically proposed that the NACA develop a 20-inch subsatellite for determination of air density in the Vanguard program, he expressed the opinion that the NACA had to extend its research into the satellite field. His justification for this viewpoint clearly showed foresight:

> It is now well known as a result of numerous theoretical studies that the present state of development of rocket propulsion and guidance systems makes the launching of artificial earth encircling satellites entirely within the realm of physical possibility. That this is the status of present technical knowledge is attested by Project Vanguard. It is the conviction of the writer, and many others, that earth satellites can and will be developed and used for numerous defense and commercial purposes. Among the commercial uses envisioned are continuous worldwide weather reconnaissance for the assistance of every activity of mankind particularly aviation; worldwide radio and television communications through the use of earth satellites as relay stations; and as a tool of scientific research leading to the discovery and utilization of knowledge for the benefit of all mankind. Not least among the foreseeable benefits is the lessening of world tension by bringing closer together the various nations through interest in a common beneficial development in a manner analogous to that accomplished by the development of transportation and communications. The development of earth satellites is therefore inevitable. It is the conviction of the writer that the NACA not only should, but must, engage in research contributing to their development as it has in the past in the development of airborne aircraft. The necessity of doing so is most vividly brought out by considering the consequences of failure to engage in satellite research. In every industry, failure to undergo evolution in pace with technological development inevitably leads to extinction. In the field of research, by virtue of it being the technological frontier, no time lag between recognition of an important problem and initiation of work upon it can exist without loss of ground. The general suggestion is therefore made that the NACA immediately undertake research directed at the development of earth satellites.

For the implementation of the proposal to develop a 20-inch inflatable subsatellite, O'Sullivan recommended the formation of a special team at Langley to manage the project. Assistant Director R. R. Gilruth endorsed O'Sullivan's proposal and suggested that the project be directed by O'Sullivan, with additional assistance (ref. 83). NACA Headquarters was very receptive to the proposal and approved it on July 26, 1956, subject to acceptance by the U. S. National Committee on the International Geophysical Year (USNC-IGY). In a letter written on the same day, J. W. Crowley informed USNC-IGY of the willingness of the NACA to develop such a satellite. At its meeting in September 1956, the Technical Panel on Earth Satellites approved inclusion of the NACA proposal as an official experiment (ref. 84).

To carry out the development as proposed, a special group, reporting to the Division Office, was established at PARD on December 26, 1956. It was designated as the Space Vehicle Group, with W. J. O'Sullivan, Jr., as its head. J. L. Mitchell from Aircraft Configurations Branch and W. E. Bressette from the Performance Aerodynamics Branch also were assigned to the new group (ref. 85).

The NACA 20-inch inflatable sphere was approved as a subsatellite to an NRL magnetometer experiment, as satellite package III in the Vanguard program. The fact that this was to be a companion package to the NRL magnetometer complicated the design problem because the package had to be designed to fit the space available. In addition, the complete package had to be ready in time for the environmental tests scheduled for the main satellite package. In operation, the inflatable sphere was folded into a compact package for minimum size during ascent and was ejected and inflated by nitrogen gas contained in a small pressure bottle. The bottle was separated after inflation.

In selecting material for the inflatable sphere, O'Sullivan considered gold foil, lead foil, and aluminum before deciding upon Du Pont Mylar plastic film, which he chose because of its toughness and availability in thin sheets.Thin aluminum foil was bonded to the outside of the Mylar sheets, to provide the required rigidity after inflation in case of pressure loss, as well as to provide a suitable radar reflective surface and to protect the Mylar from damage from ultraviolet radiation. The special thin aluminum foil was produced by the Reynolds Metals Company of Richmond, Virginia. Reynolds also bonded the aluminum foil to the Mylar sheet. The material was cut in gores and glued along overlapping seams. One of the 20-inch spheres is shown in figure 397.

When the weight of the system turned out to be less than estimated, the diameter of the sphere was increased to 30 inches. This decision was relayed to NRL on February 1, 1957. The complete 30-inch subsatellite is shown in figure 398. This system was finally launched on April 13, 1959, along with the

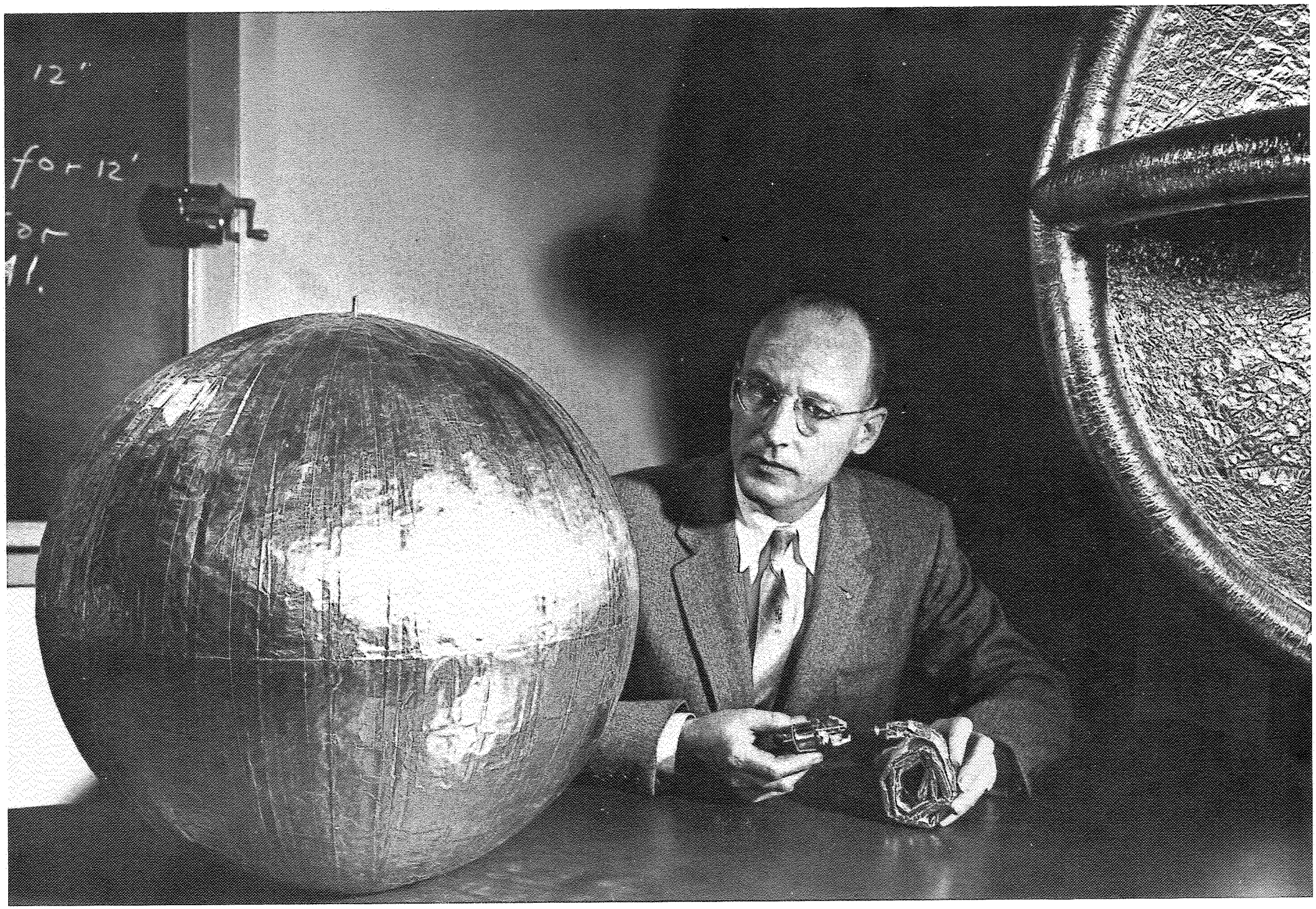


FIGURE 397. Engineer W. J. O'Sullivan, Jr., looks at inflated 20-inch subsatellite while holding inflation bottle and folded duplicate copy (photograph taken in February 1957).

FIGURE 398. Engineer W. J. O'Sullivan, Jr., seated beside 30-inch subsatellite. He holds inflation bottle and folded duplicate copy (photograph taken in July 1957).

NRL magnetometer on Vanguard vehicle SLV-5, but failure in the second-stage control system ended the flight prematurely. This ended the attempt to determine air density with a subsatellite, for by this time interest was focused on the use of a 12-foot inflatable satellite. The 30-inch sphere did find an application as a calibration target for the MIT long-range radar at Millstone Hill in launchings from Wallops even before the attempted Vanguard firing.

Work on the 20-inch subsatellite at Langley had just begun when the Lincoln Laboratory of MIT heard of it and sent G. H. Pettingill to Langley to discuss the possibility of using the subsatellite as a target in research on long-range radars. Official interest of MIT was expressed to NACA Headquarters in a desire for a cooperative flight program.[35] A program was initiated to launch 20-inch inflatable spheres from Wallops with Nike-Cajun sounding rockets.

The 20-inch-diameter radar target was changed to one 30 inches in diameter as soon as the subsatellite was changed. The packaging of the radar target was simpler than that of the Vanguard subsatellite because there was less restraint on space available. The 30-inch aluminum sphere after inflation provided an ideal radar target of known size and reflectivity. Because the sphere was of the same general size as the Cajun rocket motor, however, it was desired to separate it from the Cajun. A small third-stage rocket motor was added to the system to provide this separation as well as to propel the sphere to a higher altitude. The development of this small motor delayed the tests by about a year. The radar target project was called Hiball and was designated SV-56 in the PARD system.

The special separation rocket for Hiball was designed and constructed by the Rocket Section of PARD at Langley. The case and nozzle were made of fiberglass and plastic to provide a low-radar-reflective object that would minimize interference with the radar signal from the 30-inch sphere. The case of this special motor was constructed with four low-aspect-ratio fins formed into the rear portion of the case. A cavity was formed in the case just ahead of the propellant to contain the folded balloon and inflation mechanism. The entire unit of rocket motor and inflatable sphere assembly was attached to the front end of the Cajun motor and was protected by a four-segment metal cone. At ignition of this third stage, the metal segments opened like the peeling of a banana and the rocket accelerated away from the Cajun. The plastic motor, named "Little David" by its designers, had a diameter of 3.5 inches and a length of 20 inches. The stabilizing fins extended 1.75 inches out from the case. The rocket motor grain, consisting of 2.31 pounds of Thiokol propellant, was contained in the rearward half of the case. It provided a thrust of about 100 pounds for 3 seconds.

The 30-inch inflatable sphere was made from 0.0005-inch aluminum foil laminated on both sides with 0.00025-inch Mylar film. Ground tests in a vacuum chamber indicated that the ejection and inflation mechanism design was satisfactory.

The first test at Wallops was of the Little David rocket motor. The motor and its metal shield, as used with the Cajun, was fired from the launch pad on March 5, 1958. The test showed that the metal shield was pushed out of the way with ease and the motor ignited without any apparent delay and flew out of its container. The unit was apparently unstable aerodynamically, however, for it went through several gyrations and did not rise more than 20 feet. It came down on a concrete road about 100 feet from the launcher (ref. 86).

The rocket designers were pleased with the absence of ignition lag in the motor, for this had been the only problem in early ground firings at the PARD rocket test area at Langley. The instability was solved by testing the unit in the Langley Unitary Wind Tunnel to determine a stable center-of-gravity location. Later flight tests indicated stability.

Three flight tests were made of the complete three-stage vehicle on April 7, May 21, and October 7, 1958. In the first test, the sphere did not inflate, and in the third test the third-stage motor failed to fire. In the second test, however, everything worked as planned. The complete vehicle, ready for launch, is shown in figure 399. After burnout of the first stage Nike motor, there was a coast period of 20 seconds before the second stage Cajun was ignited. The third stage was ignited after a second coast period of about 35 seconds, by the end of which time an altitude of about 160,000 feet had been reached. The sphere was ejected and inflated at an altitude of about 500,000 feet, and it then continued on to an

35. Letter from M. G. Holloway, Director, MIT Lincoln Laboratory, to H. L. Dryden, Director, NACA, Dec. 27, 1956, regarding use of inflatable aluminized objects in long-range radar research.

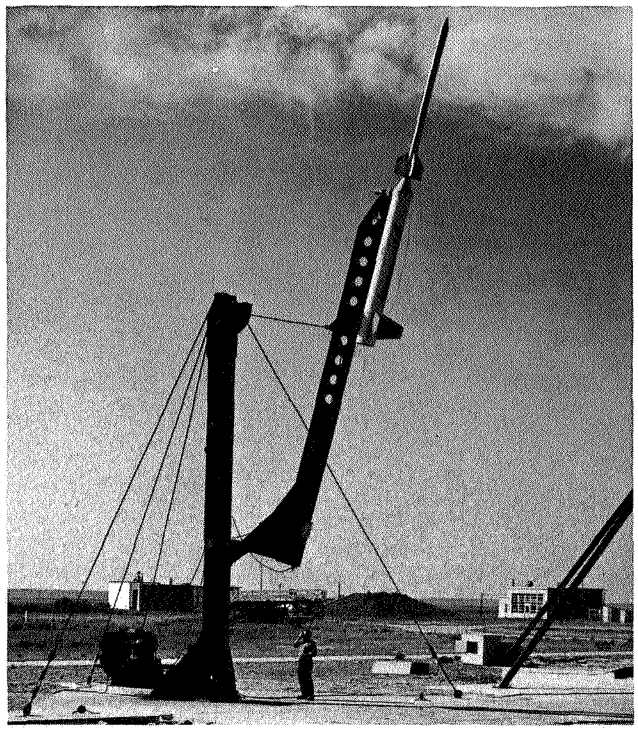


FIGURE 399. Nike-Cajun-Little David test vehicle for 30-inch inflatable radar target. Vehicle is shown ready for high-altitude test on May 21, 1958.

altitude of 800,000 feet. The empty Cajun reached an altitude of only about 400,000 feet. The vehicle was launched at 7:57 PM and the sphere was clearly visible to all observers after it emerged from the shadow of the earth. It was seen for about 2 minutes as it moved across the star field. The trail was recorded on a fixed camera plate, as shown in figure 400 (ref. 87). The MIT Millstone Hill radar was in operation during the flight tests of Hiball, and recorded some returns during the successful test on May 21, 1958; but for some unexplained reason the returns were considerably weaker than expected.

Lincoln Laboratory personnel were most appreciative of the aid given by the NACA in providing targets for use in the development of long-range radars. In this connection, Carl F. J. Overhage, Director, stated:

> We greatly appreciate the cooperation already being afforded us in the Hiball program and the extensions thereof. As you can well imagine, we still have much to learn about the long-range detection and tracking of small objects, and the targets Mr. O'Sullivan's program is providing for our Millstone Hill radar are most helpful in this regard.[36]

The Hiball system was not pursued further because by this time a 12-foot inflatable sphere had been developed. (See figure 401.)

During the latter part of 1957, after the 30-inch subsatellite package was essentially completed and awaiting availability of a Vanguard vehicle for launching, O'Sullivan made calculations of the size of sphere that could be used if it were the sole payload on Vanguard. After estimating that a 12-foot sphere could be constructed for about 10 pounds' weight, he made plans to construct a prototype. Before construction was very far along, world events raised the priority of such a sphere, and its construction was expedited.

The events that precipitated official action on the 12-foot sphere were the orbiting of *Sputniks I* and *II* by Russia. These satellites were clearly visible as a light of varying intensity as the payload cylinder tumbled end over end. Everyone involved with decisions regarding U. S. satellites, from the TPESP to the President and including the State Department and the Central Intelligence Agency, expressed a desire to put up a U. S. satellite that would be visible over Russia as well as the United States. The TPESP recommended O'Sullivan's 12-foot sphere for this purpose and officially approved it as a separate satellite project. At the November 1957 meeting of TPESP, at which the payload for the newly

36. Letter from Carl F. J. Overhage, Director, Lincoln Laboratory, to Hugh L. Dryden, Director, NACA, June 6, 1958.

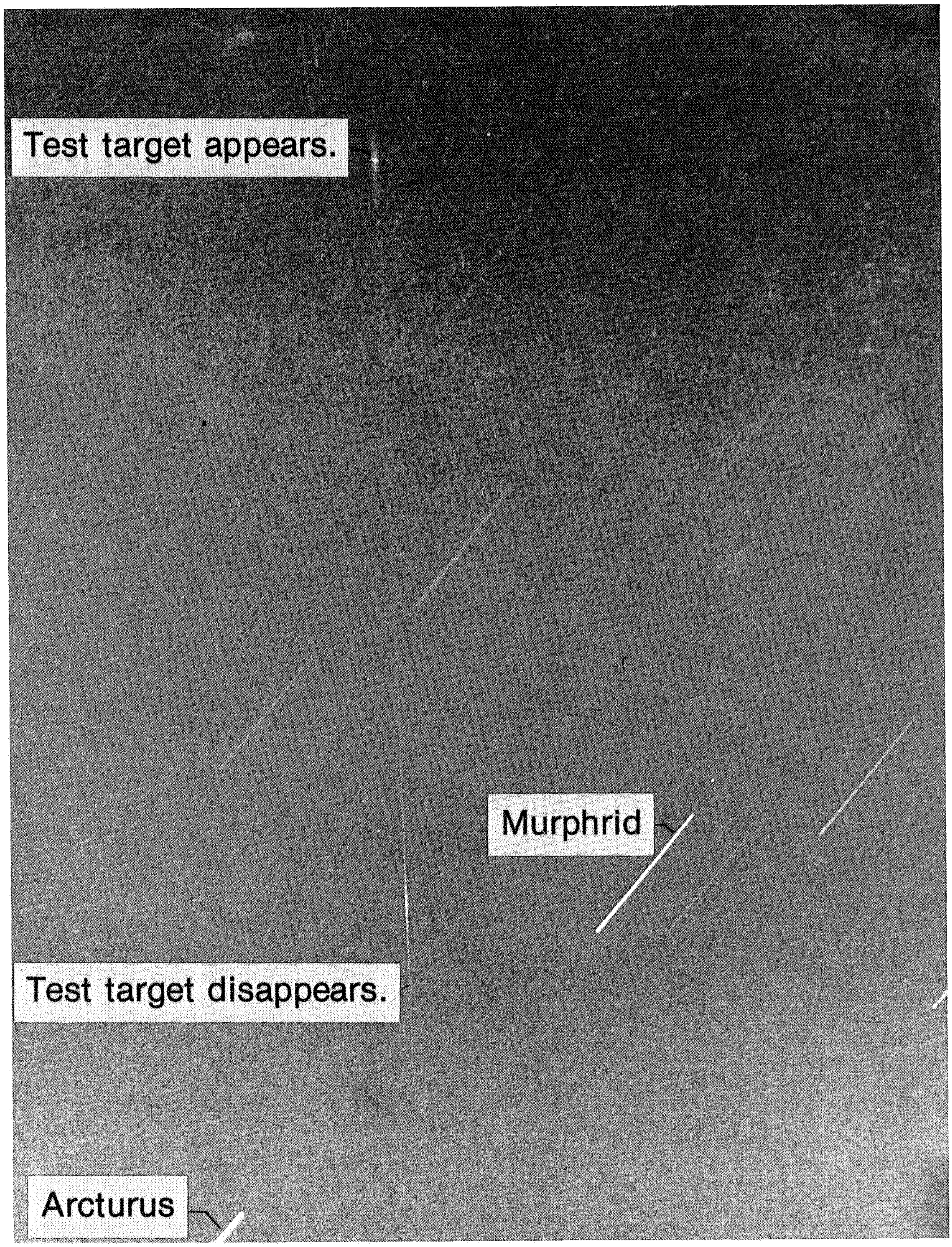


FIGURE 400. Visible trail of 30-inch inflatable radar target after inflation on the evening of May 21, 1958, at an altitude of 500,000 feet.

FIGURE 401. Engineer W. E. Bressette (left) stands beside 12-foot inflated sphere, and engineer J. L. Mitchell studies surface of 12-foot radar target while W. J. O'Sullivan, Jr., displays both the inflated 30-inch subsatellite and the folded form with inflation bottle and container (photograph taken in February 1958).

activated Jupiter C satellite vehicle was selected, the 12-foot sphere was recommended at first but was replaced by an existing IGY cosmic ray experiment. The Jupiter C required the use of a "high-kick" rocket motor to be fired at apogee of the satellite in order to achieve the desired perigee of 300 miles for the 12-foot sphere. Final decision on the use of a Jupiter C was postponed, but action was initiated to substitute a 12-foot sphere for one of the Vanguard payloads. Now the NACA was officially committed to inflatable spheres on two Vanguard vehicles. On November 26, 1957, word was received from Sirey of NRL that the Secretary of the Navy had ordered NRL to prepare a flight plan for launching an NACA 12-foot sphere on a Vanguard vehicle (ref. 88).

At the next meeting of TPESP, April 3, 1958, Vanguard TV-4 was listed as a backup vehicle, or possibly as the carrier for the NACA 12-foot satellite. Jupiter C vehicle No. 44 was also listed as a carrier for the 12-foot sphere. In an effort to fly the sphere as soon as possible, the Navy had proposed that it be flown as an attachment to the 6.4-inch-diameter Vanguard test satellite on TV-4, so that it could be tracked day and night. The NACA agreed to furnish the sphere and inflation bottle, while NRL was to furnish the carrier. When the first two Vanguards failed during launch, however, the NRL effort on the 12-foot sphere came to a halt. Since at the April meeting of TPESP, it had been listed as only a possible payload on a Vanguard, O'Sullivan concluded that the possibility of flying the sphere on a Vanguard was rather remote. He therefore recommended that all efforts be devoted to preparing the sphere for a launch on a Jupiter C (ref. 89).

At the April meeting, it was decided by the panel that the satellite would be placed in an orbit with a perigee of 400 miles and with an inclination of 51 degrees, to make it visible over a large area of the earth. The panel also recommended that the sphere be designed to separate from its carrier after inflation. In May 1958 when the ARGUS Program was initiated, the Jupiter C vehicle No. 44 and its backup No. 47 were assigned to launch the *Explorer IV* satellite as a part of that program. This left the 12-foot sphere without a launch vehicle, and the components were placed in storage.

On June 17, 1958, R. B. Canright of ARPA informed O'Sullivan that Jupiter C No. 49, the last of these vehicles, could be used for the 12-foot satellite project (ref. 90). This would be a one-shot affair with no backup. The NACA accepted the offer, and a joint team from JPL and Langley were assigned responsibility for the payload. The Jupiter C was launched from Cape Canaveral on October 23, 1958, without success, because the cluster of rockets forming the upper stages atop the Redstone separated early. A mockup of the packaged sphere, as used with Jupiter C, is shown in figure 402 along with a fully inflated sphere.

Early in 1958, in the development of the 12-foot inflatable sphere, a spherical vacuum chamber 41 feet in diameter was erected at Langley specifically to test the inflation characteristics of the sphere. Following successful completion of these tests, flight trials in a real space environment were made at Wallops with Nike-Cajun vehicles. The first of these vehicles, launched on April 24, 1958, is shown in figure 403. In this test, the inflated sphere was never seen in flight, and it was concluded that it failed to emerge from the nose cone.

On the following day, however, a quite successful test was made. The sphere was tracked by Wallops Mod II radar and by two long-range radars at Millstone Hill. Following separation of the nose cone from the Cajun motor, the sphere was ejected and inflated at an altitude of 200,000 feet. It continued on up to a peak altitude of 240,000 feet, and then descended slowly until it reached the jet stream at an altitude near 60,000 feet. At that point, it acquired considerable horizontal velocity as it continued on down to splash in the ocean. It was estimated that the sphere collapsed from external dynamic pressure at about 120,000 feet (ref. 91).

The sphere in the flight test was made of 0.001-inch Mylar film with a layer of 0.00045-inch aluminum foil glued to each side. This provided enough rigidity so that the sphere would retain its shape after inflation even if internal pressure were lost later. For the flight test, the air inside the sphere was removed by a vacuum pump, and the material was folded into two very compact rolls and packed into the nose cone of the Nike-Cajun, as shown in figure 404. The nose cone was 7.5 inches in diameter and 48 inches in length. In flight, the nose cone was separated from the Cajun by a strong compression spring actuated by an explosive bolt. Nitrogen gas in a storage bottle in the nose cone was used to push the folded sphere out of the rear of the separated nose by means of a bellows, and then was used to inflate the sphere through a special valve in the bellows that separated the sphere from the nose cone

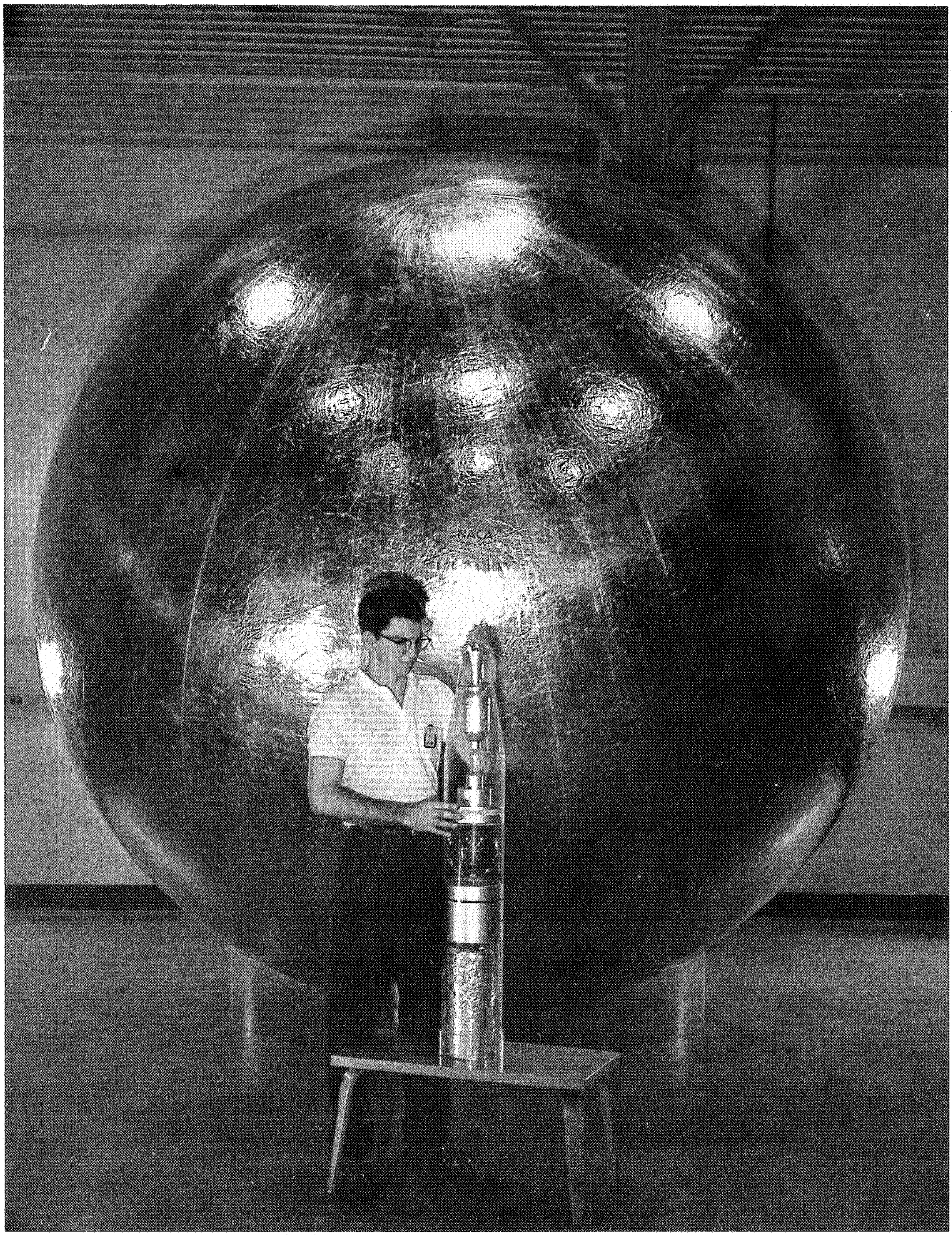


FIGURE 402. Engineer W. D. Nowlin with one of the 12-foot inflatable spheres and a simulated complete nose cone package with high-kick motor as prepared for flight test on a Jupiter C launch vehicle, October 23, 1958.

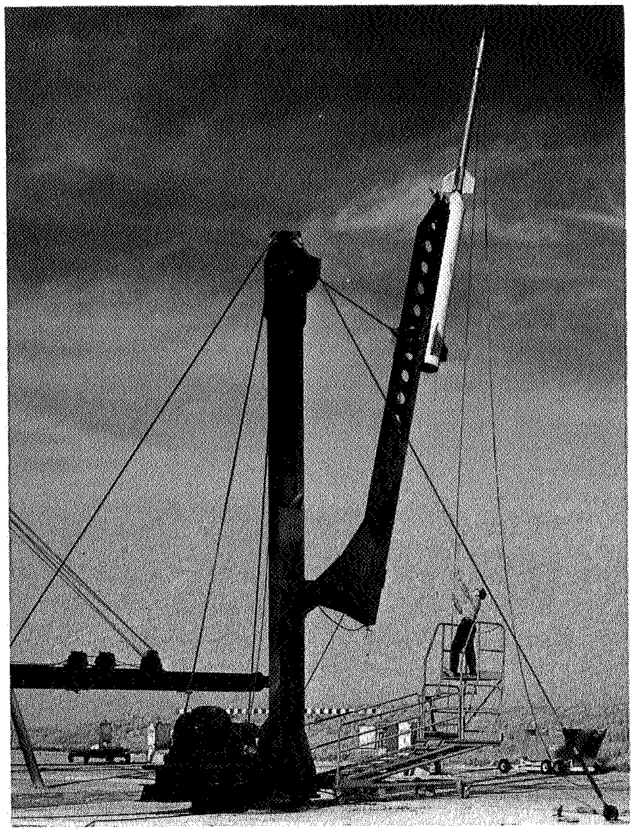


FIGURE 403. Nike-Cajun vehicle ready for high-altitude test of inflatable sphere, April 24, 1958.

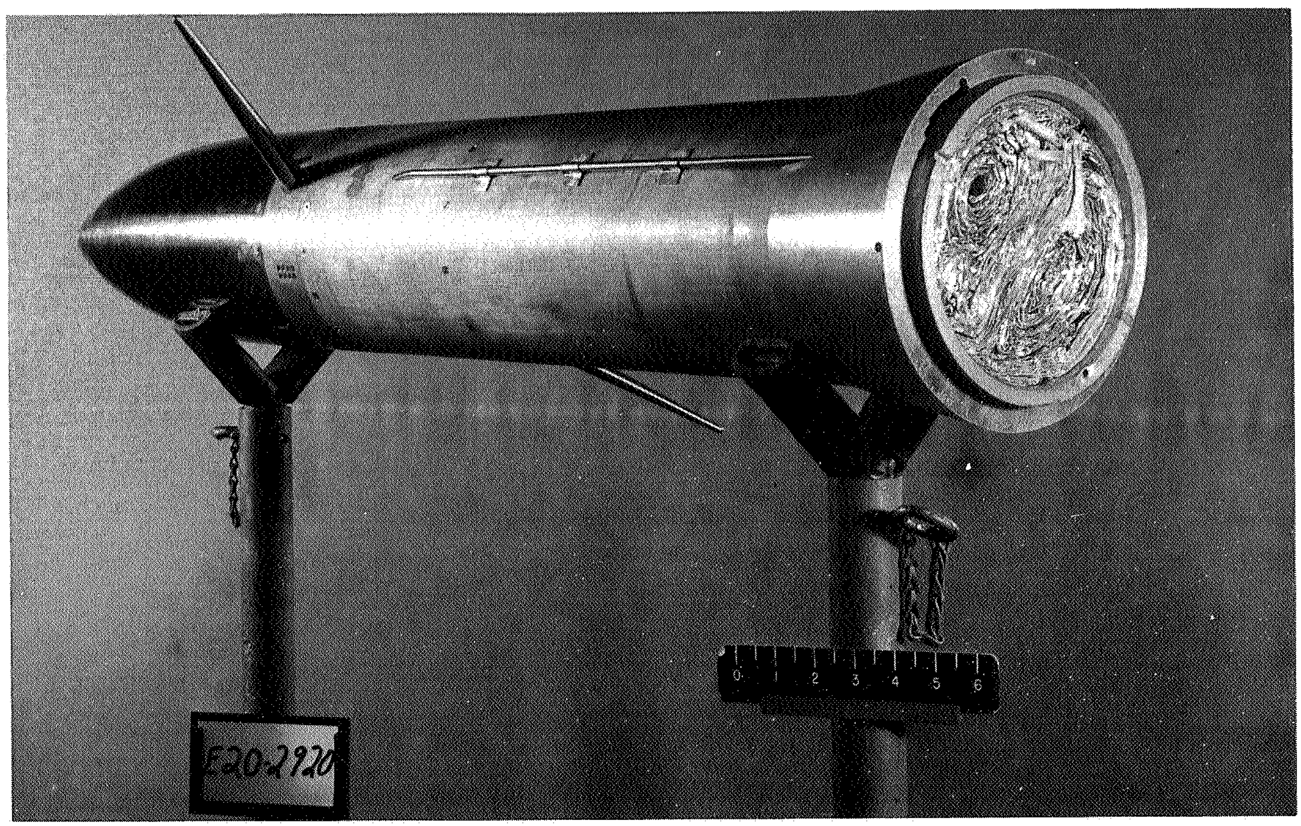


FIGURE 404. Nose cone of Nike-Cajun test vehicle, showing 12-foot inflatable sphere as packaged for first flight test at Wallops, April 24, 1958.

after it became fully inflated. In tests in the 41-foot vacuum chamber, the sphere was fully inflated in 30 seconds and separated from the nose section about 180 seconds after ejection. In flight, it appeared from an analysis of the trajectory that separation from the nose cone likewise occurred in about 180 seconds. By this time, the sphere was on the descending part of its trajectory.

A third Nike-Cajun launching was made on September 11, 1958, and again the sphere did not emerge. It was reasoned that a tumbling motion of the second stage at high altitude might have caused the failure.

A fourth attempt, on January 28, 1959, was successful. This time the fins on the Cajun motor were canted to give this stage a spin rate of 13.3 revolutions per second. This rate was high enough to prevent instability from cross-coupling with pitch or yaw motions. In this flight, the peak altitude was about 400,000 feet, and the sphere, launched at dusk, was clearly visible in the night sky with a brightness greater than that of Mars. All three radars at Wallops tracked the sphere. The new FPS-16 radar, in fact, tracked it out to a range of 100 nautical miles, at which time it was at an altitude of 18,000 feet. The Millstone Hill radar also tracked the sphere.

By the time of the fourth Nike-Cajun launching, January 1959, NASA had taken over all scientific space research, and numerous proposals were being considered for the determination of air density at high altitudes. One proposal was to launch a number of 12-foot spheres with Nike-Cajun vehicles. An attempt was made to deduce density from the trajectory of the fourth sphere launched at Wallops. There were too many uncertainties involved, however, and the estimated accuracy of this method did not appear good enough for the purpose. Calculations still indicated, however, that analysis of the motions of a 12-foot sphere in earth orbit would provide data of the desired accuracy. Consequently, attempts to place a 12-foot sphere into earth orbit continued.

The next attempt to orbit a 12-foot sphere was made on March 23, 1960, with a Juno II launch vehicle. This vehicle was similar to the Jupiter C except that it had a Jupiter missile as the first stage instead of a Redstone. The upper stages were clusters of Baby Sergeants, as with Jupiter C, except that neither the single fourth stage nor the small "high-kick" motor was required to place the sphere in the desired orbit. Unfortunately, however, trouble developed with the upper stages in the flight, and an orbit was not achieved.

By this time, as will be discussed in more detail in the next chapter, the four-stage solid-motor Scout vehicle was under development, and plans were made to use a 12-foot sphere as a payload in one of the development firings. This was done on Scout 3, launched December 4, 1960, but again no orbit was achieved, because the second stage did not ignite. Success came finally with Scout 4, on February 16, 1961. The spherical satellite, identified as *Explorer IX*, had an orbit with a perigee of 392.8 miles and an apogee of 1,607.2 miles. It was to remain in orbit for many years and to provide new data, not only on air density, but on solar radiation pressure as well. Data on air density in the exosphere were to be obtained for the first time, the effects of solar activity on density were determined, and a new phenomenon called the "helium bulge" was discovered. The success of the project was certainly worth the effort and persistence of the researchers. *Explorer IX* was so successful that additional spheres were to be orbited at 2-year intervals to provide continual coverage of density variation throughout a solar cycle.

In figure 405, the sphere used in *Explorer IX* is shown inflated. It was made of a four-ply laminate consisting of alternate layers of 0.0005-inch aluminum foil and 0.0005-inch Mylar film. It was painted with white "polka dots" to provide proper temperature control in space for the tracking beacon contained within the sphere. Reflection of light from the sphere was more nearly specular than diffuse, which ensured visibility over a wide angular range. Details on the design of the various 30-inch and 12-foot inflatable spheres were given in a special NASA report (ref. 92).

LEWIS HYDROGEN-FLUORINE ROCKET ENGINE

The search for high-impulse propellants for rocket engines led the Lewis Laboratory to give serious consideration to a hydrogen-fluorine system for space application. Such an engine would theoretically yield a gain of 15 to 20 percent over a hydrogen-oxygen engine. A successful operation of a hydrogen-fluorine engine, as well as that of a hydrogen-oxygen engine, had been demonstrated in

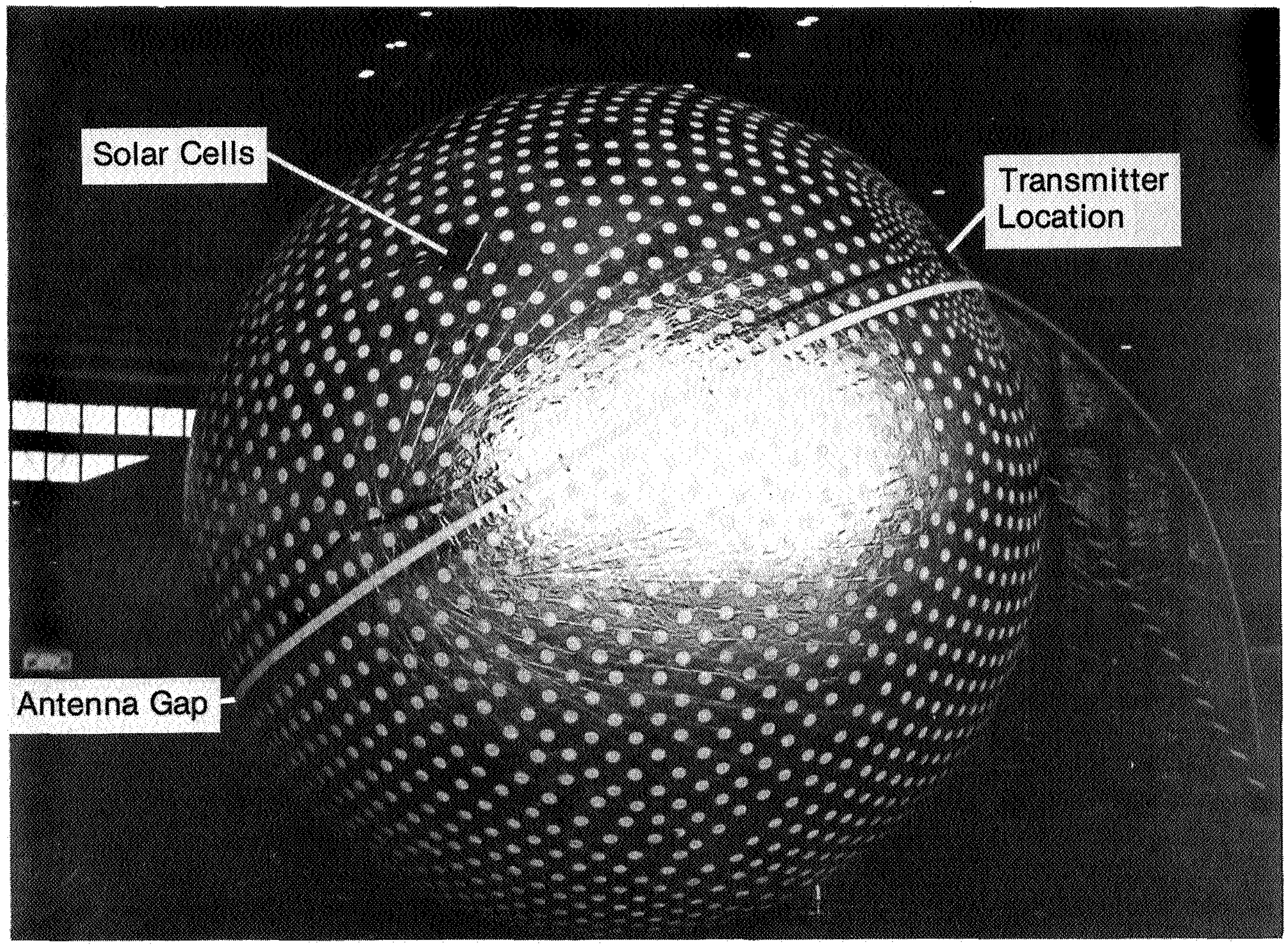


FIGURE 405. Inflated 12-foot sphere showing polka-dot painting of surface for temperature control as used on *Explorer IX* satellite, launched at Wallops by Scout vehicle on February 16, 1961.

static tests at Lewis. The main unanswered questions were whether the propellant-mass fraction of a hydrogen-fluorine system could be made comparable with that of a hydrogen-oxygen system, and whether the system was practicable. The extremely low temperatures of these cryogenic fuels created difficult handling problems. To provide some answers to these questions, Lewis proposed that a ground-launched flight test be made at Wallops, and Langley was asked to assist in development of the launch vehicle. A. C. Bond of PARD was assigned to the project, and during his visit to Lewis on May 28, 1958, some decisions were made about the flight program (ref. 93).

It was planned to use a Sergeant rocket motor with two strap-on Recruit motors in the launch vehicle. The hydrogen-fluorine rocket engine and propellant tanks with an instrumentation package on the front of it would be mounted ahead of the Sergeant as a second stage. Bond calculated that the Sergeant first stage could propel the test engine to an altitude of 30,000 feet and a Mach number of 3.1 at burnout. The hydrogen-fluorine stage was expected to propel the test vehicle to about 400,000 feet, after which the vehicle would coast to an altitude of 530 miles and then splash between 1,100 and 1,400 miles downrange. The test stage was estimated to have a weight of 5,000 pounds. Langley proceeded with design of the first stage and Lewis concentrated on the second. Special wedge-cross-section fins with an area of 15 square feet per panel were designed to stabilize the overall vehicle. The design and construction of four sets of these fins were accomplished by Aerolab Development Company. The same fins were later to be used on the Shotput vehicle, to be discussed in the next chapter. Overall suitability of the design of the vehicle was investigated with three scale models launched at Wallops between October 1958 and April 1959. The PARD designation was H59.

By August 1958, Lewis personnel considered it desirable to static-test the hydrogen-fluorine engine prior to the flight test. Because of the hazards involved with fluorine, Wallops was proposed as the site for the static tests. For safety, it was proposed that all nonessential personnel be evacuated from the island and that the engine be loaded and fired from a remote bunker. The hot exhaust gases were to be allowed to flow upward and to be carried out to sea by prevailing winds. A water scrubber to contain the toxic gases was not recommended for two reasons, both of which alarmed Krieger because of the hazards. First, water would turn some of the exhaust gases into hydrofluoric acid, a most corrosive agent. Second, Lewis stated that it was necessary to inject hydrogen into the engine prior to the fluorine to ensure that fluorine would not enter the engine first and destroy the metal components. Injecting hydrogen ahead of the fluorine, however, would create a highly explosive mixture in the scrubber, very easily ignited.[37] By this time, a static test was planned for February 1959 and a flight test for April 1959. Although Krieger had been concerned about the hazards of a flight test of a hydrogen fluorine engine at Wallops, he did not object because the actual test was to be conducted at high altitudes. Now that the project called for a static firing at Wallops with many new hazards, he voiced his objection. In September 1958, Gilruth, Faget, and Bond visited Lewis to discuss the whole situation. During this visit, the decision was reached to change the propellants from liquid hydrogen-fluorine to liquid hydrogen-oxygen. While the reason officially given was the long development time required for the fluorine system, the extreme hazards were, no doubt, a contributing factor.

After NASA was established in October 1958, many of the men involved in this program, including Bond, Gilruth, and Faget, were transferred to either NASA Headquarters or the Space Task Group at Langley. When the Goddard Space Flight Center was established, Silverstein transferred responsibility for the flight test to that center, and W. K. Ritter, the project manager from Lewis, transferred to Goddard. At Goddard, the program lost its impetus and the project as conceived was canceled. The fact that a contract had been let to develop the Centaur rocket, also a hydrogen-oxygen system, probably contributed to the demise of the project. The components remaining at Langley were placed in storage for later use in other projects.

References

1. Gilruth, R. R., Memorandum for Dr. Dryden, Jan. 5, 1956, regarding additional rockets and space radar for hypersonic program.
2. Reeder, John P., Head, Flight Operations, Memorandum for Director, Mar. 12, 1958, regarding helicopter airlift for Wallops Island personnel.
3. Hinson, William F.: *Transonic and Supersonic Ejection Release Characteristics of Six Dynamically Scaled External-Store Shapes From an 0.086-Scale Model of a Current Fighter Airplane.* NASA TM X–128, Dec. 1959.
4. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Space and Technology in the Exploration of Space, 1915–1960.* NASA, 1961, p. 85.
5. *Ibid.*, p. 98.
6. Swanson, Andrew G.: *Free-Flight Investigation of Aerodynamic Heat Transfer to a Simulated Glide-Rocket Shape at Mach Numbers Up to 10.* NACA RM L58G03.
7. Royals, John F.; and Newcomb, John F.: *Investigation of Heat Transfer on a Simulated 82° Swept Delta Wing in Free Flight at Angle of Attack at Mach Numbers Up to 9.8.* NASA TM X–622, Mar. 1962.
8. Falanga, Ralph A.: *Free-Flight Heat-Transfer Investigation at Supersonic Speeds of Two Slender Cone-Cylinder Bodies at an Angle of Attack of 8° With One Body Rotating.* NASA MEMO 12–31–58L.
9. Hall, James R.: *Free-Flight Measurements of Heat Transfer to a Simulated Winged-Cone Glide Vehicle at Angles of Attack and at Mach Numbers From 10 to 14.3.* NASA TM X–586, Aug. 1961.
10. Hoffman, Sherwood; and Blanchard, Willard S., Jr.: *Free-Flight Investigation at Supersonic Speeds of the Stability and Drag of a 79° Clipped Delta Boost-Glide Configuration Including an Analog Study of Coupled Motions During the Flight.* NASA TM X–425, Jan. 1961.
11. Raper, James L.: *Flight Test and Analysis of the Rolling Motions of a 79° Clipped Delta Configuration With Wing-Tip Fins at Supersonic Speeds.* NASA TN D–2017, Nov. 1963.
12. Goodman, George P.; and Betts, John, Jr.: *Exploratory Environmental Tests of Several Heat Shields.* NASA TN D–897, Sept. 1961.
13. Green, Joseph M.; and Rosecrans, Richard: *Elevated-Temperature Tests Under Static and Aerodynamic Conditions on Corrugated-Stiffened Panels.* NASA TM X–34, Sept. 1959.
14. Hall, James R.; and Garland, Benjamine J.: *A Feasibility Study of the Flare-Cylinder Configuration as a Reentry Body Shape For an Intermediate-Range Ballistic Missile.* NACA RM L58C21.
15. McFall, John C., Jr.: *Polaris: Drag Measurements of a 1/3-Scale Reentry Body With Rocket-Boosted Models in Free Flight at Mach Numbers From 2.8 to 0.6.* NASA TM X–1, Aug. 1959.
16. McFall, John C., Jr.: *Free-Flight Drag Measurements of Rocket-Boosted Models of Two Reentry Body Configurations at Mach Numbers From 4.3 to 0.6.* NASA TM X–118, Oct. 1959.

37. Letter from Lewis to NACA Headquarters, Aug. 12, 1958, regarding future flight test of hydrogen-fluorine rocket.

17. Hoffman, S., Memorandum for Associate Director., Sept. 16, 1957, regarding visit of NOL and NOEU representatives on Aug. 27, 1957, to discuss rocket models of Polaris to provide data for fuzing switch.
18. Mayhue, Robert J.; and Blanchard, Willard S., Jr.: *Free-Flight Investigation of the Base Pressure and Drag of a Flare-Stabilized Blunt-Nose Reentry Body Having a Fineness Ratio of 3.11 at Mach Numbers From 0.70 to 1.90.* NASA TM X−214, Mar. 1960.
19. Mayhue, Robert J.: *Free-Flight Measurements of the Base Pressures and Drag of a Flare-Stabilized Cylindrical Reentry Body With an Elliptical Blunt Nose at Mach Numbers From 1.9 to 0.7.* NASA TM X−309, Sept. 1960.
20. Faget, M. A., Memorandum, for Associate Director, July 31, 1957, regarding visit of Polaris representatives on June 27, 1957, to discuss heat transfer tests.
21. Faget, M. A., Memorandum, for Associate Director, Dec. 27, 1957, regarding visit to Lockheed on Dec. 12, 1957, to discuss heat transfer tests.
22. Hall, J. R., Memorandum, for Associate Director, Feb. 5, 1958, regarding heat transfer tests of Polaris models.
23. Hall, James R.; and Graham, John B., Jr.: *Aerodynamic Heating and Lateral Force Measurements of a Blunt-Nose Flare-Cylinder Configuration Undergoing Large Lateral Oscillations at Mach Numbers Up to 10.15.* NASA TM X−45, Sept. 1959.
24. *Jane's All The World's Aircraft,* 1959−1960, p. 450.
25. Hastings, E. C., Jr., Memorandum, for Associate Director, Sept. 2, 1958, regarding conference on rocket test program on Corvus missile.
26. Hastings, E. C., Jr., Memorandum, for Associate Director, May 11, 1959, regarding additional rocket model tests of Corvus missile parachute recovery system.
27. Hastings, E. C., Jr., Memorandum for Associate Director, Aug. 4, 1959, regarding rocket model test of Corvus missile at White Sands Proving Ground.
28. Hastings, E. C., Jr., Memorandum for Associate Director, Aug. 20, 1959, regarding second Corvus model test at White Sands.
29. Dickens, Waldo L.: *A Parachute Recovery Test of a Full-Scale Free-Flight Model of an Air-to-Surface Missile With Recovery Initiated at a Mach Number of 1.43.* NASA TM X−451, Apr. 1961.
30. Nason, Martin L.: *An Evaluation of an Aeromechanical Method of Minimizing Servo-Missile Transfer-Function Variations With Flight Conditions.* NACA RM L56A31.
31. Robins, Clarence A., Jr.: *Flight Investigation at Supersonic Mach Numbers of a Torque Plus Position Servocontrol System.* NASA TM X−60. Oct. 1959.
32. Gardner, W. N., Memorandum for Associate Director, Mar. 24, 1958, regarding proposed tests of Tart rocket at Wallops Island.
33. Bond, A. C., Memorandum for Associate Director, Nov. 25, 1957, regarding visit of G.E. representative Nov. 14, 1957, to discuss need for flight test of ablative nose cone.
34. Gilruth, R. R., Memorandum for Dr. Dryden, Jan. 5, 1956, regarding additional rockets and space radar for hypersonic program.
35. Krieger, R. L., Memorandum for Associate Director, Dec. 2, 1957, regarding request for assistance from the Navy for space on a ship for a telemeter receiver.
36. Rumsey, Charles B.; and Lee, Dorothy B.: *Heat-Transfer Measurements on a Blunt Spherical-Segment Nose to a Mach Number of 15.1 and Flight Performance of the Rocket-Propelled Model to a Mach Number of 17.8.* NASA TM X−77, Nov. 1959.
37. Purser, Paul E.; and Fields, E. M.: "Some Research on the Lift and Stability of Wing-Body Combinations." Paper presented to Fin-Stabilized Committee, Picatinny Arsenal, Dover, N.J., July 20, 1955. Reissued as NACA RM L55G06a.
38. Lundstrom, Reginald R.: *Stability of Two Rocket-Propelled Models Having Aspect-Ratio-5 Unswept Tails on a Long Body For the Mach Number Range of 1.7 to 2.4.* NACA RM L57A31a.
39. Henning, Allen B.: *Stability Characteristics of Two Missiles of Fineness Ratios 12 and 18 With Six Rectangular Fins of Very Low Aspect Ratio Over a Mach Number Range of 1.4 to 3.2.* NASA Memo 12−2−58L.
40. Baber, Hal T., Jr.; and Henning, Allen B.: *Stability Characteristics From Mach Number 1.0 to 3.2 of a Missile of Fineness Ratio 11.5 With a 10° Flared-Skirt Afterbody.* NASA Memo 4−2−59L.
41. Lyons, W. C., Jr.: *Design of an Acceleration Insensitive Skin-Friction Balance For Supersonic Flight.* Defense Research Laboratory of the University of Texas. Report DRL−397, Bumblebee CF−2605, June 1957.
42. Fenter, F. W.; and Lyons, W. C., Jr.: *The Direct Measurement of Local Skin Friction on a 15° Cone Re-Entering the Atmosphere at Hypersonic Speeds.* Defense Research Laboratory of the University of Texas, Report DRL−415, Bumblebee CM−918, Feb. 14, 1958.
43. Piland, R. O., Memorandum for Associate Director, Sept. 3, 1957, regarding visit of University of Texas and APL representatives to propose tests of skin-friction drag balance on RM−10, Sept. 3, 1957.
44. Thompson, M. J.; Westkaemper, J. C.; and Murphy, C. E., Jr.: "Skin Friction and Heat Transfer Measurements on Flight Research Vehicles." Paper presented at Bumblebee Symposium, Ann Arbor, Mich., May 10−11, 1960.
45. Emme, *op. cit.*, p. 101.
46. Shortal, J. A., Memorandum for Associate Director, May 7, 1958, regarding visit of Captain John J. Buckley of AFSWC to Langley on May 6, 1958, to discuss ARGUS program.
47. Swanson, A. G., Memorandum for Associate Director, May 27, 1958, regarding visit of representatives of Lockheed, Aerolab, and Air Force on May 19, 1958, to discuss Project JASON.
48. Swanson, Andrew G.: *A Five-Stage Solid-Fuel Sounding-Rocket System.* NASA Memo 3−6−59L.
49. Piland, R. O., Memorandum for Associate Director, Apr. 8, 1957, regarding visit of University of Michigan representatives to discuss high-altitude tests.
50. Parks, J. H., Memorandum for Associate Director, Mar. 27, 1958, regarding visit of University of Michigan personnel to PARD on Mar. 21, 1958.

51. Dickens, Waldo L.; and Hastings, Earl C., Jr.: *A Three-Stage Solid-Fuel Sounding Rocket System Suitable For Research at Altitudes Near 200 Nautical Miles.* NASA TM X−132, Reissued as NASA TN D−219, Dec. 1959.
52. Hansen, W. J.; and Fischbach, F. F.: *The Exos Sounding Rocket.* University of Michigan, AFCRC TR−59−216, Dec. 1958.
53. May, Ralph W., Jr., Memorandum for Record, May 8, 1958, regarding visit of S. F. Singer and R. T. Bettinger to NACA Headquarters to discuss checkout firings at PARD of a small one-stage high-altitude rocket.
54. O'Sullivan, W. J., Jr., Memorandum for Associate Director, June 13, 1958, regarding proposal by S. F. Singer for atmosphere research.
55. Parks, J. H., Memorandum for Associate Director, Aug. 4, 1958, regarding PARD participation in Oriole project.
56. Shufflebarger, C. C., Memorandum for Associate Director, Aug. 22, 1958, regarding PARD participation in Oriole project.
57. Shufflebarger, C. C., Memorandum for Associate Director, Oct. 8, 1958, regarding status of Oriole project.
58. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Oct. 24, 1955, regarding Atlantic Research Corporation proposed sounding rocket.
59. Townsend, John W., Jr.; and Hartz, F. J.: *ARCON and IRIS Rocket Report No. 1.* NRL Report 5073, Jan. 21, 1958.
60. Jackson, Bruce G., Memorandum for Associate Director, June 3, 1958, regarding conference with NRL engineers concerning Wallops tests.
61. Wallops PARD Log, July 21, 1958.
62. Townsend, J. W., Jr., Office Memorandum to M. B. Ames, Jr., Mar. 4, 1959, requesting assistance of Langley in working up data from Arcon firings at Wallops.
63. Krieger, R. L., Memorandum for Associate Director, Aug. 16, 1957, regarding New York Regional Airspace Subcommittee Meeting No. 114.
64. Krieger, R. L., Memorandum for Associate Director, Jan. 24, 1958, regarding NACA position on airway proposal included in agenda of Meeting No. 118 of the Airspace Subcommittee.
65. Minutes, New York Regional Airspace Subcommittee Meeting No. 118.
66. Krieger, R. L., Memorandum for Associate Director, Apr. 21, 1958, regarding range safety at Wallops Island.
67. Markley, J. T., Memorandum for Associate Director, Nov. 24, 1958, regarding visit of CAA officials to Wallops Island on Nov. 20, 1958.
68. Wood, Clotaire, Memorandum for the Administrator, Dec. 18, 1958, regarding briefing of E. Quesada on proposed Wallops expansion. (Markley, J. T., Memo for Record, Dec. 23, 1958.)
69. Shortal, J. A., Memorandum for Associate Director, July 9, 1959, regarding Wallops−FAA airspace coordination.
70. *Joint Utilization of Airspace, Wallops Island.* Langley Staff Study, Oct. 16, 1958.
71. Robillard, G.: *The Explorer Rocket Research Program.* ORDCIT Publication No. 145, Jet Propulsion Laboratory, Oct. 31, 1958.
72. *NACA Research Into Space.* NACA, Dec. 1957.
73. *A National Research Program For Space Technology.* NACA Staff Study, Jan. 14, 1958. Released to the public Jan. 27, 1958.
74. Dryden, Hugh L.: "Space Technology and the NACA," speech delivered at luncheon meeting of Institute of the Aeronautical Sciences, New York, N.Y., Jan. 27, 1958.
75. Swensen, Loyd S., Jr.; Grimwood, James M.; and Alexander, Charles C.: *This New Ocean, A History of Project Mercury.* NASA, 1966.
76. Thompson, F. L., Memorandum for All Concerned, Nov. 21, 1958, regarding change in organization of Langley.
77. Thompson, F. L., Memorandum for All Concerned, Feb. 18, 1959, regarding change in organization of IRD.
78. Thompson, F. L., Memorandum for All Concerned, Nov. 5, 1958, regarding establisment of Space Task Group.
79. Shortal, J. A., Memorandum for All Concerned, Dec. 1, 1958, regarding change in organization of PARD.
80. Reid, H. J. E., Memorandum for All Concerned, Dec. 23, 1959, regarding changes in organization of Langley Research Center.
81. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Feb. 7, 1956, reporting on Project Vanguard and the IAS, UARRP, and TPR meetings of Jan. 25−27, 1956.
82. O'Sullivan, W. J., Jr., Memorandum for Director, June 29, 1956, proposing that the NACA undertake research on development of earth satellites—in particular, an air-density satellite.
83. Gilruth, R. R., Memorandum for Associate Director, July 13, 1956, commenting on suggestion for research on drag of earth satellite.
84. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Sept. 19, 1956, reporting on action taken by USNC−IGY Technical Panel on Earth Satellites on Sept. 5, 1956, regarding NACA proposal.
85. Shortal, J. A., Memorandum For All Concerned, Dec. 26, 1956, regarding changes in organization of PARD.
86. Wallops PARD Log, Mar. 5, 1958.
87. Rose, James T.; and Smith, R. Donald: *A Radar Test Target System.* NASA TN D−164, Jan. 1960.
88. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Dec. 5, 1957, regarding NACA 12-foot spherical satellite.
89. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Apr. 9, 1958, regarding decisions made on NACA 12-foot satellite at Apr. 3, 1958 meeting of TPESP.
90. O'Sullivan, W. J., Jr., Memorandum for Associate Director, July 11, 1958, regarding reactivation of NACA 12-foot satellite.
91. Kehlet, Alan B.; and Patterson, Herbert G.: *Free-Flight Test of a Technique For Inflating an NASA 12-Foot-Diameter Sphere at High Altitude.* NASA Memo 2−5−59L.
92. Coffee, Claude W., Jr.; Bressette, Walter E.; and Keating, Gerald M.: *Design of the NASA Lightweight Inflatable Satellites For the Determination of Atmospheric Density at Extreme Altitudes.* NASA TN D−1243, Apr. 1962.
93. Bond, A. C., Memorandum for Associate Director, June 5, 1958, regarding visit to Lewis to discuss flight test of hydrogen-fluorine rocket motor.

CHAPTER 16

FIRST YEAR UNDER NASA: 1959

ACQUISITION OF CHINCOTEAGUE NAVAL AIR STATION AND REORGANIZATION OF WALLOPS

From the beginning of the NASA space program, it was planned for Wallops to have a vital part. This was so because Wallops and PARD were already heavily engaged in space-related activities by the time NASA was established. In fact, the long-term successful rocket-model program at Wallops was a strong factor influencing the decision to give the NACA responsibility for all civilian space activity under a greatly expanded NASA. In early discussions, the NACA had pointed out that the activities of PARD and Wallops were about 90 percent space and missile related. In discussions of the role of Wallops, the only question was just how large a role it should have. The expansion discussed involved an expenditure of about $20 million to provide long-range instrumentation and facilities for launching satellite launch vehicles that would have a first stage as large as a Thor missile. One plan discussed was to make Wallops the main space flight center, with the possibility of expansion to the size of Cape Canaveral. After Beltsville, Maryland, was selected for the new space center, however, this type of planning was abandoned. Since NACA Director Hugh L. Dryden had decreed early in the period that the existing research centers were not to be burdened with space flight activities, it was only natural that because Wallops, the only rocket test range of the NACA, was soon to be expanded for even greater space flight capabilities under NASA, it would be separated from Langley and PARD. This was particularly necessary because, as a space flight range of NASA, it would now be a part of the Office of Space Flight Development, while Langley would be under the Office of Aeronautical and Space Research. This assignment to the Office of Space Flight Development was a fortunate one for Wallops, for space funds were assured for that department, and considerable growth was inevitable.

For some time, Wallops (on paper) was a unit of the Goddard Space Flight Center, but, as has been discussed in Chapter 15, this relationship did not last long, and in operation Wallops became an independent field station. The expansion of facilities at Wallops will be discussed later in this chapter. The change in organization and responsibility required for operation as an independent unit was quite extensive, and it was some time before Wallops had acquired sufficient personnel to take over the many support functions previously handled by Langley. The transition was easier than it might otherwise have been, because the contact for Wallops in the Office of Space Flight Development was E. C. Buckley, Assistant Director for Flight Operations, a man with whom Krieger had maintained a close working relationship since the beginning of his service with the NACA.

Although Krieger had been the Engineer-in-Charge for Wallops since 1948, he held a dual position, having been stationed at Langley since 1951, with responsibility as a branch head in PARD. As was discussed in Chapter 8, this branch became the "Research Techniques and Operations Branch" in 1954. John C. Palmer was acting Engineer-in-Charge for Wallops whenever Krieger was not there. Although Krieger spent a considerable amount of time on a travel status at Wallops, much of the direction was handled by telephone contact. The day-to-day operational decisions were made by Palmer.

Wallops was a test facility of PARD and had a support function. In turn, the service and support divisions at Langley provided the same support for Wallops that they did for the other research divisions at Langley. Organizationally, only the Research Section under Palmer at Wallops was directly assigned to Krieger's RT&O branch of PARD. The Technical Service Unit under W. E. Grant reported to the Mechanical Service Division at Langley, while the Administrative Unit under J. E. Robbins reported to the Administrative Officer. In effect, then, only about 25 of the 90 people at Wallops were actually assigned to Krieger. This did not present any problems, however, because the only reason for anyone's being there was to support the PARD research tests. The line of authority extended from H. J. E. Reid, Director, to Krieger through F. L. Thompson, Associate Director, R. R. Gilruth, Assistant Director, and J. A. Shortal, Division Chief. Until Krieger actually moved to Wallops in July 1959, he continued to serve as a PARD branch head, and operations continued as before, although plans for eventual independent operation were being made.

The original plan for expansion of Wallops in its space role called for the construction of service facilities on the mainland, where a new causeway would cross over from the island. The facilities were to include an administrative building, a large shop, and model assembly facilities. Construction would require acquisition of a large area of land on the mainland. This plan was short-lived, however, for when the Navy decided to close down its base at Chincoteague, NASA saw this as the answer to the need for more land and facilities.

On January 9, 1959, T. S. Gates, Jr., Secretary of the Navy, informed T. K. Glennan, NASA Administrator, of his plan to deactivate Chincoteague Naval Air Station. After consultation with Buckley and Krieger about the adaptability of the station to Wallops' needs, Glennan requested, on January 22, 1959, that the station be turned over to NASA on June 30, 1959, for operations in support of the NASA space program.

The first information on the planned closing of Chincoteague came from a newspaper article late in December 1958. It must have been a surprise to the Air Station personnel, for they had several new buildings under construction, and one runway had just been extended to 10,000 feet. In May 1958, the Navy Public Works Office of the Fifth Naval District requested the NACA to permanently transfer to the Navy the portion of Wallops Island in use by NAOTS.[1] Even later, on August 25, 1958, NAOTS requested permission of Langley for construction of a concrete impact strip 100 feet by 800 feet, with a thickness of 10 inches. Dryden gave permission for this on November 28, 1958. On December 22, 1958, Krieger, Hooker, and Norsworthy of Langley, accompanied by R. E. Ulmer, NASA Budget Officer, visited the Air Station to determine the effects of the contemplated closing of the Air Station and NAOTS facilities on Wallops operations. At this time, they were mainly concerned about the loss of the Navy airport and hospital, but the existence of modern missile-handling and shop facilities was appealing to Krieger. Ulmer proposed to Glennan that the station be considered for the new Space Projects Center because it was already in being, as opposed to the Beltsville location, which was undeveloped (ref. 1).

An agreement was reached between Glennan and Gates on January 23, 1959, for transfer of the Naval Air Station to NASA, effective June 30, 1959. It was estimated that this transfer would save NASA $2.5 million and reduce the needed purchase of mainland property from 1,200 acres to about 350 acres.[2] The civilian work force at Chincoteague numbered 760, while Wallops had about 90 employees, with an expected expansion to 250.

Although the transfer of Chincoteague to NASA was considered a blessing, it was a mixed one for there were many problems associated with this takeover and the conversion for Wallops' use. The desire to absorb many of the Navy civilian workers who did not want to leave the area, and the actual

1. Letter from H. F. Mackay, Deputy District Public Works Officer, to H. J. E. Reid, May 5, 1958, regarding permanent transfer of a portion of Wallops Island to the Navy.
2. NASA release, Jan. 24, 1959, regarding acquisition of Chincoteague Naval Air Station.

housekeeping chores for such a large base, were just two of the many considerations. The fact that many of the Chincoteague employees did transfer to NASA served to lighten the burden somewhat.

The Chincoteague Naval Base, with its 2,400 acres, was much larger than the planned expansion of Wallops at the mainland and contained many more buildings than were needed. At the first announcement of the transfer, NASA indicated that only a part of the station would be used. This left open the possibility for other tenants, and many avenues were explored.

The local newspapers were optimistic about a large influx of industry and the possibility of a second Cape Canaveral on the Eastern Shore. The *Peninsula Enterprise* for February 26, 1959, noted that a planned meeting of the Accomack County Board of Supervisors with an engineering firm from Washington, D.C., might bring contracting firms into the area in support of NASA. "Still guessing, such a plan might involve a corporation taking over the management of a part of the Air Station, as a landlord, leasing parts of it to private concerns. When the men from Washington meet the supervisors at Accomack Wednesday, March 11, at 2 PM, the news emerging from the session could be mighty good." The *Eastern Shore News* on February 26, 1959, was just as optimistic. Delegate Melvin Shreves was quoted as saying that NASA would grow into an even bigger operation than the Naval Base and "In my opinion in one or two years NASA will be a tremendous operation."

Buckley was disturbed by the thought that perhaps a large number of contractors might be allowed to operate at the Chincoteague Base, and took steps to forestall any such move. On March 2, 1959, he sent a memorandum to A. F. Siepert, NASA Director of Business Administration, pointing out that allowing other users to move into Chincoteague could pose a serious problem of radio interference. The long-range radar and telemeter receiving equipment planned for Chincoteague and Wallops for the tracking of high-altitude probes and satellites would be so sensitive that their operation could be jeopardized by emissions from industrial activity. He cited the fact that the other long-range tracking antennas in the world, such as the one at Goldstone, California, the telescopes in West Virginia, and a recently chosen site in Spain, were selected for their isolation from populated areas and were protected by mountains from extraneous radio signals. He recommended that NASA limit additional use of Chincoteague by keeping to a minimum both aircraft traffic and any use of electrical power (ref. 2). Twelve years later, the area would still be waiting for an influx of industrial contractors.

The mechanism for turning the Naval Air Station over to NASA was for the Navy to issue NASA an interim occupancy permit, pending permanent transfer. Such a license was issued on June 12, 1959.[3] The Navy placed a freeze on movement of equipment out of Chincoteague, pending formal inventory and statement of interest of NASA in the equipment. Eventually, Wallops acquired a large quantity of valuable equipment with the transfer. Many items were released early by NASA, such as ammunition, airplane parts and maintenance equipment, and refueling trucks. The Secretary of the Navy cooperated fully with NASA in the transfer of the station and equipment, and wrote Glennan, "I wish to convey the appreciation of the Navy Department for the timely and effective assistance you have provided in this matter. The knowledge is particularly gratifying that an important installation representing a large investment will continue to serve the needs of the Government."[4]

Glennan, Dryden, Siepert, and other NASA management officials visited Wallops on January 7, 1959, to get a firsthand look at the island and the Air Station (see figures 406 and 407). Later in the month, Dryden escorted members of the NATO Advisory Group for Aeronautical Research and Development (AGARD) to Wallops, as shown in figure 408. Most of the countries represented by this group were interested in research with rocket models, and some were to be direct participants in the NASA international space program.

Just outside the entrance to Chincoteague Naval Air Station, a 300-unit Wherry Housing facility had been constructed for rental to station personnel. As the disestablishment of Chincoteague progressed, the occupancy rate began to drop until on March 4, 1959, it was down to 40 percent. The attorney for the owner telephoned Kurt Berlin, NASA Counsel, for information as to the future expansion of NASA and whether NASA requirements for housing would be high enough to make it

3. License for use of U.S. Naval Air Station, Chincoteague, Va., by NASA, Noy(R)-65516, signed by Commander M. E. Scanlon, for Department of Navy, June 12, 1959.
4. Letter from F. A. Bantz, Acting Secretary of the Navy, to T. Keith Glennan, Mar. 5, 1959, regarding transfer of Chincoteague Naval Air Station to NASA.

FIGURE 406. NASA Administrator T. K. Glennan makes his first visit to Wallops with Deputy H. L. Dryden, January 7, 1959. Left to right: Dryden, R. L. Krieger, and Glennan.

FIGURE 407. NASA Administrator T. K. Glennan and party receive briefing by Krieger on launch operation at Wallops, January 7, 1959. Left to right: W. E. Grant, J. C. Palmer, A. F. Siepert, H. L. Dryden, T. K. Glennan, J. E. Robbins, R. L. Krieger, J. P. Gleason, and J. A. Johnson.

FIGURE 408. NATO AGARD group on Wallops ferry for visit, January 24, 1959. Left to right: E. Rasmussen, Denmark; K. Oswatitsch, Germany; D. C. Smith, AGARD office; L. Branders, Belgium; F. Wattendorf, AGARD Director; A. J. Marx, Holland; J. E. Bullock, USAF; E. J. Jones, England; H. J. Van Der Maas, Holland; J. J. Green, Canada; N. Papadimitriou, Greece; H. L. Dryden, NASA; H. Kristiansen, Denmark; C. Alippi, Italy; F. Ulug, Turkey; G. E. Lairmore, AGARD office; H. A. Sergeaunt, NATO office; M. M. Stephens, England; W. Schultz, Germany; J. R. Deschamps, AGARD Deputy Director; R. H. Dasteel, AGARD office; D. C. MacPhail, Canada; W. J. Williams, USAF; R. A. Willaume, AGARD office.

economically feasible to continue with the housing project. Berlin did not provide such assurance (ref. 3), and by July the facility was empty and the Government took possession. Part of it was later to be converted to a branch of the University of Virginia.

Two facilities at Chincoteague, which were considered indispensable, were the base hospital and the cafeteria. Special action was taken to ensure their continued operation. Krieger made a strong plea to NASA Headquarters on March 9, 1959, that the hospital and equipment be turned over to NASA.[5] He pointed out that Wallops had relied upon the Chincoteague hospital for treatment of emergency cases, and its closing would work extreme hardship because of the unavailability of any nearby community hospital, the nearest one being 50 miles away. With personnel at Wallops expected to increase by a factor of three or four, an even greater need for emergency services would exist. The equipment was added to the list to be transferred from the Navy to NASA, and a staff was acquired. The cafeteria was a different story, because the equipment was owned by USN Ship's Store Service, Brooklyn, New York. This Navy unit operated the cafeteria as well as a retail section, a gasoline station, and an enlisted men's club. The Navy Exchange Officer at Chincoteague informed Robbins that the equipment, with a value of $79,000, could be procured by NASA for $27,500. If not so purchased, the equipment would be removed for use of other Ship's Stores.[6] Langley asked NASA Headquarters for authority to establish a cafeteria at Chincoteague and to purchase the equipment from the Navy.[7] The purchase was made with regular Government funds.

With the takeover of Chincoteague becoming a reality, new estimates of funding needs for operation of Wallops were submitted to NASA Headquarters.[8] The period covered was fiscal 1960, beginning July 1, 1959. Buckley had asked Krieger to submit new estimates in view of the latest developments. A total operating budget of $4,528,000 was requested, of which $1,295,500 was itemized as Research and Development. Request was made for a total of 250 personnel. Some of the plans for an expanded Wallops were beginning to take shape. At the request of Goddard, an Aerobee launch facility was planned just south of Launching Area No. 2; and the Control Center, at this time being used as a photo laboratory, was to revert to its original use. Space would also be available for payload contractors in this center. With the movement of housekeeping facilities to Chincoteague, the Utility Shop Building would be converted to a shop for the Preflight Jet, while the space in use by the Preflight Jet would become available for assembly of large rocket vehicles. The Scout was the first large vehicle to use this area. It was planned to use the large Fasron hangar at Chincoteague as an additional assembly area for contractors and as an available space for other NASA center activities (ref. 4) (See figure 409).

On May 1, 1959, T. Keith Glennan issued a memorandum that transferred Wallops Station (later changed to "Wallops Flight Center") to the Office of Space Flight Development and outlined the functions and authority of the station. The chief function was to conduct "tests of rocket-propelled vehicles as requested by other NASA facilities or NASA Headquarters." Conspicuously absent was any mention of providing support for the military services. With receipt of the May 1 memo, a study was made at Langley of the many actions required to ensure an orderly transfer of management operations to Wallops. Up to this time, Wallops had been almost completely dependent on Langley for support in such operating areas as engineering, instrumentation, budget, fiscal control, personnel, and procurement. In addition to the transfer of these functions to Wallops, personnel had to be acquired and trained to take over the functions. Krieger received the assurance of H. J. E. Reid of a continuance of Langley support until such time as Wallops could take over all necessary functions. A list of 28 actions required by Langley and Wallops was prepared.[9] In addition, Langley prepared a list of 22 additional actions required of NASA Headquarters to effect the transfer.[10]

5. Telegram from Krieger to NASA, Mar. 9, 1959, regarding need for hospital at Chincoteague.
6. Letter from Navy Exchange Officer, U.S. Naval Air Station, to Administrative Officer, Feb. 9, 1959, regarding Navy Exchange equipment.
7. Letter from Langley to NASA, Feb. 19, 1959, regarding cafeteria at Chincoteague Air Station.
8. Letter from Langley to NASA, Mar. 18, 1959, regarding budget estimates for Pilotless Aircraft Research Station.
9. Letter from R. L. Krieger, Wallops, to Langley, June 3, 1959, regarding review of actions required to transfer Wallops to the Office of Space Flight Development.
10. Letter from Langley to NASA Headquarters, June 4, 1959, regarding actions required by separation of Wallops from Langley Research Center.

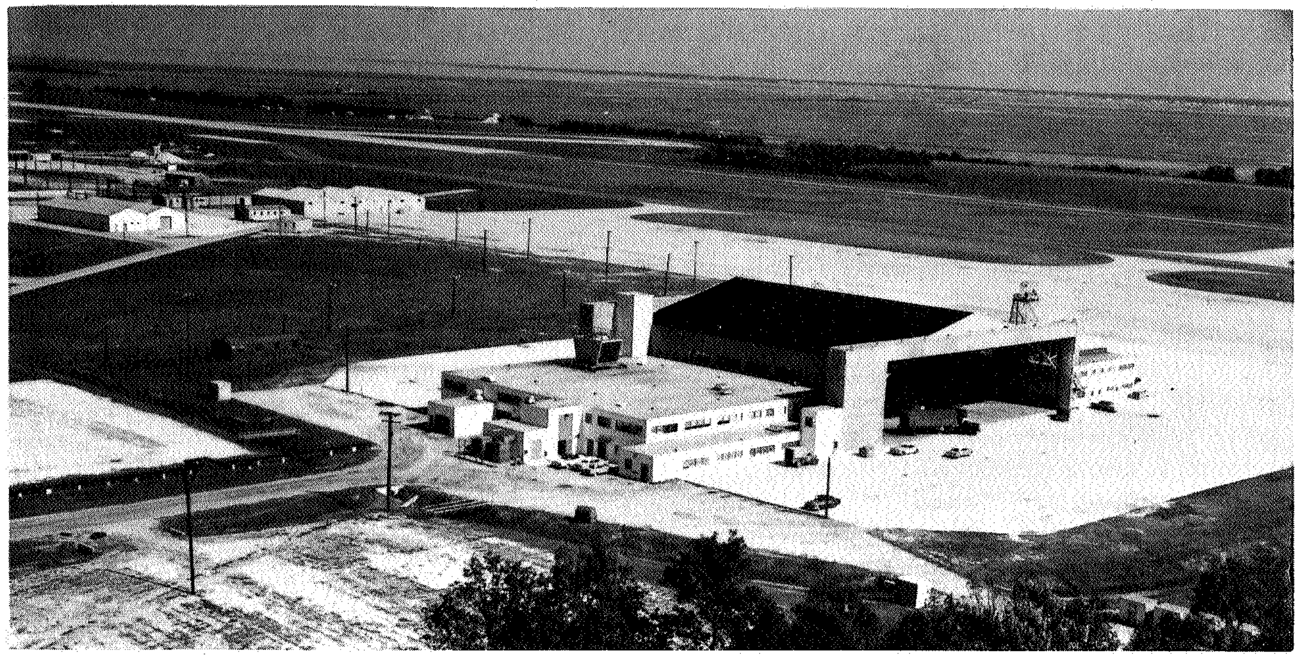


FIGURE 409. Fasron hangar (Building N–159) on Chincoteague base, converted by Wallops to range center and facility for model assembly.

The first step in physically taking over Chincoteague Air Station was the relocation of about 22 Wallops people there on June 4, 1959. These included J. E. Robbins, L. T. Birch, and A. D. Spinak. Then on June 30, 1959, the Navy formally turned the base over to NASA in a special ceremony, shown in figure 410. Captain Toth, Commander of the Base, read a Deactivation Notice and then the Notice of Transfer to NASA. The Navy people had already moved out and were only at Chincoteague that day for the ceremony. After the reading of the transfer notice, the American flag belonging to the Navy was lowered from the flagpole and replaced by a flag belonging to NASA. The Navy Marine folded the Navy flag and gave it to Captain Toth, who then gave it to Krieger. At the close of the ceremony, the Navy contingent jumped into their waiting cars and sped away.[11] The official Post Office address was changed the following day to NASA Wallops Station, Wallops Island, Virginia.

Krieger organized Wallops into three main divisions, effective July 13, 1959. The divisions were as follows:

Flight Test Division	John C. Palmer, Chief
Administrative Services Division	Joseph E. Robbins, Chief
Technical Services Division	William E. Grant, Chief

The memorandum of organization listed a total of 180 people. Krieger designated Palmer as Acting Chief of Wallops in his absence. Krieger moved to Chincoteague on July 31, 1959.

When the Navy moved out of Chincoteague, the airfield was essentially closed. There were three runways, two of which were 8,000 feet long. Krieger did not try to maintain the tower or landing facilities because Wallops had no airplanes of its own, and the only contemplated user was an occasional visiting airplane. The airport was, therefore, usable only under visual daylight conditions. By prior arrangement, a fire truck could be available for landing and takeoff operations. J. P. Reeder, Head, Langley Flight Operations, made a study of the situation and recommended that night operation facilities be installed, since some visitors would require them (ref. 5).

Because of the distance between Chincoteague base and Wallops Island, a shuttle bus service was installed. Until the causeway was opened in 1960, the bus ran between the base and the Mainland Dock, leaving Chincoteague every half hour. The bus not only transported passengers but also served as a mail carrier. The service was started in August 1959.

11. Interview by the author with R. L. Krieger and J. E. Robbins, Aug. 6, 1971.

FIGURE 410. R. L. Krieger, acting for NASA, accepts Chincoteague Air Station from Navy Captain Toth in change-of-command ceremonies in front of Administration Building, June 30, 1959. Right of Krieger: Wallops staff members W. E. Grant, J. C. Palmer, and J. E. Robbins (left to right).

On September 1, 1959, the Flight Test Division was divided into three branches:

Facilities and Techniques	A. D. Spinak, Head
Range Instrumentation	R. R. Westfall, Head
Vehicle Preparation and Launching	E. H. Helton, Head

The Administrative Services Division was divided into four branches, as follows:

Fiscal	A. R. Knapp, Head
Personnel	G. A. Matzner, III, Head
Procurement	L. T. Birch, Head
Management Services	J. E. Robbins, Acting Head

The Technical Services Division was divided into the following elements:

Machine Group	R. T. Holdren, III, Head
Maintenance Branch	F. L. Townsend, Head
Wallops Maintenance Section	H. D. Kellam, Head
Chincoteague Maintenance Section	P. C. Mears, Head
Plant Protection Unit	H. J. Whealton, Head
Electrical Service Unit	J. W. McAllister, Head

An Executive Safety Committee was established on September 2, 1959, with W. E. Grant as Chairman. On the same date, Grant appointed a Subcommittee on Range Safety with A. D. Spinak as Chairman.

There were a number of housing units on the Chincoteague Base, which had been occupied by naval personnel. These were made available to Wallops personnel. On September 2, 1959, Krieger appointed a Committee on Housing and Rent, to establish a fair rental charge for the units. The committee consisted of J. E. Robbins, Chairman, with A. R. Knapp as secretary, and G. S. Brown as the third member. Krieger was assigned the former Commanding Officer's quarters on the base, and W. E. Grant also occupied one of the units.

The process of expanding Wallops to include Chincoteague Base was a lengthy one. Chincoteague eventually developed into the main center of control, with the island becoming almost solely a launch site. Adding to the confusion during the changeover was the large influx of project personnel from Langley, and many visits from contractors in connection with the large rocket-model flight projects during 1959, as will be discussed later in this chapter. In particular, the Little Joe and Scout projects nearly saturated the area, for a while.

EXPANSION OF FACILITIES

As has been discussed earlier, the 1959 supplemental appropriation for NASA included an expansion of facilities at Wallops. By the time the appropriation was approved in August 1958, two C & E projects were already in progress there. The first was Project 1826, an NACA 1958 C & E item for $1,560,000 for Modernization of Instrumentation. This included installation of the RCA FPS-16 radar discussed in Chapter 15, the Reeves Mod II radar, GMD radiosonde equipment, and the 60-foot antenna for the Spandar radar. The second project was construction of groins along the beach, for erosion control. This was Project 1827, approved as a C & E item in the NACA 1959 regular budget.

The problem of erosion of the beach also has been noted earlier. When the subject was first discussed with the Beach Erosion Board of the Army Engineers in May 1946, they advised that groins should be installed when the beach had eroded sufficiently to reduce the distance between mean high water and the seawall to 50 feet. Groins, walls constructed of timbers and piling at right angles to the seawall and extending out into the ocean, had been used effectively in restoring the beach at Ocean City, Maryland, and Rehoboth Beach, Delaware, on the Atlantic Ocean north of Wallops. According to existing records, the beach at Wallops had eroded 600 feet between 1846 and 1945, 30 more feet between 1945 and 1949, 60 feet during a storm in April 1956, and another 50 feet in October 1956. The October 1956 storm exposed the seawall, as shown in figure 411. The metal sheet piling of the seawall was 18 feet high, with most of it driven into the sand. It was reasoned that if 9 feet of the total height became exposed, the wall would probably fail. The Erosion Control Board inspected the beach at Wallops again on May 9, 1956, and concurred in the need for groins. Approval was obtained for construction of eight groins, on a trial basis. They would extend 200 feet from the seawall at 400-foot intervals along a 2,800-foot length of the beach. The approved C & E item was for $130,000. A contract was awarded for the construction, and was completed for a total cost of $128,779. The completed groins may be seen in figure 412. They were found to be very effective, and in later years additional groins were to be installed.

As stated above, the main expansion of facilities at Wallops in 1959 was authorized in the NASA 1959 supplemental appropriation. The budget request identified as Expansion of Facilities, Pilotless Aircraft Station, was for a total of $24,500,000. It was proposed to provide for the launching of large solid- and liquid-fuel rockets, to move the housekeeping functions from the island to the mainland, and to connect the two areas with a causeway. The proposed purchase of land included 1,000 acres on the

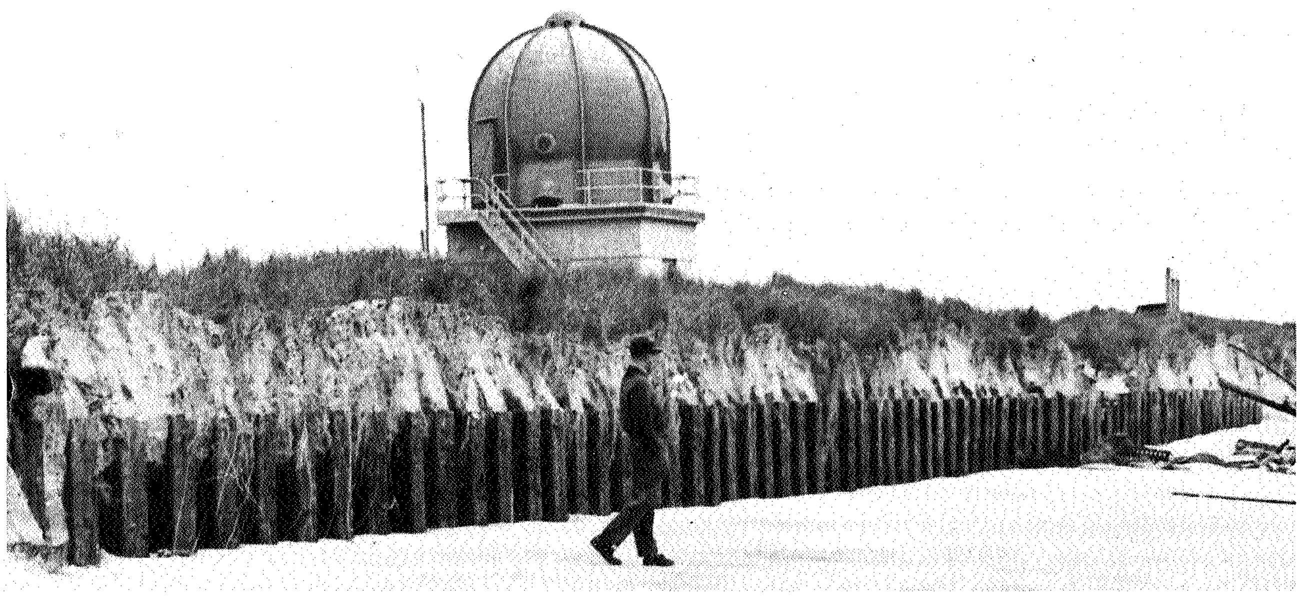


FIGURE 411. Wallops engineer J. C. Palmer examines portion of seawall exposed by storm, October 1956. Rawin station is seen just behind seawall.

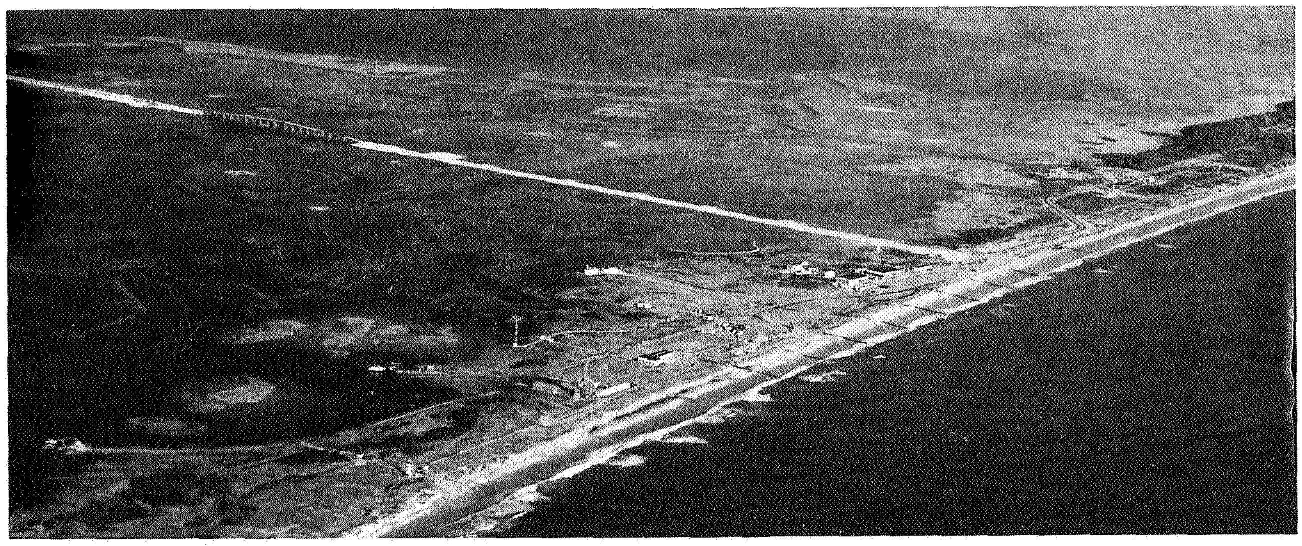


FIGURE 412. Aerial view of Wallops Island, December 1959, showing groins extending into the ocean from the seawall between the Assembly Shop area and the causeway.

mainland, plus 1,600 acres of intervening marsh, and the 800-acre Assawaman island to be used for tracking stations. The location of land to be purchased is shown in figure 413.

The estimated breakdown of costs was as follows:

Item		*Cost*
Mainland Facilities		
Administration Building	670,000	
Model Assembly Building	1,095,250	
Technical Service Shop	950,000	
Causeway	2,300,000	
Utilities	1,167,250	$6,182,500
Island Facilities		
Launch pads	85,500	
Blockhouse	646,000	
South launcher and tower	912,500	
North launcher and tower	1,035,000	
Equipment	1,165,000	
Seawall	456,000	
Utilities	380,000	4,680,000
Instrumentation Systems		
Insertion guidance system	3,480,000	
Long-range radar	2,950,000	
Data-handling equipment	900,000	
Cameras	350,000	
Tracking telescope	450,000	
High-gain telemetry antenna	1,150,000	
Telemetry receiving systems	700,000	
Launch area programmer	850,000	
Range safety and destruction system	800,000	
Computation system	600,000	
Meteorological instrumentation	270,000	12,500,000
Land Acquisition		600,000
Design and Engineering		537,500
	Total	$24,500,000

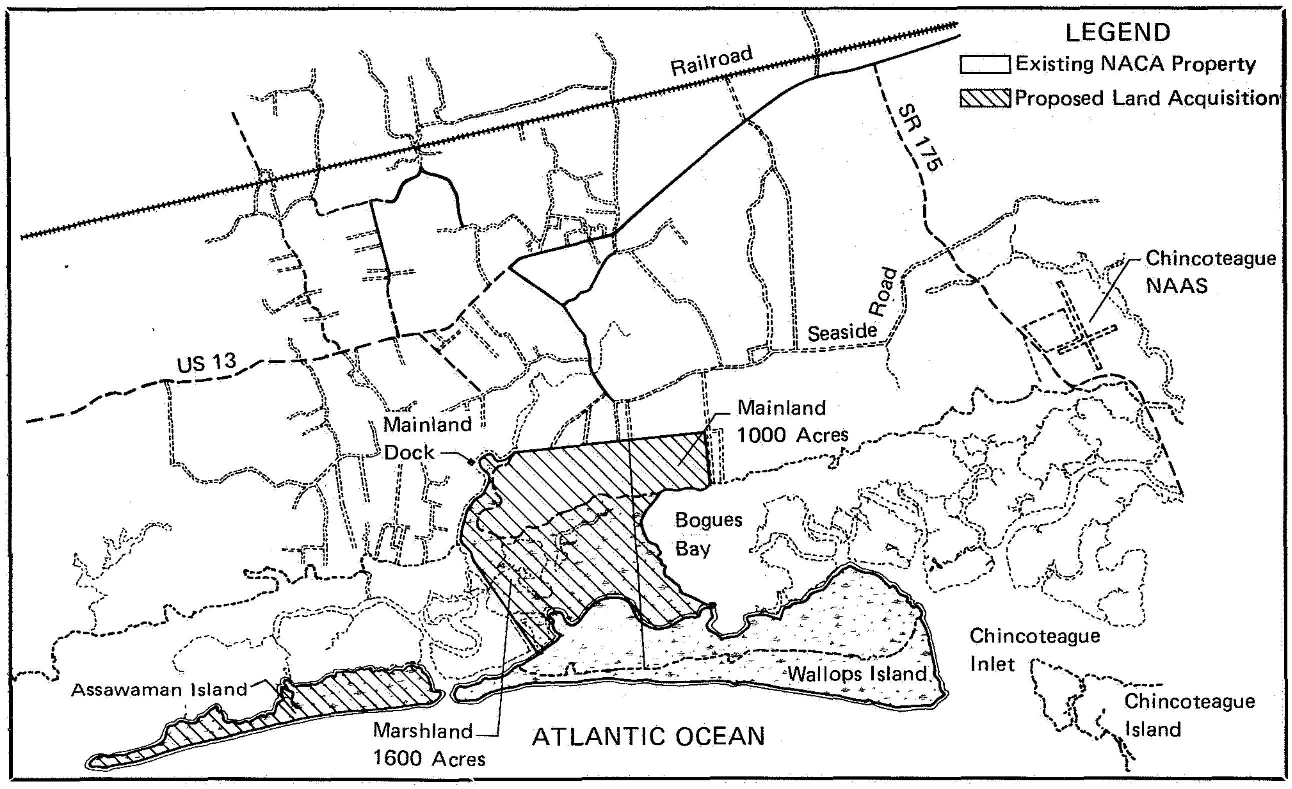


FIGURE 413. Map of Wallops Island and vicinity, showing proposed land acquisition for expansion of facilities, May 1958.

The planned location of these facilities is shown in figure 414.

Although this seemed to be a large expansion, it actually provided for only one additional launching area on the island, to be equipped with a special blockhouse and two launch towers. The seawall was to be extended northward 6,000 feet. Three large buildings were planned for the mainland, with a causeway to the island. The remainder of the funds was for utilities and a greatly expanded instrumentation system, including the long-range radar and telemetry antenna.

Early in October 1958, NASA Headquarters asked Langley to reevaluate the planned expansion of Wallops facilities. The first question raised was "Why expand Wallops when AMR and PMR can be used for the launching of large vehicles?" Then, to evaluate variations of the proposed expansion, it was requested that three cases be considered. Plan I would provide a causeway, but a minimum of mainland facilities and no satellite or large liquid-fuel rockets. Plan II would include a solid-fuel satellite vehicle, but no large liquid rockets. Plan III would include solid-rocket satellite vehicles and Thor-type liquid rockets.

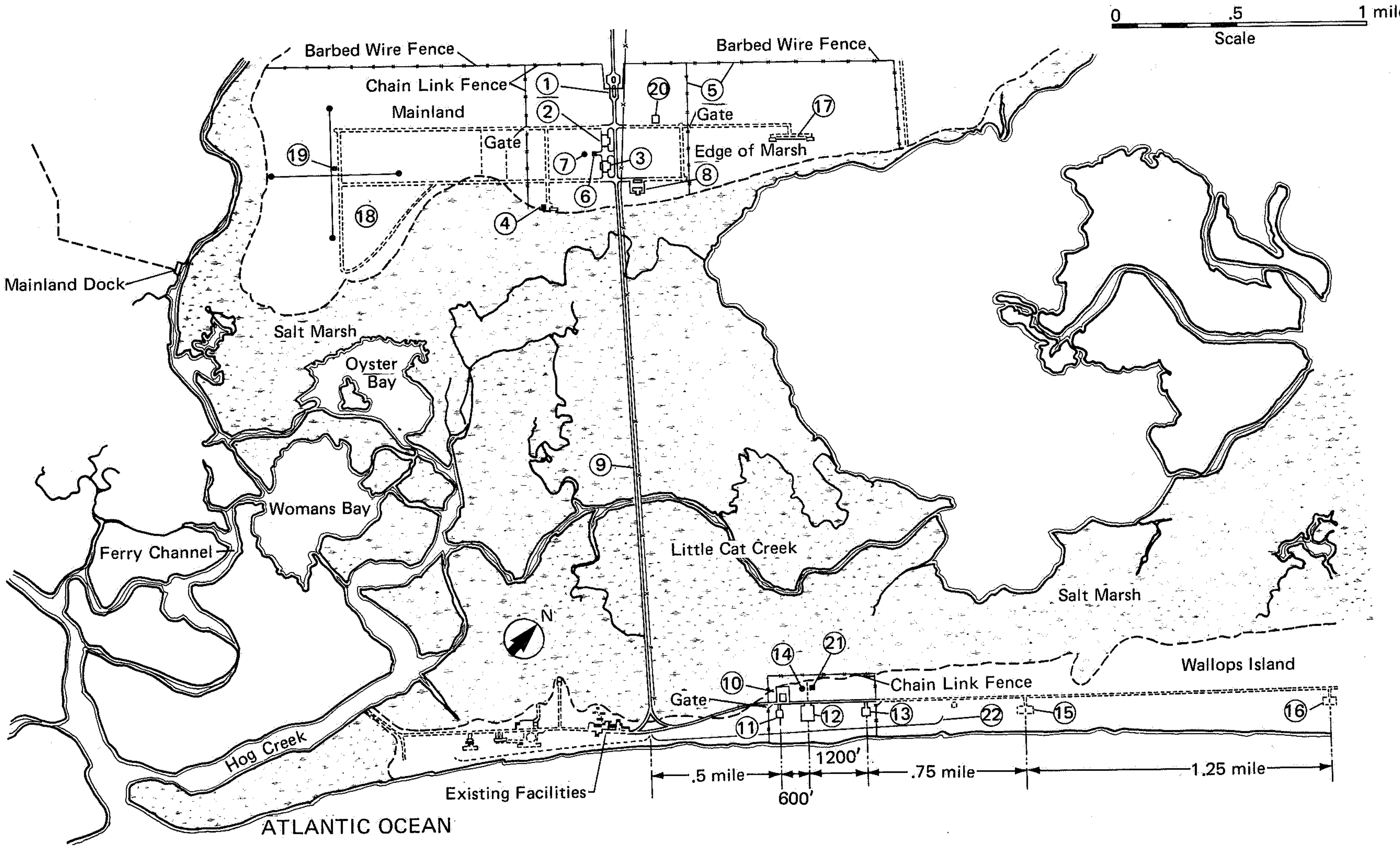
From this study, submitted October 8, 1959, Langley concluded the following:

> A relatively small, civilian-controlled scientific range is decidedly in the National interest because the military ranges are not well suited for many relatively simple scientific experiments. A civilian range would result in lower overall costs and the civilian projects would proceed more rapidly.

A study of locating all of the new facilities on the island showed this to be inadvisable because of higher costs, prevention of future expansion on the island, the need to force the Navy off the island, and the difficulty of maintaining precision electronic equipment in a salt spray area. The costs for the proposed variations of the original plan were found to be as follows:

Plan I	$18,250,000
Plan II	20,250,000
Plan III	21,250,000

The costs of the plans in this study were all substantially lower than the original budget proposal of $24,500,000, principally as the result of lower estimates of instrumentation costs.



PROPOSED ADDITIONAL FACILITIES

1. Gate House
2. Technical Service Shop
3. Model Assembly and Reliability Check Laboratory
4. Sewage Disposal Plant
5. Security Fence
6. Heating Plant
7. Water Tank
8. Administration and Range Control Building
9. Causeway and Bridge
10. Mobile Equipment Parking
11. Intermediate Range Launching Area
12. Launching Site Control Station
13. High Energy Launching Area
14. Fire Protection Equipment
15. Future Large Liquid Fuel Rocket Launching Area
16. Future Launching Area
17. Long Range Radar and Telemetering
18. Fuel Storage Area
19. Radio Interferometer
20. Substation
21. Power and Auxiliary Shelter
22. Sea Wall Extension

FIGURE 414. Map showing proposed plan for expansion of facilities at Wallops, May 1958.

This new review of plans for Wallops stemmed from the opposition of E. R. Quesada, the newly appointed Director of the FAA, as discussed in Chapter 15. When a decision had not been received from top management by October 22, Buckley and his staff were getting impatient. His assistant, Frank B. Smith, located Dryden in a conference and passed him an informal note asking if Wallops could begin construction in view of the fact that Krieger had reached an agreement with Quesada's staff on an operation plan. Dryden's terse reply "Yes. HLD" penciled on the note was all that was needed to go ahead. When formal approval came, however, Quesada's opposition was found to have at least one effect. The plan to launch large Thor-type liquid-rocket vehicles at Wallops was dropped, and Plan II was selected. The projected cost was rounded off at $21,000,000.

Both Wallops and Langley had wanted a causeway since the beginning of the facility on the island in 1945, but up to this time all attempts to secure one had failed. It was not unexpected, then, that as soon as an indication of approval for a causeway was obtained, steps would be taken to get its construction under way. The planned location of the causeway, shown in figure 414, was the same location selected in 1945. The existing powerline across the marsh was already located along this route. On May 29, 1958, NACA Headquarters approved Project 2045, entitled "Preliminary Site Investigation Studies of a Causeway to Wallops." The total expense, not to exceed $45,000, was to be covered by GOE funds. The Langley Architect-Engineer Advisory Board, with J. C. Messick as Chairman, wasted no time, and at a meeting on June 2, 1958, selected J. E. Greiner Company of Baltimore, Maryland, to make the preliminary studies and recommend a design (ref. 6). NACA Headquarters approved the selection on June 11, and a contract was awarded without delay.

One of the first actions of Greiner was to initiate proceedings to obtain approval from the Army Engineers for construction of a bridge across Cat Creek. An 80-foot span with a 40-foot clearance above mean high water was recommended. The design of the causeway and bridge was completed on December 1, 1958, and on December 5 1958, Army Engineers approved the plans for the bridge over Cat Creek.[12] Navigation lights for the bridge were approved by the U. S. Coast Guard on December 31, 1958. A contract for construction of the causeway and bridge was awarded to Tidewater Construction Corporation under C & E Project 2080, the number assigned for the overall expansion of facilities. The contract with Greiner was extended to include consultation services in connection with the construction. Greiner's contract was completed on July 31, 1959, for a cost of $38,019.

The causeway crossed a wide expanse of marsh between the mainland and the island. (See figure 414.) It was difficult to determine the ownership of this marsh because the deeds were vaguely worded. The owner appeared to be Sewell A. Taylor. On January 13, 1959, Taylor gave NASA permission to proceed with the construction of the causeway without jeopardizing his right to compensation. As a result of condemnation proceedings, the U. S. Court in Norfolk, Virginia, on June 19, 1959, awarded Taylor $9,000 as complete compensation for 898 acres of marshland owned by him. An additional 133.40 acres of adjoining marsh were acquired from Fred S. Chesser in the same manner, for a payment of $4,200.

The causeway was essentially completed in March 1960, as shown in figure 415, and was officially put into operation on March 21, 1960. On this date, the ferry and small boats were placed on a standby status (ref. 7). Now employees, for the first time, could drive to their work area on the island in private automobiles. Gone was the old portal-to-portal workday, however, for now employees were required to report on the island at 8:00 A.M. and depart at 4:30 P.M. When the ferry had been in use, the workday had begun and ended at the Mainland Dock.

The opening of the causeway ended the amphibious transportation between Langley and Wallops with the Grumman Goose. Now all air transportation was to the airfield at the main base at Chincoteague. Thus, a most successful airlift to Wallops came to an end after more than 14 years of operation without any serious injuries. It began on July 23, 1945, when a JRF Goose with M. N. Gough (pilot), H. H. Hoover (copilot), and M. L. Murden, (crew) transported E. Johnson, H. Morris, and R. Hooker from Langley to Wallops. The airlift ended on January 8, 1960, when R. W. Sommer (pilot) and E. C. MacDonald (crew) carried Dorothy Lee to Wallops for a rocket launching.

12. Letter, Corps of Engineers to Langley, Dec. 10, 1958, enclosing Army approval of location and plans for a bridge over Cat River at Wallops Island.

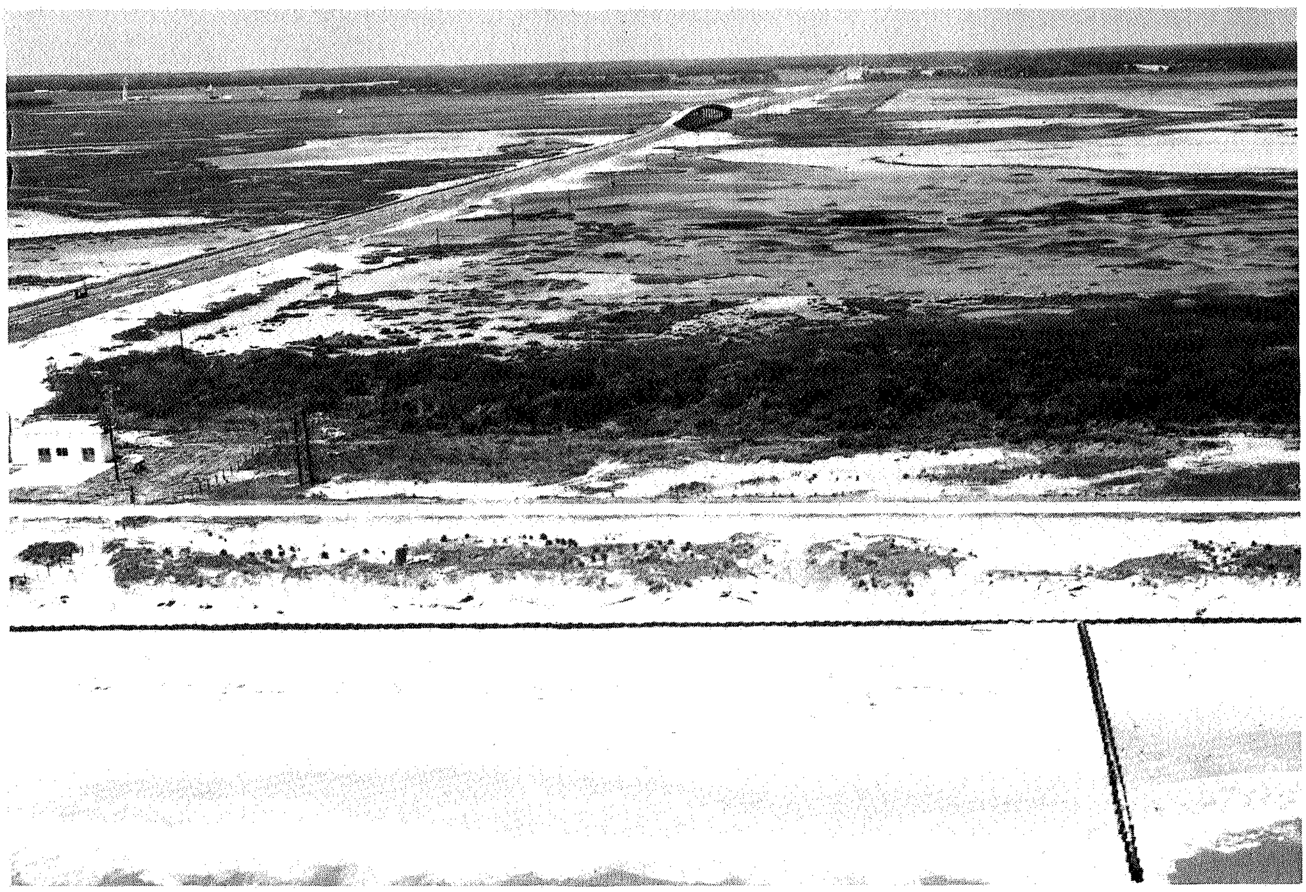


FIGURE 415. Aerial view of Wallops Island, showing causeway to mainland, one of the groins, and part of the extended seawall.

The second contract was awarded for extending the seawall 6,000 feet north of the cafeteria area. This contract was awarded to Doyle and Russell, Norfolk, Virginia, for a total of $487,768, and was completed on October 12, 1960. The construction was similar to that of the existing seawall.

Construction of Launch Area No. 3 began with the preparation of two concrete pads, called "south pad" and "north pad," and the building of a blockhouse between them. Required wiring connecting the pads to the blockhouse was placed underground, ending in terminal buildings at each pad. The south pad was located about 750 feet from the blockhouse, and the north pad about 1,500 feet from it. One pad (north) was planned to handle larger rockets than the other. The south pad was later to be identified as Pad 3b, and the north, as Launch Area No. 5. Bids were opened on April 23, 1959, for construction of the blockhouse, north and south launch pads, roads, and related work. Doyle and Russell was low bidder at $1,922,848.

The original plans for use of the two launch pads were modified as time went by. The first use of the south pad was made by Scout. The Scout contract included construction of a service tower and launcher which were installed on the south pad. (Construction will be described later in this chapter.) The north pad was never used as intended, but later became a general launch area for medium-size vehicles. The original plan called for this pad to have a large service tower on rails, with a flame deflector equipped for flooding with water, as was the procedure at Cape Canaveral.

The blockhouse had inside dimensions of 40 feet (width) and 60 feet (length), and contained two floors. It was constructed of reinforced concrete and was covered with protective sand, over which was sprayed a layer of "gunite" cement. It was to provide much better blast and fire protection than the Control Center at Launch Area No. 1 or 2. This construction was completed in 1960 and is shown in figure 416.

The original plan for the mainland was to acquire 1,000 acres, as shown in figure 413, and construct three large service buildings, a long-range radar, telemeter-receiving equipment, and a long-range radio interferometer. This strip of land was about 0.6 mile in depth and extended along the

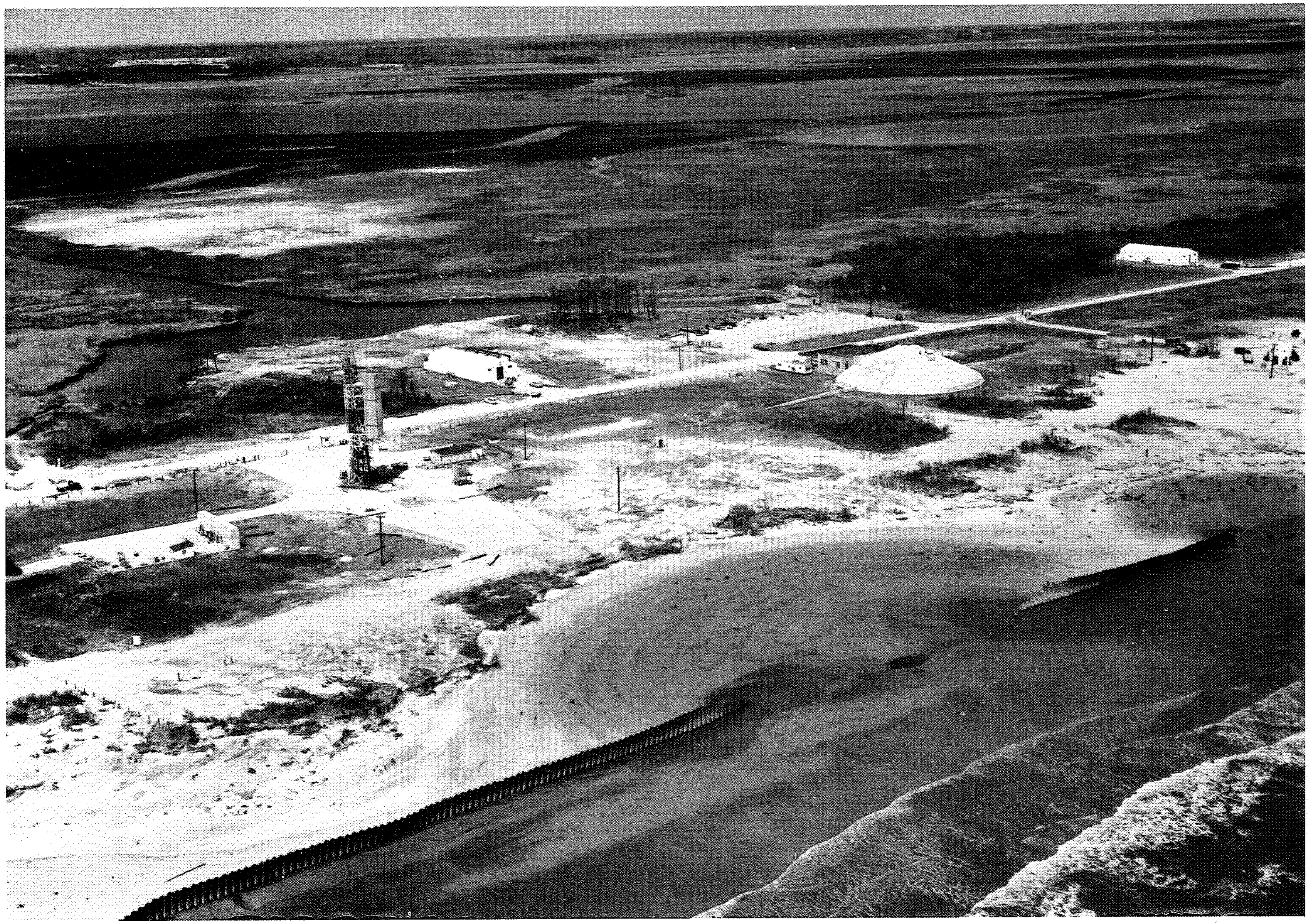


FIGURE 416. Aerial view of Launch Area No. 3, showing Scout launch tower and blockhouse after 1962 storm damage to seawall.

marsh for about 2.5 miles, starting at a point just across the creek from the existing Mainland Dock and running to a point about a mile beyond State Road 803, which led to the proposed causeway. The local farmers protested to Senator A. Willis Robertson of Virginia over this taking of "prime farmland." The protest made headlines in the Norfolk, Virginia, *Virginian-Pilot* for September 24, 1958. The Pocomoke City, Maryland, *Worcester Democrat* editorially saw the planned expansion of Wallops as a boon to the business area. The only assurance that Glennan gave to an inquiry by Senator Robertson was that "only such amount of land will be acquired which is essential for our operations.[13]

A survey was made of the general mainland area, in accordance with the planned expansion; but before any action was taken, the Navy had decided to close Chincoteague Naval Air Station (as discussed earlier in this chapter) and the plans for Wallops Station were drastically changed. With NASA's acquisition of the Air Station, the existing buildings there could now take the place of the planned large buildings on the mainland and the land needed on the mainland thereby reduced to a strip about 6,000 feet long extending back about 1,500 from the marsh, as shown in figure 417. This area was needed for a guardhouse and for installation of long-range radars with a protected access area.

The needed acreage on the mainland, as well as the marsh acquired earlier, was obtained by condemnation, which allowed immediate taking of the property with later legal settlement of payment. State Road 803 led to the causeway through the property of F. S. Chesser. At the town of Assawaman, SR 803 joined SR 679, which then led to the air station, as shown in figure 417. Land totaling 102.22 acres on both sides of SR 803 was acquired from Chesser for $14,500. To the south of the Chesser property, 54.85 acres of land were acquired from the Fletcher sisters, S. R. Bundick and M. B. Fletcher, for $7,000. The last piece of land, 59.54 acres adjoining this section to the south, was acquired from E. J. Marshall for $9,600. This made a total of 216.61 acres of high ground and 1,031.40 acres of marsh.

State Roads 803 and 679 were considered unsuitable for the transportation of large rocket motors and other vehicles between the Air Station and the island, and steps were taken to have these sections of the roads improved. NASA asked the U. S. Bureau of Public Roads to evaluate the highways and make recommendations. The roadway was too narrow, the curves were too sharp, and, in addition, a new section of road 0.7-mile long was desired, to connect road 679 directly with the main gate of the Air Station.[14] The Bureau of Public Roads evaluated the cost of the improvements and addition at $581,000 and arranged for the Virginia State Highway Department to have the work performed with funds transferred from NASA (ref. 8).

By the time NASA had acquired the mainland property, MIT's Lincoln Laboratory had decided to install two large, long-range radars for use in the D58 Trailblazer reentry project. (The project will be discussed later in this chapter.) The southern part of the mainland area was allocated for long-range radar use, and a parcel of the land was leased to MIT for its radars. An access road to this site was constructed. NASA also had a long-range radar constructed for location in an area adjoining the MIT radars. The NASA radar, developed under contract with MIT, was an S-band radar with a 60-foot antenna dish, as shown in figure 418. It had a range of about 1,000 nautical miles and 5 megawatts of peak power. It was given the name "Spandar" and was to see extensive use in satellite and reentry vehicle tracking.

On the Chincoteague base itself, there were more than enough buildings to meet the expanded needs of Wallops as originally proposed. A large Fasron hangar (shown in figure 409) appeared to be ideal for vehicle assembly and for a range control center. Eventually, firing control and tracking were to be exercised from this center. Administrative offices were located in Building F6, and technical service shops in F7, F8, and F10. Location on the main base was planned for the new high-gain telemetry receiving antenna as well as for improved telemeter receiving equipment. Operations at Wallops Island, including an actual launch, were monitored from the control center on the base with the aid of television cameras. To effect this remote control, a communications cable was buried in a trench running along State Roads 679 and 803 and across the causeway to the island.

13. Letter from T. K. Glennan to A. Willis Robertson, Sept. 24, 1958, regarding acquisition of land for expansion of Wallops.
14. Letter from A. F. Siepert to E. R. Armstrong, Commissioner, U.S. Bureau of Public Roads, Mar. 11, 1959, regarding roads between Chincoteague Air Station and Wallops Island causeway.

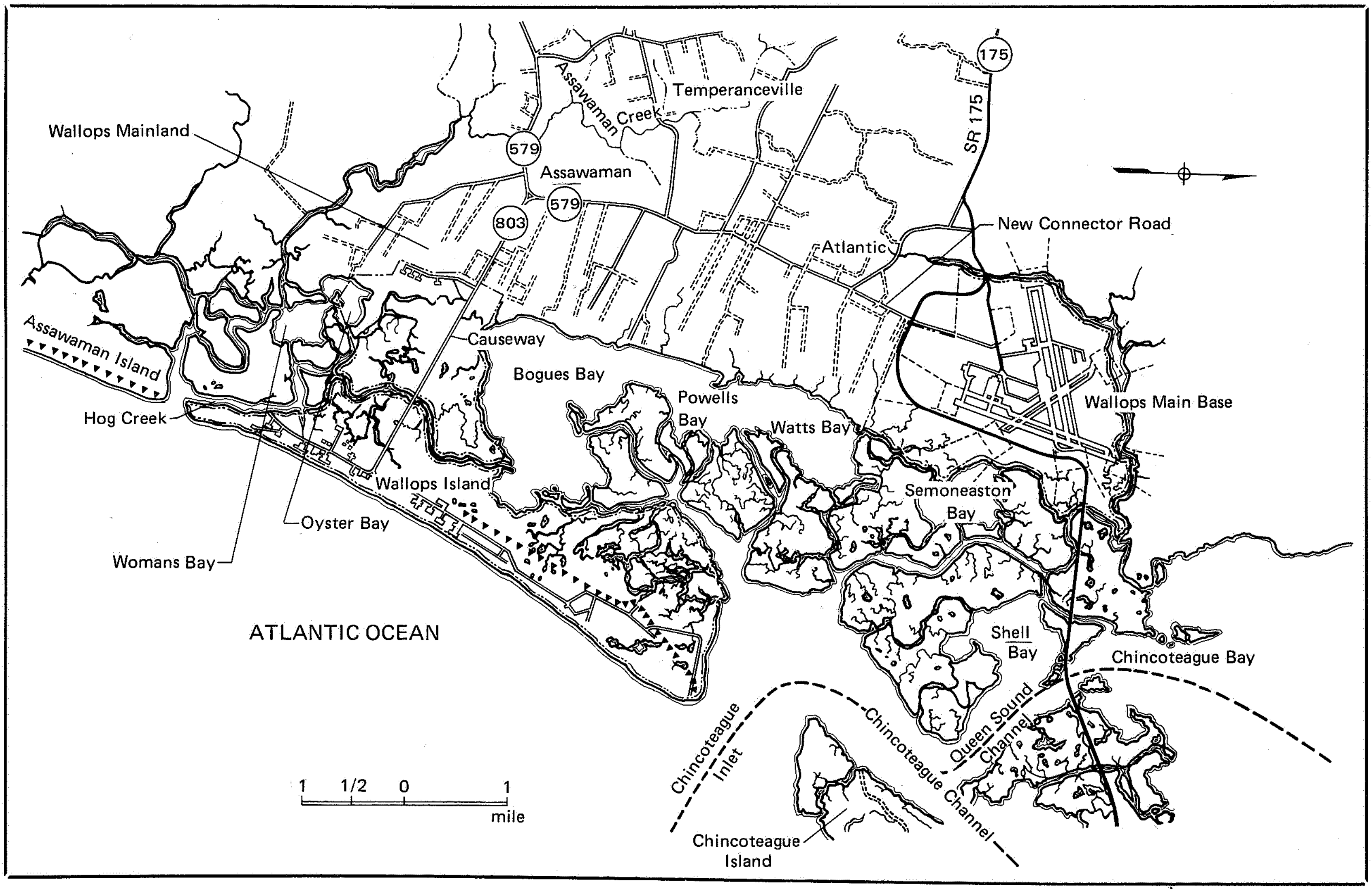


FIGURE 417. Map giving overall view of Wallops area, including Chincoteague base.

FIGURE 418. View of Spandar radar on mainland near Wallops Island.

WALLOPS SUPPORT OF THE MERCURY MANNED SATELLITE PROJECT

The history of Project Mercury, the undertaking that placed this nation's first man into orbit around the earth, has been well documented in *This New Ocean* by Swenson, Grimwood, and Alexander (ref. 9). Since Mercury originated at PARD, extensive use was made of Wallops for tests of models and full-scale capsules. The history of Wallops would not be complete without a discussion of the many contributions of Wallops to the successful execution of this project.

The Mercury capsule, barely large enough to hold its lone astronaut, was designed to ride into orbit atop an Atlas ICBM, replacing the nose cone of the missile. A prototype of the capsule, more of a cone than the missile it replaced, is shown in figure 419 as it awaited hoisting atop its Little Joe test booster at Wallops in August 1959. The astronaut lay on his back on a special form-fitting couch across the base of the cone, which was just over 6 feet in diameter. Although the capsule could develop a little lift if pitched to an angle of attack, it was designed basically as a zero-lift true ballistic vehicle. This made it the simplest and lightest type of spacecraft; but having to provide for the safety of the astronaut made its construction more complicated than that of a missile nose cone. Many months of painstaking research and development were required before Alan B. Shepherd, Jr., the first man to ride in the capsule, made a suborbital test flight on May 5, 1961, and John H. Glenn, Jr., rode it into a complete orbit of the earth on February 20, 1962.

FIGURE 419. PARD Chief J. A. Shortal examines full-size Mercury capsule at Wallops for first flight test of Little Joe, August 20, 1959.

The Mercury capsule was attached, base down, to the top of its Atlas booster and rode with it to the orbital altitude of about 100 miles and the orbital velocity of 18,000 miles per hour. The main, centrally located, sustainer rocket engine on the Atlas burned throughout the flight into orbit and was assisted during the early part of the flight by two booster engines that were dropped off after they had served their purpose. Once in orbit, the capsule was unlocked from the empty Atlas and separated from it by the firing of three small posigrade rocket motors located in the retrorocket package attached to the base of the capsule. At this time, the capsule was in a horizontal attitude and the astronaut was in a rather normal upright seated position in his couch, although, in the weightless state, it made little difference. Small reaction controls enabled the astronaut to change the attitude at will. To bring the capsule back to earth required the firing of only a single burst of rocket power. The retrorocket system was fired with the base of the capsule forward so as to reduce the velocity of the capsule. With proper reduction in velocity, the capsule would then return to earth in a long, sweeping trajectory stretching halfway around the globe. The capsule reentered the atmosphere base-end first, and after it decelerated to subsonic speeds, a large parachute was released from the upper canister for a safe splash-down and recovery from the ocean. Prior to the opening of the large parachute, a small drogue chute was opened to add stability to the capsule as well as to pull the main parachute out of its canister. During the extreme heating conditions of reentry, the capsule was protected by a special heat shield covering the outside of the entire base. The empty separation rocket and retrograde rockets on the base were ejected prior to reentry.

The astronaut in Mercury did not have a personal parachute. For safety during the final landing, a reserve capsule parachute was available. Safe escape while on the launch pad atop the Atlas or while in exit flight through the atmosphere was provided by a special capsule-escape system. This system was essentially a high-thrust rocket motor mounted on top of an open-lattice tower that was clamped to the top of the capsule. If needed in an emergency, the capsule, on command, would be unlocked from the Atlas and simultaneously the escape rocket would fire and pull the capsule safely away from Atlas. After this maneuver, the tower would be unlocked from the capsule and a separation rocket motor, also located on the tower, would pull the escape system away from the capsule, allowing the normal sequence for safe parachute recovery of the capsule to take place. In a normal flight, the escape tower was jettisoned at high altitude, shortly after the booster engines of Atlas were separated.

The basic design of the capsule was made by M. A. Faget and his coworkers at PARD during the winter of 1957–1958. It was natural, then, that extensive use was made of the facilities at Wallops during the development of the spacecraft. The tests at Wallops consisted of 26 full-size capsules, either launched from the ground by rocket power or dropped from airplanes at high altitude, and 28 scaled models, either rocket-boosted or released from balloons. Emphasis in the Wallops program was on dynamic stability and aerodynamic heating of the capsule, and effectiveness of the pilot-escape and parachute-recovery systems. The largest part of the Wallops program was concerned with the series of full-size capsules, rocket launched with the Little Joe booster that had been developed especially for Mercury.

A ballistic capsule for the first manned orbital spacecraft was selected over an airplane type of glide rocket because its development, making use of ICBM technology, would undoubtedly be faster; and Atlas, the only large missile far enough along to be considered for propulsion, did not have the capability of placing into earth orbit anything heavier. In fact, the Mercury capsule, the lightest of all proposed manned spacecraft, was severely limited in size and weight by Atlas. There was no time available to develop a larger launch vehicle if the United States wanted to be in the space race with the Russians, whose *Sputnik II* satellite, launched November 3, 1957, weighed 1,120 pounds and included the dog, Laika. *Sputnik II* offered sufficient evidence that a manned satellite was soon to follow. The Air Force was strongly interested in developing a glide rocket with orbital capabilities, but had also concluded that the ballistic capsule would provide the quickest way to put a man in space. The Air Force, in fact, had proposed the development of both types of spacecraft as far back as March 1956.

During the 1955–1957 period, the extensive research at Langley and Wallops on blunt nose cones for ballistic missiles provided the information needed for selection of a shape for the Mercury manned ballistic capsule. The results of an analysis by Faget and his coworkers were presented at the NACA

Conference on High-Speed Aerodynamics, held at Ames on March 18, 1958 (ref. 10). This study and related research had the approval of NACA Headquarters through the issuance of RA A72L250 on December 3, 1957, entitled "Aerodynamic Problems of Simple Lightweight Manned Orbital Vehicles." The analysis showed that, for a capsule 7 feet in diameter and weighing 2,000 pounds, the maximum aerodynamic heating rate for a nearly flat entry surface was about one-half that for a hemispherical one, and the total heat to be absorbed during a typical reentry from orbit was also considerably less. Either a 30-degree cone with a large bluntness, or a 106-degree cone with a small bluntness, had higher maximum heating rates than the hemisphere, and higher total heat than the flat face. The heating rates were considerably below those for a typical ballistic missile, because of the flatter reentry angle, and indicated that a heat sink such as copper or beryllium could be used.

Faget was a strong proponent of a flat face for missile nose cones, and initiated a special series of refinement tests in the Preflight Jet at Wallops (discussed in Chapter 14), which indicated that a spheroid of large radius would be preferable to a completely flat face. A spheroid of radius equal to 1.5 times the diameter of the face was shown to have an equal heating rate across the face and was the actual shape selected by Faget in the manned capsule study. The total spacecraft analyzed in detail is shown as capsule A in figure 420.[15] A 30-degree cone was assumed for the main body of the capsule.

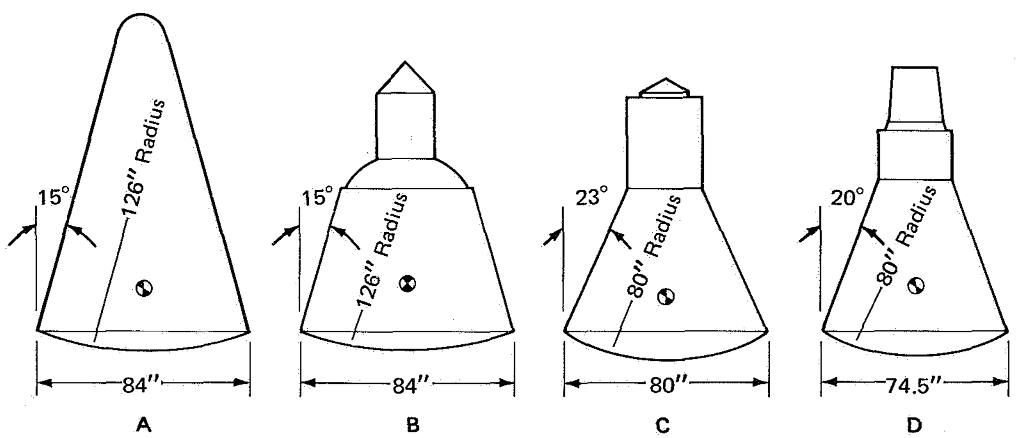


FIGURE 420. Sketch of four capsule shapes tested in the evolution of Mercury.

Most of the innovations of the final Mercury capsule came out of Faget's analysis and were described by him at the March 1958 conference at Ames. The supine position for the pilot was selected from aeromedical results which had shown overwhelming superiority over a normal seated position in tolerating acceleration loads. The capsule would leave the atmosphere pointed-end first on top of the Atlas and reenter backwards, or blunt end first. Faget pointed out, "This reversal in attitude also simplifies the support system for the occupant, since the same couch is properly aligned for both the acceleration and deceleration phases of flight." Also proposed was the possibility of exercising some control over the reentry path by offsetting the center of gravity from the centerline to induce a slight trim angle of attack and some lift. Although not used on Mercury, such a scheme was to be used with both the Gemini and Apollo spacecraft. After reentry, the capsule was to be lowered to the ocean by a large parachute, for recovery by naval forces.

The motions of missile nose cones during reentry had been analyzed by J. D. Bird of Langley. In a paper also presented at the Ames Conference in March 1958 (ref. 11), he extended his analysis to include the Faget capsule shape. The usual dynamic stability calculations for such a shape would indicate dynamic instability even though the body possessed static stability and damping in pitch, because the lift-curve slope was negative. Unlike a normal lifting body, the capsule had to be trimmed to a downward or negative angle to produce a positive lift. In his analysis, however, Bird found that when the transient conditions of a reentry were included, the amplitude of an oscillation existing at the

15. This letter designation refers only to figure 420 and is used in this history only as a matter of identification.

beginning of reentry at an altitude of 400,000 feet would decrease significantly down to an altitude of 200,000 feet. Below 200,000 feet, the amplitude would start to increase, and by the time the capsule had decelerated to Mach 1, the amplitude would have increased to its beginning value. This apparent damping of the oscillation during the early part of reentry was a most encouraging finding, for now it was indicated that the capsule, even without an attitude control system, would not have large oscillations in pitch during the critical high-heating period of reentry.

Tests of capsule shape A in the Langley Spin Tunnel in December 1957 verified the calculations of dynamic instability at low subsonic speeds, but for this shape the amplitude of the pitch oscillations built up to only 45 degrees and then remained constant. This was fortuitous because some stubbier shapes had indicated a tendency to tumble end over end quite rapidly. Additional tests in this tunnel indicated that a small drogue parachute had a stabilizing effect and limited the oscillations to about 25 degrees (ref. 12). For this reason, it was planned to open the drogue chute in flight before it was needed to pull the main chute out of its canister.

Shortly after the March 1958 conference at Ames, it was fairly certain that the NACA would evolve into the space agency, although it was not until October 1958 that authorization to proceed with the development of Mercury was issued. The proponents of the manned ballistic capsule at Langley, however, assumed that they would get the assignment and continued in-house research and development to finalize the design. Pending completion of this research and selection of the final shape, a full-size mockup of the type A capsule was constructed of wood in the Langley shops during the spring of 1958 to get a feel for the space available and the general layout. This was followed by construction of a mockup from sheetmetal or "boilerplate."

Although no official approval for the development of a manned capsule had been received, Faget was able to obtain the support of a large segment of Langley through personal persuasion. He already had the backing of P. E. Purser and C. L. Gillis, two other PARD branch heads, who contributed ideas to the project, and he now proceeded to enlist the support of other divisions. He found considerable enthusiasm for the project, although there was some hesitation about going too far in the development with full-scale capsules. The service divisions that supported all PARD projects—IRD, Engineering Services Division, and Technical Service Shops—naturally gave all requested aid. The assistance of the Spin Tunnel has already been mentioned. Certain members of the Flight Research Division were enthusiastic about assisting because of the prospect of a manned flight, but they did not want to give the impression that they were trying to take over the project. In fact, one morning, C. W. Mathews, a branch head in that division and one of the men to be transferred to the Mercury Project later, called on J. A. Shortal, PARD Chief, to assure him that this was not the case and that he had taken an active interest in the capsule after F. L. Thompson, Langley Associate Director, had asked him to "keep an eye on the project from the standpoint of the pilot."

The Hydrodynamics Division provided assistance in determining landing loads. In this connection, after PARD engineers had unofficially approached that division to make some water impact tests with the boilerplate capsule, J. B. Parkinson, Hydrodynamics Chief, visited Shortal to find out if the request had his support. Finding out that it did, Parkinson said, "It's your capsule. If you want us to drop it in the water, we will do it." This was the beginning of a series of impact studies with full-scale and model capsules.

Many wind tunnels supported the project by tests of the specific shape or generalized versions. Preliminary tests of the type A capsule made in the unitary tunnel, the 8-foot transonic tunnel, the Langley transonic blowdown tunnel, the 11-inch hypersonic tunnel, and the spin tunnel were summarized in a single document (ref. 13). After the project became the NASA Mercury Project, an extensive wind-tunnel program was conducted for the Space Task Group.

During May 1958, considerations of high aerodynamic heating on the long conical afterbody of the type-A capsule, and practical aspects of housing parachutes, led to the shape shown as type B in figure 420. The lower half of B was the same as that of A, but the afterbody was a spherical dome, topped by a cylindrical parachute canister. The models tested at Wallops during the summer of 1958 were generally of type A or B.

The first models tested at Wallops were small ones, constructed hurriedly to obtain some free-flight data. They were carried aloft by radiosonde balloons and then released for free fall from an altitude of about 6,000 feet. The first such drop was made on June 17, 1958. One model is shown in figure 421. These and wind-tunnel tests indicated the possibility that shape B would tumble continually. A rocket-model program was planned to evaluate this characteristic at hypersonic Mach numbers. Two such models were tested with Nike-Recruit boost systems on June 18 and August 4, 1959, respectively. By the time the models were ready, the capsule shape had been changed, but the tests were made for possible application to future programs. The first of these models at Wallops is shown in figure 422 with its boost system. This two-stage system propelled the model to a maximum Mach number of 2.62 at an altitude of 35,000 feet. The model was then separated from the second stage, which had a large stabilizing flare, selected to ensure drag separation from the test model after detonation of an explosive bolt holding the two together. Motions of the capsule were transmitted by a telemeter sensing accelerometer readings. The model was released with its small end forward, as in a regular launch. It quickly reversed itself to present its blunt end forward, and although it did not tumble, it oscillated through an angle range that decreased from 160 degrees to 140 degrees as it slowed to Mach 1.11 (ref. 14). The second model is shown in figure 423.

Concurrently with study of the external shape of the capsule, studies of the internal design for the pilot were also under way. J. C. Heberlig and W. M. Bland, Jr., of PARD were working on the couch required for the pilot in his supine position in the capsule. On May 26, 1958, they visited the Aviation Medical Acceleration Laboratory (AMAL), NADC, Johnsville, Pennsylvania, to discuss the possibility of testing the couch on the Johnsville centrifuge to establish acceleration limits for a pilot on the couch. The Johnsville people were agreeable and suggested a date in July, following the conclusion of work for the X-15 research airplane already scheduled. Bland suggested that NACA Headquarters make the request official by sending a brief memorandum to Johnsville requesting "the centrifuge tests on the basis that the planned capsule program is moving rapidly toward the flight test stage" (ref. 15). On June 4, 1958, Langley proposed a research authorization entitled "Study and Design of Manned Space Capsule" to cover this and other work at Langley; but it was not approved by NACA Headquarters until August 8, 1958, after the initial tests at Johnsville had been completed. Headquarters changed the title to "Study of Occupied Space Capsule."

On June 17, 1958, NACA Headquarters asked NADC for use of the Johnsville facility; and on July 21, the centrifuge tests began. By the end of the week, Langley pilot R. A. Champine, for whom the couch was moulded, had reached a maximum of 15 g without ill effects. Champine was scheduled to attend an X-15 airplane conference the following week, but the Johnsville men were so enthusiastic about the results so far that Lieutenant Carter Collins of AMAL volunteered to test the couch to higher accelerations the following week. On July 30, 1958, Faget and Bland accompanied Heberlig to Johnsville to witness these additional tests and were delighted at the finding that Collins was able to endure 20.7 g for over 6 seconds without difficulty, establishing a world's record. The next day, R. F. Gray duplicated Collins' performance (ref. 16). The first couch, with Heberlig in place, is shown in figure 424. This was the beginning of a development program to perfect a couch support system for Mercury. It is of interest that Major John H. Glenn was invited by Langley to participate in later centrifuge tests at Johnsville during January 1959. This was before he was selected as one of the first seven astronauts.

By October 1958, the spherical shape of the afterbody had been changed to a simpler cone-cylinder shape, shown as shape C in figure 420. The cone half-angle was also changed to 23 degrees and the diameter was reduced to 80 inches. The radius of the spheroidal bottom was reduced to 80 inches to provide a somewhat lower center of gravity. Shape C had better stability than shape B. The slight increase in heat transfer with this modification was not considered a problem.

The first tests at Wallops with full-size capsules began on November 25, 1958. They were first proposed by J. B. Hammack, research engineer in the Flight Research Division, on April 28, 1958 (ref. 17). Hammack stated, "It is proposed that the Flight Research Division conduct a brief drop-test program on the PARD manned ballistic satellite. These tests are considered important from the standpoint of safety, control, and pilot familiarization." He proposed the use of a Lockheed C-130 Hercules airplane, to be borrowed from the Air Force, as the drop airplane. Drops were proposed to study the motion of the capsule in free fall, the stabilizing effect of a drogue chute, the opening shock

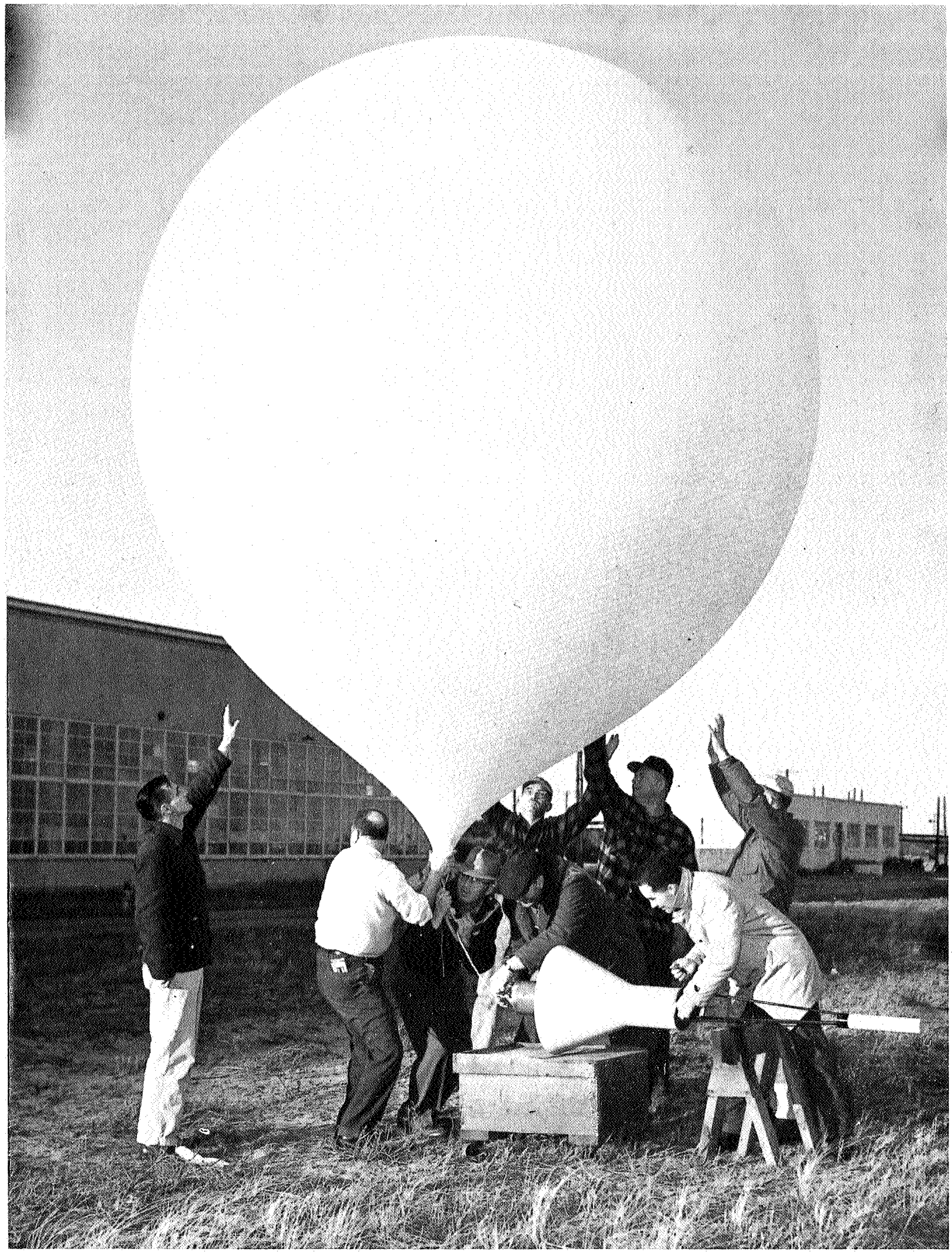


FIGURE 421. Typical low-speed model of Mercury capsule being prepared for a drop test from a balloon flown at Wallops, March 4, 1959.

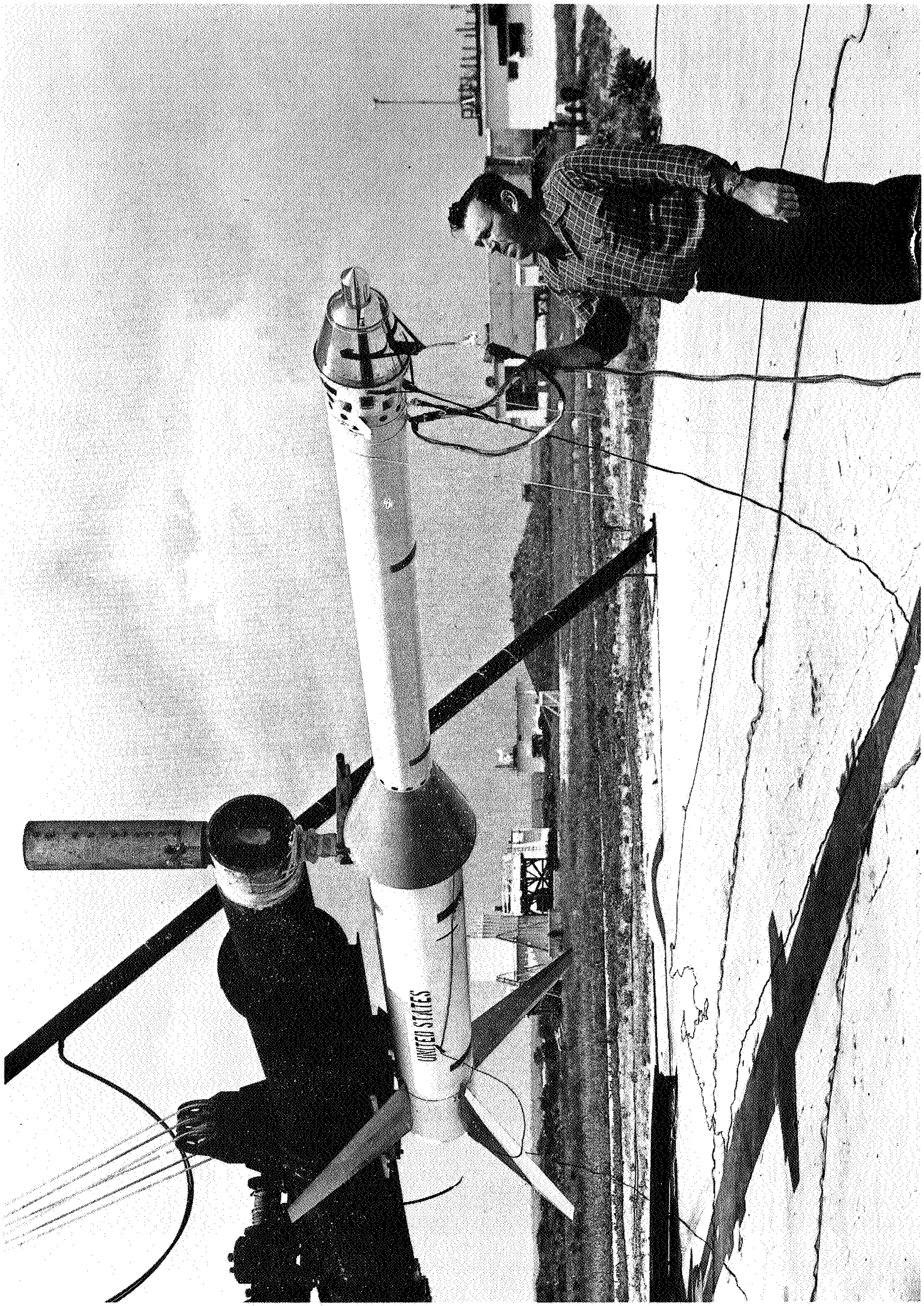


FIGURE 422. Technician Harry Bloxom examines Mercury capsule model with Nike-Recruit booster, in preparation for flight stability test, June 18, 1959.

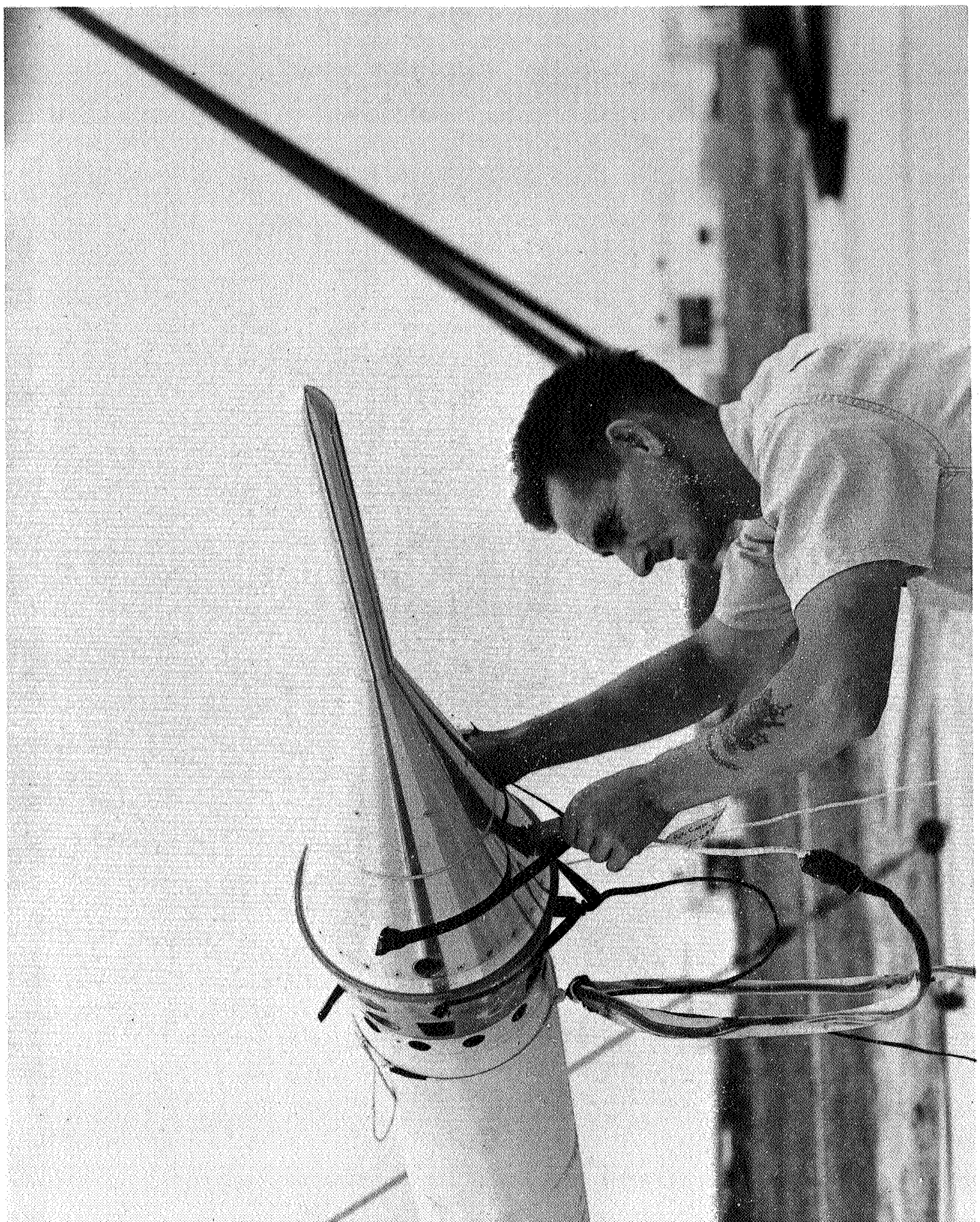


FIGURE 423. Technician Roy Hindle checks wiring to model of Mercury capsule with simplified escape tower. Model is shown on Nike-Recruit booster, August 4, 1959.

FIGURE 424. J. C. Heberlig demonstrates pilot position in first supine pilot-support system developed on Johnsville Centrifuge for Project Mercury.

loads from the main chute, and landing impact loads. The drogue chute would be used to pull the capsule out of the C-130 airplane compartment. "The initial program would serve to correct any deficiencies of the capsule, and all subsequent drops could be with pilot." In the actual tests, a C-130 airplane was used, and the behavior of the capsule and parachutes was studied, but no drops were ever made at Wallops with a pilot.

On August 22, 1958, Langley requested approval of the parachute drop program, and on September 11, 1958, RA A73L284 was issued to cover it. On August 27, 1958, Hammack, accompanied by J. W. Dodson, Langley Dynamic Model Engineering Section (DMES), visited the Pioneer Parachute Company to discuss its 46.5-foot extended-skirt parachute to be used in the drops at Wallops (ref. 18). This was a smaller parachute than that eventually used with the Mercury capsule, because this test capsule was somewhat lighter.

Prior to the high-altitude drops at Wallops, several tests were made in flight of the explosive systems for opening the canister and deploying the parachutes. The tests were made by attaching a canister to a 55-gallon drum filled with concrete and dropping it from a helicopter at an altitude of about 3,000 feet over a remote area. Next, the operation of the extraction system with a boilerplate capsule inside a C-130 airplane, was tested at Pope Field, North Carolina, on September 29, 1958.

The first drop at Wallops, on November 25, 1958, was made with a capsule having shape C of figure 420, but a 126-inch-radius base. The capsule is shown in figure 425. A new element had been added to the program by this time. The heat shield was assumed to be made of beryllium, and the plan was to discard it prior to the opening of the parachute because of the possible danger from dropping the capsule either into the water or on land while its bottom was red-hot. The capsule was dropped from the C-130 airplane, shown in figure 426, at an altitude of 10,000 feet. On station for the test were a Lockheed T-33 photo plane on loan to Langley from the Air Force, two Marine Sikorsky HUS helicopters to retrieve the capsule, and a local fishing boat hired to pick up the parachute. After a 24-second free drop, an onboard timer armed the explosive mechanism to open the canister, release the heat shield, and then fire the main-chute extraction mortar. All events occurred as planned, and a successful recovery was made by one of the helicopters, which carried the capsule to the airfield at Chincoteague Air Station for loading on the C-130 for return to Langley. After the water landing, a salt-water-actuated switch released the parachute, which was then recovered by the hired boat. The only unsatisfactory finding in this test was a pitch oscillation of the capsule of 90 degrees in both directions (ref. 19). The air-drop program was now under the direction of Max C. Kurbjun of the Langley Flight Research Division, who took over after Hammack joined the Space Task Group.

FIGURE 425. Marine helicopter retrieves boilerplate Mercury test capsule from water after air-drop from C–130 airplane, November 25, 1958.

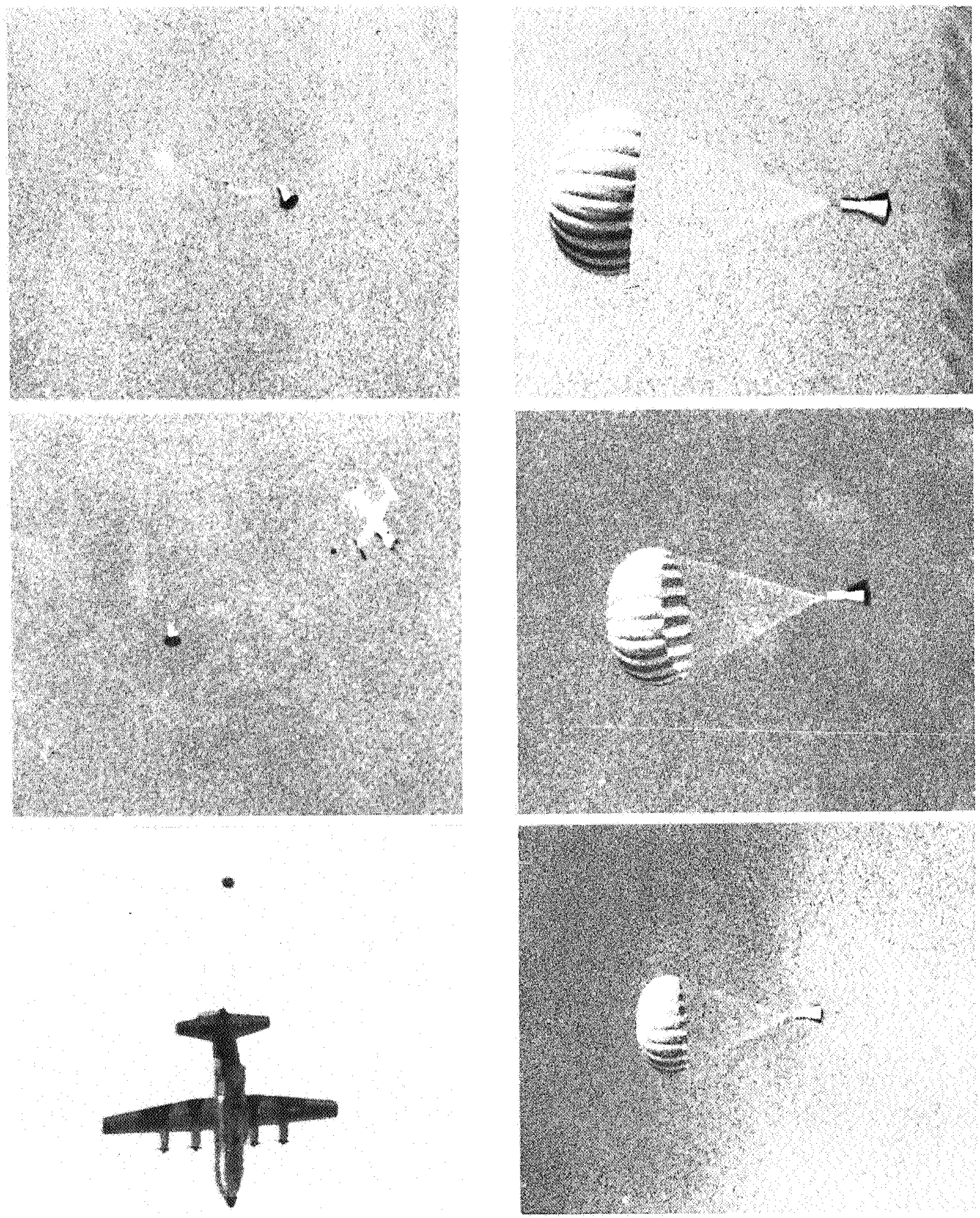


FIGURE 426. Sequenced pictures showing events from release of boilerplate Mercury capsule from C–130 airplane to opening of recovery parachute, December 1958.

The second drop was made on December 1, 1958, from an altitude of 5,000 feet. Everything went as planned until the time came to release the heat shield. The explosive bolt that held the heat shield to the capsule failed to fire, and the capsule hit the water with the heat shield in place. Thereupon, the salt-water switch did not function, and the parachute remained attached to the capsule. The wind caught the parachute and pulled the capsule along in a tipped attitude. The boat crew cut the parachute loose and the helicopter hooked onto the capsule but, as it was being lifted, the hoist safety release failed, and the capsule dropped back into the water. The boat started towing the capsule to the Assateague Coast Guard Station, but it sank in relatively shallow water. The next morning as a Navy boat attempted to recover the capsule, it sank in deep water. Two days later, the capsule was recovered by Navy divers and returned to Wallops. The onboard records indicated that this capsule was even more unstable than the first one and that parachute deployment had been in an abnormal attitude. For added stability, the program was changed to extend the drogue chute some time prior to deploying the main parachute.

The third drop, on December 10, 1958, was made from an altitude of 23,000 feet. This time, the drogue chute did reduce the amplitude of the oscillations, but the motions were still fairly violent when the heat shield was separated. The heat shield struck and damaged the canister area of the capsule and dislodged a camera. The capsule floated in the water on its side and could not be righted for pickup by the helicopter, but the boat towed it safely to the Coast Guard Station. The parachute loads were found to be well within the design limits.

The fourth drop, on December 17, 1958, was made from an altitude of 20,000 feet. This time, as the parachute was opening, it suddenly left the capsule, which then fell into the ocean and sank. It appeared that the heat shield had struck the parachute while it was emerging and somehow closed the release circuit. The capsule was retrieved, but it was a complete loss, although the data records were saved. The idea of discarding the heat shield during reentry was abandoned.

The fifth and last drop in this series at Wallops was made on March 24, 1959. In this test, the parachute did not open fully and alternately opened and closed in a maneuver known as "squidding." Further testing was delayed pending solution to this problem. The Space Task Group and McDonnell representatives met with parachute specialists from the Air Force and Radioplane and decided to change from the extended-skirt design to a 63-foot ringsail design (ref. 20). Tests of this parachute, as well as of the 6-foot Fist ribbon drogue chute, were conducted during 1959 at Edwards Air Force Base, California, and at the El Centro Naval Parachute Test Facility, Salton Sea, California. Concurrently, a new series of full-scale drops with this new parachute began at Wallops on April 22, 1959. These drops were to be qualification tests for the Big Joe Project, with the first capsule to be launched by an Atlas at Cape Canaveral on September 9, 1959.

The Big Joe capsule was similar to those in the Little Joe series, to be described later, except that its purpose was to flight-test a new ablative[16] heat shield under development as an alternate to the beryllium heat-sink shield. Because of the heavy workload already imposed on the Langley shops in constructing the Little Joe capsules, the lower portion of the Big Joe capsule, including the instrumentation, was constructed at the Lewis Research Center.

An ablative heat shield had been considered for Mercury from the beginning although the preliminary specifications for Mercury, October 1958, asked that only a beryllium shield be considered for the initial proposal. The idea of using the latent heat of vaporization of a material to absorb some of the reentry heating had been under investigation by the NACA and the military, and by industry, notably Convair and General Electric, for some years in connection with the ICBM nose cone problem. Transpiration cooling with water made use of this property, although higher efficiency was found with heat shields made of composite materials. On August 8, 1957, the impressive recovery of an ablative nose cone, flight tested by ABMA with a Jupiter C missile, opened the eyes of skeptics who favored the chemically purer process of heat absorption of the heat-sink system. A different composite material was

16. The aeronautical purists at Langley objected to the use of the word "ablation" to describe the process undergone by this type of heat shield during reentry. Medically, ablation meant "taking away" or "removal," usually by cutting, whereas the heat shield lost material through a chemical process consisting of a combination of heating, melting, vaporizing, and burning, with some physical removal. For lack of a better word, however, ablation was accepted.

required for the Mercury capsule than for an ICBM nose cone because the heating cycle during reentry was quite different. Whereas the missile encountered a high heating rate for a short period, the capsule would encounter a much lower heating rate but for a longer period. Additional research was required.

The Air Force had favored an ablative heat shield for its man-in-space program from the beginning and by the summer of 1958 was supporting an extensive research program whose results were to be of great benefit to the Mercury project. The NACA participated in this program, but the required conditions of high temperature and low heating rate were difficult to simulate in existing facilities designed for the missile reentry condition of high heating rate. On July 30, 1958, a test program was proposed at WADC at a meeting attended by A. C. Bond of PARD and C. W. Mathews of FRD. The program envisioned the use of four different facilities that came the closest to the desired simulation. It was proposed that tests be held in the subsonic plasma jet at the Midway Laboratories of the University of Chicago, the ceramic heater at Brooklyn Polytechnic Institute, the ceramic heated air jet at Langley, and the Ethylene Jet at Wallops (ref. 21). Extensive tests of many different ablation materials were made in the Ethylene Jet at Wallops during the fall of 1958. These tests included the Mercury capsule shape as well as the WADC shape.

The heat shield finally selected for Mercury, after tests in all suitable facilities, was a fiberglass phenolic resin. This composite had the advantage of high absorption of heat with low conduction of temperature to the main structure. At the outer surface, the phenolic resin underwent a chemical decomposition or pyrolysis at a relatively low temperature, forming a char layer supported by the fiberglass reinforcing material. The exposed surface of the char melted and oxidized. Its high temperature radiated a large quantity of heat. The transpiration of the cooler gases from the base material through the char layer provided further cooling. Since the pyrolysis occurred at a relatively low temperature, little conduction of heat took place back to the base.[17] These many advantages made it a prime candidate for Mercury, but there remained the proof test under actual reentry conditions. This was the purpose of Big Joe. The ablative shield flown on Big Joe was developed by General Electric Company to meet STG requirements. Fabrication of the flight article was performed under a subcontract with B. F. Goodrich Company. General Electric also developed special ablative sensors for this heat shield. The Big Joe test, on September 9, 1959, demonstrated the effectiveness of this heat-shield concept, and it was adopted for Mercury. The heat shield actually used on Mercury was of the same type, but fabrication was provided by the Cincinnati Testing and Research Laboratory, with some variation in the phenolic binder from that of the GE development. In addition, the thickness was reduced about 60 percent after the Big Joe test indicated a conservative design.

To get back to the air drop tests in preparation for the Big Joe launching: five drops were made at Wallops between April 22 and May 6, 1959, to test the parachute. In this series, the same C-130 airplane, the two T-33 photo airplanes on loan from the Air Force, two Marine helicopters, and two rented boats—the *Cynthia* and the *Eva K*, from Chincoteague—participated at Wallops. In the first test, "the programmed sequence of events occurred as scheduled and the capsule was gently lowered into the ocean. Helicopter HR2S picked the capsule up with little trouble" (ref. 23). The major variable in these tests was the reefing arrangement for the main parachute. The events were duplicated on April 23 and again on April 29, 1959.

In the afternoon of April 29, 1959, another type of test was performed for the Mercury project. A C-band radar beacon, required for Mercury, was flight tested in a McDonnell F2H airplane. The FPS-16 radar at Wallops had trouble with the signal at times and actually tracked the airplane farther by skin tracking than with the beacon. The need for further development was thereby indicated.

In continuation of the Big Joe drops, a successful drop was made on April 30, 1959, but the boat *Cynthia* was required to pick the capsule out of the water after a fog bank moved in and forced the helicopters to retreat. On May 6, 1959, another successful drop was made. This time, the helicopter remained at Wallops until the capsule splashed, and yet had it out of the water 5 minutes later.

During June and July, 1959, five additional air drops were made to qualify all the recovery components for Big Joe. These tests were under the direction of STG personnel, with Peter J. Armitage as the project engineer. A sketch of the planned operation as prepared by Armitage is shown in figure

17. For an excellent summary of the ablative process, see reference 22.

427. Langley participated in these tests by assisting in packing and loading the capsule in the C-130 airplane. The first of the tests was made on June 8, 1959, with success; but on June 11 the capsule broke away from the helicopter on the way to shore, broke up on impact, and sank in the ocean. On June 22, 1959, a capsule drop was made at Wallops as a special training exercise for the Navy complement selected to recover the Big Joe capsule at Cape Canaveral. The Atlantic Fleet, headquartered at Norfolk, Virginia, had been given the overall Mercury recovery assignment. Two Navy vessels, an LSD and a DD made the recovery with two P2V chase planes assisting. The C-130 drop plane was vectored to the release point, some 40 nautical miles from Wallops, by Wallops control, and the capsule was released at an altitude of 20,000 feet. Recovery was successful.

Another drop was made on July 2, 1959, without the Navy forces. This time, the *Cynthia* picked up the capsule. The last drop was made on July 28, 1959. On this occasion, after splash-down, the capsule was anchored and used in a series of beacon-ranging runs by five Lockheed P2V *Neptune* aircraft, two from Norfolk and three from Jacksonville, Florida. Two beacons were activated: first, one at 230 mc, and then a SARAH beacon at 235 mc. Later, retrieval of the capsule was made by Marine helicopter.

The first rocket-launching of a full-scale capsule at Wallops was made on March 11, 1959, and simulated a ground-level or beach abort. This was a test of the ability of the escape system to rescue the astronaut in case of a malfunction of the launch vehicle prior to flight. The test program was carried out by PARD under the direction of W. S. Blanchard, Jr., and was a part of the program designated "F57" at PARD.

For these tests, capsule shape C of figure 420 was used. A Recruit rocket motor was used on the escape tower, pending development of the Grand Central rocket motor for Mercury. The capsule with the escape tower had been tested for stability in the Langley spin tunnel, with the use of small models. Ballast was added to the top of the Recruit motor to provide a proper center of gravity. The full-scale capsule used in the beach-abort tests was a true "boilerplate." The conical and cylindrical sections were constructed of 1/8-inch steel plate, and the heat shield was made of 3/16-inch steel. Only the parachute compartment was of lightweight construction. The overall length of the capsule plus the escape tower was about 27 feet. The capsule was ballasted to the same weight and center of gravity as the Mercury. For the first test, the drogue chute had a diameter of 42 inches, while the main chute was the Pioneer with the 46-foot extended skirt design. Six accelerometers were mounted in the capsule along with a suitable telemeter. Three accelerometers were at the center of gravity of the escape configuration at burnout, and three were at the center of gravity of the capsule after power jettison. The Recruit motor had its normal single nozzle replaced by three long nozzles canted 15 degrees away from vertical so that their exhausts would clear the tower structure. Figure 428 shows the test model ready for launch.

In the test, "the combination appeared to take off from the launcher nicely and to be stable for the first hundred or two feet; then the combination started to turn, tumbling end over end. It made three complete turns as it flew through its low trajectory and landed on the ocean, bottom first, approximately 1,000 feet from the launching area" (ref. 24). Blanchard analyzed the flight records and concluded that the graphite throat of one of the nozzles of the Recruit motor had failed, creating an unsymmetrical force. On this basis, the nozzle was redesigned to provide better support for the graphite insert forming the throat, and a second capsule was readied for launching.

A. H. Kehlet of the STG was not convinced that a nozzle failure had caused the first mishap, and therefore had five 1/3-scale models hurriedly constructed in the Langley shops. Because Kehlet reasoned that the failure was a result of an improper cant angle of the nozzles, in his model program the cant angles were varied from 10 degrees to 30 degrees in 5-degree steps. A 3.25-inch rocket motor was used with these models. There was a close race between Blanchard's second test and Kehlet's series. Two of the scale models, designated U-1 and U-2, were launched on April 13, 1959, another, U-3, on April 14, and the last two, U-4 and U-5, on April 15, 1959. The second full-scale beach-abort capsule was launched on April 14. The flight was quite successful. The thrust line of the Recruit had been given an offset of 1 inch to simultaneously pitch and translate the capsule to one side away from the launch vehicle in an actual manned launching. The Recruit motor, with its thrust of 34,640 pounds and a burning time of 1.5 seconds, closely simulated the Mercury Grand Central motor with its 52,000 pounds of thrust for 1 second. A high thrust was desired to get the capsule quickly away from danger. The sequence of photographs in figure 429 shows clearly the successful nature of all events. The

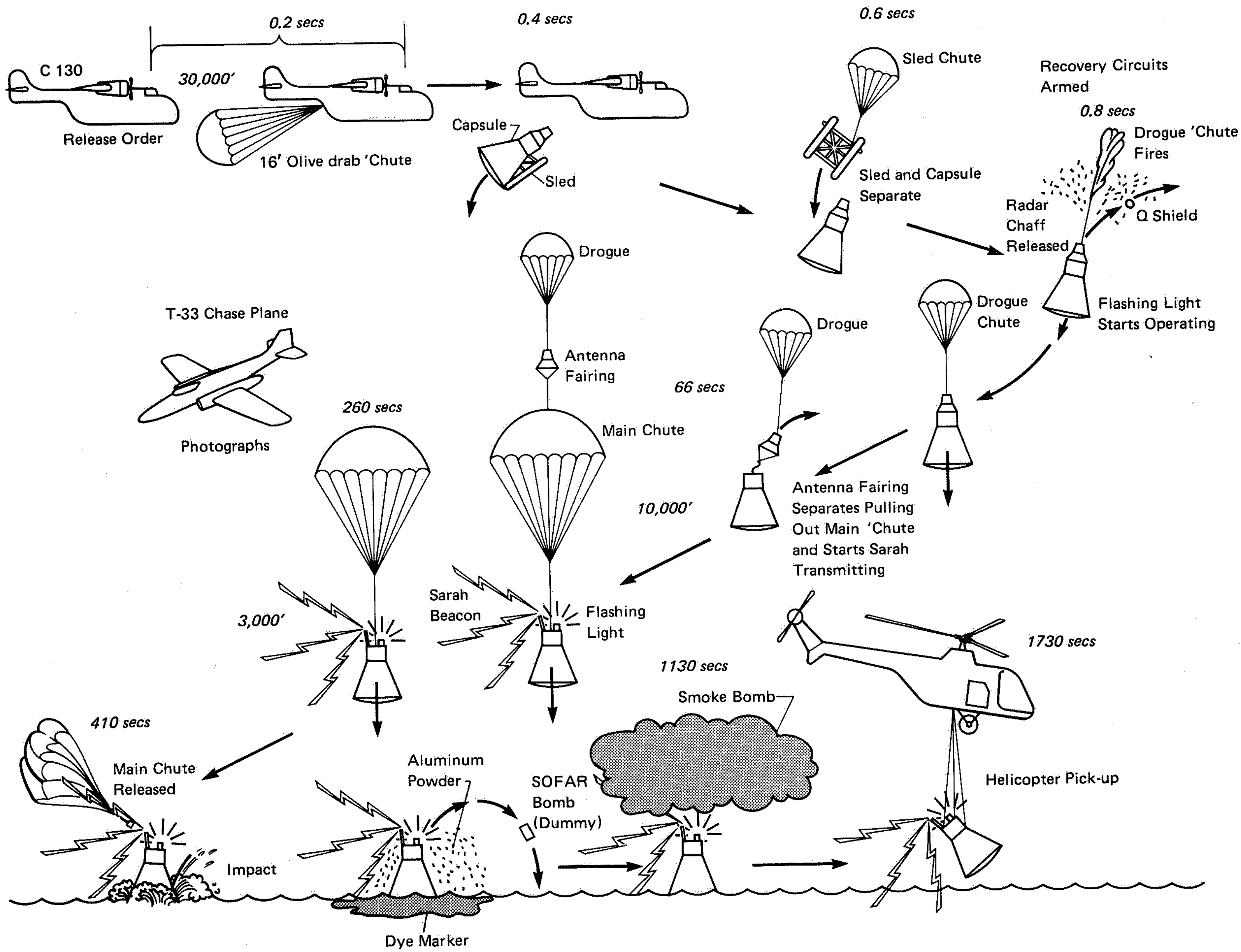


FIGURE 427. Sketch showing sequence of events as laid out by P. J. Armitage of STG for air-drop test of Mercury capsule to qualify recovery aids planned for use in Big Joe test, May 1959.

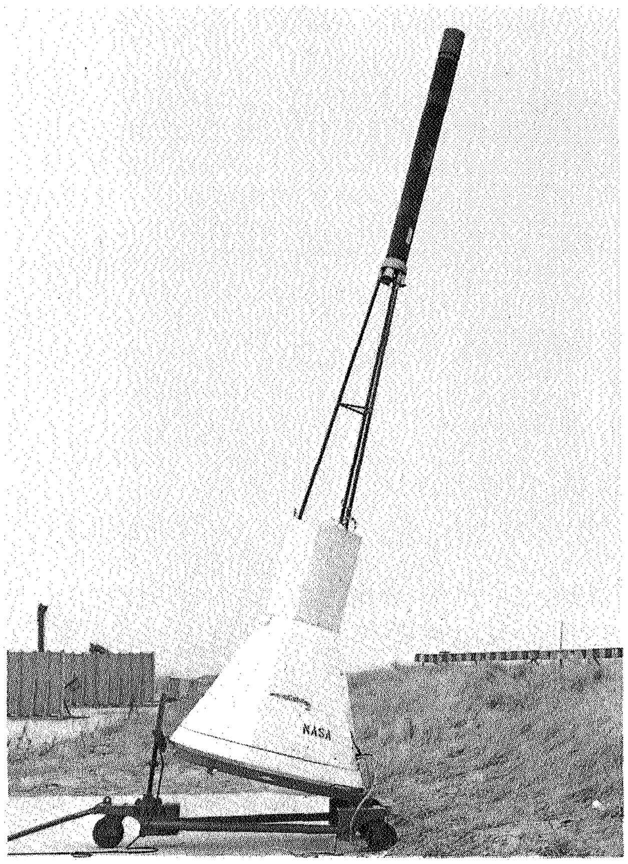


FIGURE 428. Boilerplate Mercury capsule with Recruit escape motor mounted at Wallops for first beach-abort test, March 11, 1959.

capsule and tower tumbled about one revolution before the tower was released (ref. 25). The capsule was picked up by Marine helicopter "Short Stuff" 26 and delivered to the island. The boat *Cynthia* recovered the main parachute.

The STG scaled models with different cant angles showed the models with angles of 10 degrees, 15 degrees, and 20 degrees to be unstable, while the models with 25-degree and 30-degree cant angles were stable. The unstable models tumbled slowly. The cant angles of the nozzles of the Grand Central motor for the Mercury escape tower were increased to 19 degrees, compared with 15 degrees with the Recruit.

A beach-abort test of the Mercury production launch escape system with the Grand Central rocket motor was made at Wallops on July 22, 1959. Although a boilerplate construction was used for this capsule, the shape was now type D of figure 420, very close to the final shape of Mercury. In figure 430, the capsule is shown ready for launch. The tower was attached to the top of the capsule with a Marman clamp secured by three explosive bolts. A small tower-jettison motor was employed to pull the tower away from the capsule upon ignition of the explosive bolts securing the Marman clamp. The intentional misalignment of the thrust line of the escape motor was 0.78 inch. A cone was attached to the top of the canister on the capsule to protect the capsule from the exhaust of the tower-jettison motor. A 6-foot drogue chute and a 63-foot ringsail main parachute were used, as designed for Mercury. The maximum altitude reached in this test was about 2,000 feet, sufficiently high to allow time for the complete recovery sequence. As before, the capsule and tower tumbled about one revolution before the tower was jettisoned. After this, the capsule continued to tumble until the drogue chute was opened. It was not completely stabilized until the main parachute opened. Noise measurements made inside the capsule had a level of 144 decibels, indicating the need for insulation against noise for manned flights. The accelerations of the capsule were within tolerable limits (ref. 26).

A beach-abort test of the complete McDonnell production capsule was made at Wallops on May 9, 1960. This test was conducted by STG personnel and indicated a satisfactory system.

The largest project at Wallops in support of Mercury was the Little Joe project, designed to qualify the abort-escape system under flight conditions. Little Joe was essentially a cluster of four Sergeant-type

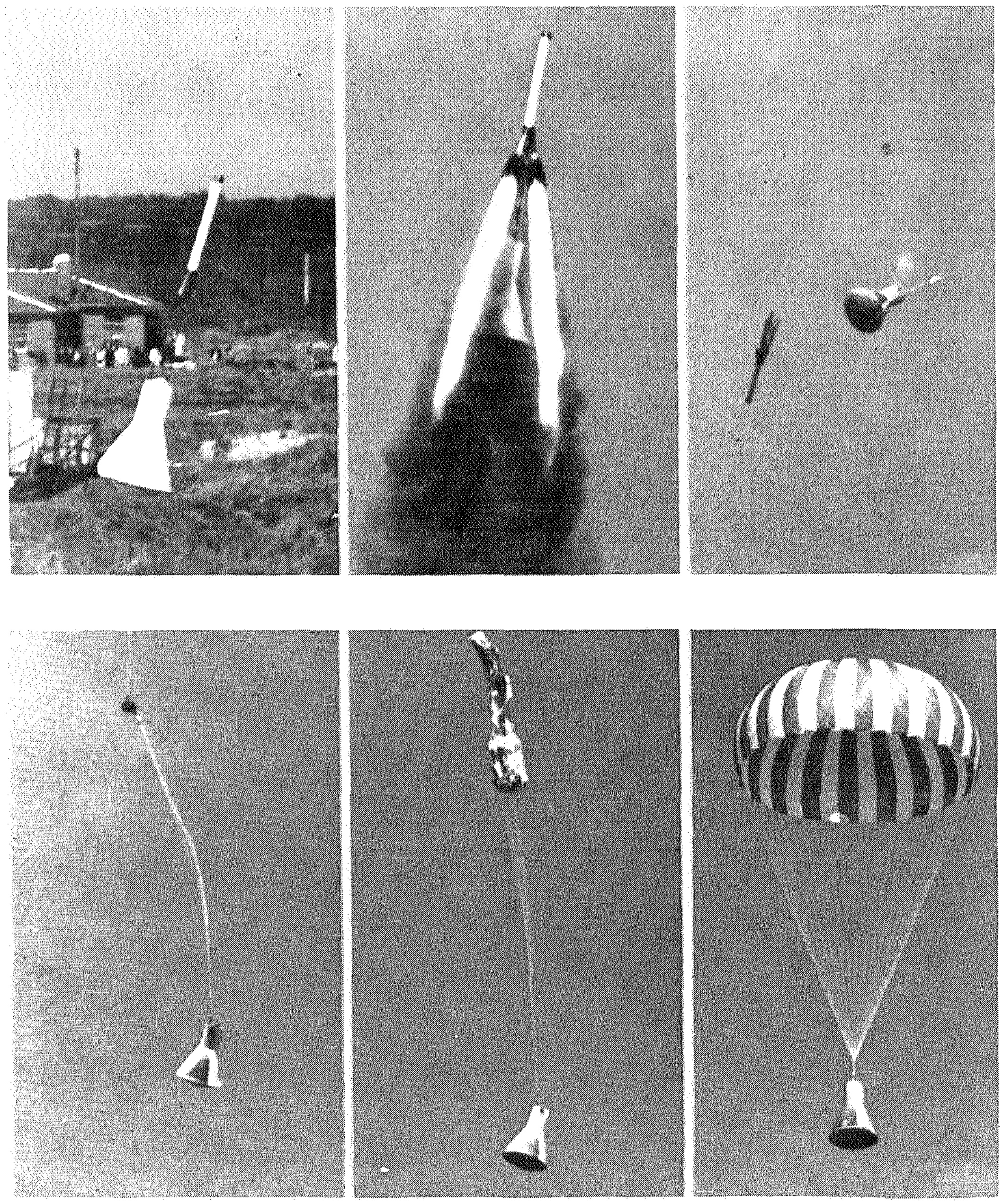


FIGURE 429. Sequenced pictures of boilerplate Mercury capsule with Recruit escape motor, showing events in beach-abort test from launch to parachute opening, April 14, 1959.

rocket motors enclosed within a fin-stabilized cylinder, on top of which was mounted the capsule and escape tower. The scheme for clustering Sergeant motors to form a booster for launching a manned capsule at Wallops originated with Faget and Purser in January 1958. At that time, they proposed clustering seven Sergeant motors to provide a booster to propel a type-A capsule to an altitude of 150 miles on a ballistic trajectory. It was proposed that the capsule be manned and a 65-foot parachute would be used for recovery by Navy forces after splash-down in the ocean. The purpose of the vehicle was to provide a means for conducting flight "research on the problems of manned space flight leading to the successful operation of Manned satellites." It was proposed that a monkey precede a man in an early flight (ref. 27). This proposal was later given the name "High-Ride," but it was withdrawn after NACA Director H. L. Dryden strongly objected to a proposal by ABMA that a Redstone missile be used for a similar purpose in Project Adam (ref. 28).

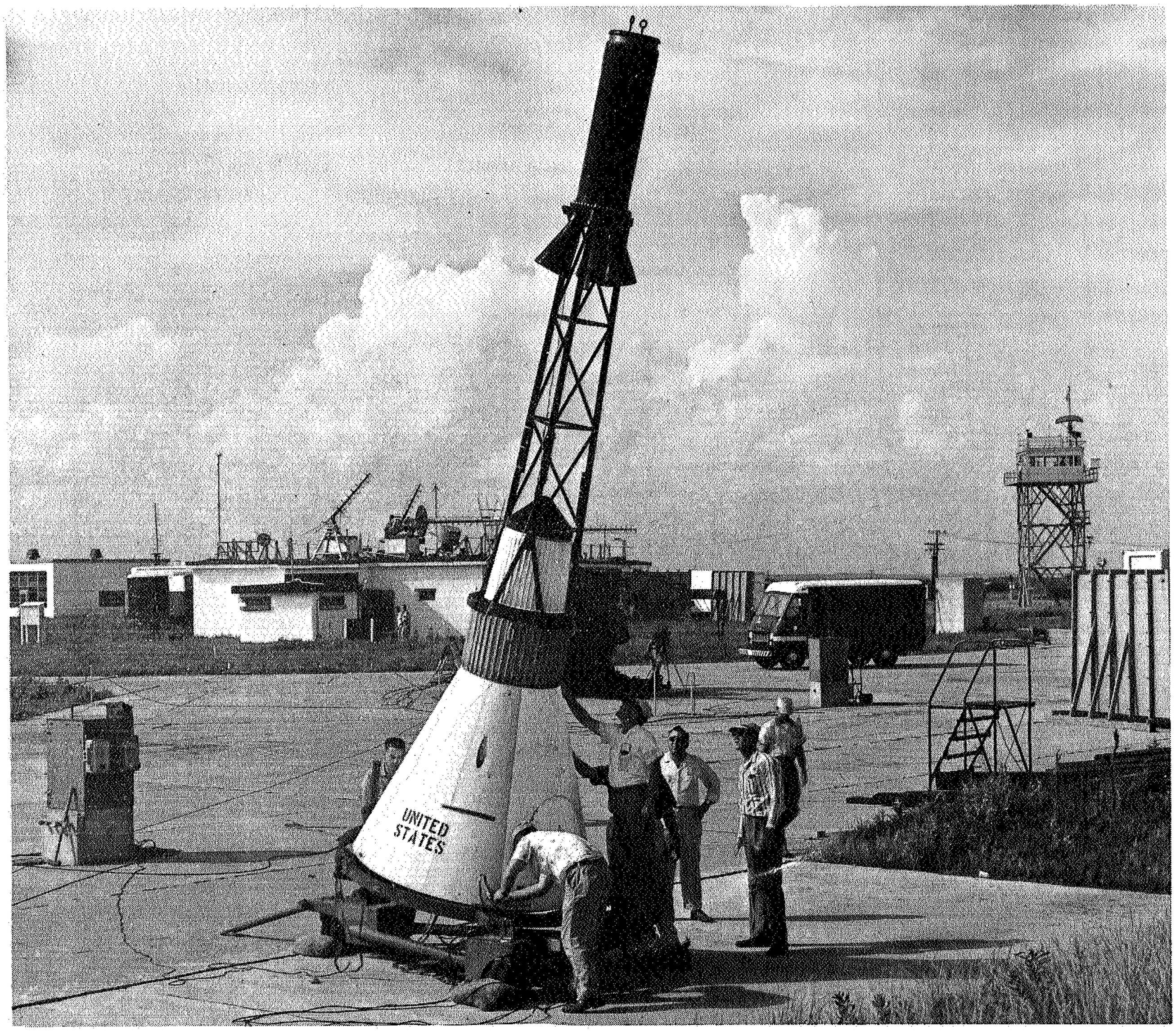


FIGURE 430. Boilerplate Mercury capsule and production version of the launch escape system with Grand Central escape motor, ready for beach-abort test at Wallops, July 22, 1959.

In August 1958, the idea of making full-scale capsule tests at Wallops with a rocket booster was revived, this time with official sanction, as a part of the step-by-step flight qualification of the Mercury capsule. It was felt that tests at Wallops with a simple rocket booster could be made faster and at less cost than by any other means and that such tests offered the best way to gain experience under full-scale launch conditions. Such a booster at Wallops could match the launch conditions and altitude—but not the speed—of the Atlas. The rocket booster's chief function, therefore, was to demonstrate the escape-system capability during boosted flight, and to determine the aerodynamic forces on the spacecraft during boosted flight and the spacecraft motions during reentry. For the booster, Faget revived the basic proposal for "High-Ride," but reduced the number of Sergeants from seven to four since an altitude of only 100 miles was now required instead of the 150-mile value of "High-Ride." Four Recruit motors were added to the cluster for additional acceleration at launch. Faget assigned W. M. Bland, Jr., of PARD the responsibility for its development. The name "Little Joe" was given the booster because of its similarity to the double deuce in a crap game of dice. The PARD designation F57 was used for the project.

Establishment of the Space Task Group at Langley on November 5, 1958, removed both Faget and Bland from PARD and made necessary the appointment of a new project manager from PARD for

Little Joe. The assignment was given to R. D. English who followed the project through the launching of all research capsules. Later launchings of McDonnell Mercury capsules were handled by the STG as a part of the development program. Nevertheless, Bland kept a close watch on all of the Little Joe launchings and informed Faget and Gilruth of the results. After Faget left PARD, C. A. Sandahl replaced him as head of the Performance Aerodynamics Branch. Sandahl was given the additional assignment of acting as chief contact at Langley for all research support for Project Mercury. The STG, in turn, designated the following contact men for the Langley support work: J. B. Hammack, scheduling; W. M. Bland, Jr., Little Joe; A. B. Kehlet, general aerodynamics; R. O. Piland, heat transfer; and J. B. Lee, landing and recovery (ref. 29).

Drawings and specifications for the Little Joe booster, exclusive of the rocket motors and the test capsule, were prepared and bids were invited. A contract was awarded North American Aviation Corporation on December 29, 1958, for the construction of seven boosters plus a launcher. F. E. Mershon of Langley's Engineering Division was the contract monitor.

The rocket motors for Little Joe were all procured from Thiokol Chemical Corporation through Army Ordnance at Huntsville, Alabama. Initially it was planned to use Sergeant motors, but by late 1958 Thiokol had proposed an improved version of the motor using polybutadiene acrylic acid and aluminum propellant instead of the original polysulfide. The 20-percent improvement in performance of such a motor was desirable for Little Joe, but—even more—it was essential to the new four-stage Scout satellite launch vehicle under development at PARD. A contract was awarded for development of the improved Sergeant plus delivery of motors for both projects. When it appeared during early test firings that the new motor might be delayed, Thiokol was asked to load some of the motor cases with the older propellant for the early Little Joe tests. The motor cases were slightly different from those of the Sergeant in attachment details. The development of these motors for Langley was monitored by J. G. Thibodaux, who had now replaced Purser as head of the High-Temperature Branch at PARD. Thibodaux named these two motors "Pollux" and "Castor," after the twin stars, with Castor being the improved version. The Recruit motors were of the same type already in use at Wallops as strap-on boosters for the Sergeant and had 12-degree canted nozzles so that the thrust would pass about halfway between the loaded and empty center of gravity of the entire vehicle. The Pollux and Castor motors were made with 11-degree canted nozzles.

Unlike the capsules used in the air-drop and beach-abort tests, the Little Joe capsules were not "boilerplate," except for one flown in a dummy test of the booster system. Structurally, they were almost as sophisticated as the final McDonnell capsules, and they are referred to herein as prototype Mercury capsules. At the time it was decided to contract for the Little Joe booster hardware, it was tentatively decided to contract for the capsules as well. Although the contractor for Mercury had not been selected, Gilruth and Faget were opposed to asking the winning contractor to build the capsules for Little Joe because this would probably delay both projects. They did not object to using a second contractor. Before any action was taken, sentiment at STG began to favor constructing the Little Joe capsules in the shops at Langley and the shop men, in turn, were enthusiastic about working directly on the full-scale capsules. PARD Chief J. A. Shortal objected to this because he feared that placing such a large workload in the shops would crowd out all other rocket-model projects. He reluctantly signed the required job order after shop management assured him that additional men would be transferred to PARD work to prevent this interference. Despite this assurance, this decision delivered the death-blow to many other rocket-model projects at PARD, from which it never recovered.

Although in comparison with the overall Mercury Project, Little Joe was a simple undertaking, the fact that an attempt was made to condense a normal 2-year project into a 6-month effort with in-house labor turned it into a major undertaking for Langley. In addition to its impact on the shop forces, it also led to a reorganization of the other two major support divisions at Langley, Engineering Service (ESD) and Instrument Research (IRD). All of the rocket-model design work had been carried out by a section of ESD, the Dynamic Model Engineering Section (DMES), headed by C. C. Johnson. With the advent of Little Joe, this section was practically doubled in size and a special room was assigned to the Little Joe group. A large number of engineers was needed to execute the detail design and to follow through to launch. Of IRD's three main branches, one, under F. B. Smith, was responsible for all instrumentation for rocket models; the second, under C. H. Nelson, was responsible for airplane instrumentation; and the third, under R. W. Hansen, was responsible for wind-tunnel instrumentation. Because the Little Joe capsule was to be recovered, it was decided to use extensive onboard recording instrumentation to supplement the usual telemetry of rocket models. The onboard instrumentation was made the responsibility of Nelson's group. For Nelson, this marked the beginning of many years' continuing participation in space flight activity.

Recovery of the Little Joe capsules was assigned to the Navy as part of the overall support of Project Mercury. Sandahl established the needs in this regard and relayed them to the Naval Liaison Officer at STG. Some practice retrievals were made with an existing STG capsule simply dropped overboard from a surface vessel offshore from Wallops (ref. 30).

Design of the Little Joe capsules began at Langley before McDonnell started on the design of the Mercury capsule and was, therefore, a separate concept. Although it was not planned for carrying a man, it did have to carry a monkey. It had to meet the weight and center of gravity requirements of Mercury and withstand the same aerodynamic loads during the exit trajectory. It contained an automatic control system with reaction jets and a destruct system. It did not have to endure the extreme heating conditions of reentry from orbit, although it did have a fiberglass heat shield, quite similar to the final one used on Mercury. The general construction of the Little Joe capsule can be seen in figure 419. The shape was type D of figure 420. The main pressurized compartment was made of fiberglass 0.2-inch thick. This compartment housed the biological package, the telemeter components, the oscillograph recorders, and the major portion of the instrumentation. Two fiberglass camera pods protruded beyond the heat shield and were coated with a low-temperature ablative material called Thermolag, made by Emerson Electric Manufacturing Company.

The effectiveness of the Thermolag coating was determined from tests in the Wallops Ethylene Jet, under the direction of H. S. Carter. For the test, the Thermolag was sprayed on a 6-inch-square test panel made of fiberglass and mounted in the jet at an angle of attack of 25 degrees, as shown in figure 431. The Thermolag was sprayed on in layers, and each coat was cured at 145°F until the desired thickness was obtained. In these tests, Type T-230 appeared to be the most promising for the protection of fiberglass. This material sublimes at 230°F, and in one test protected the fiberglass for 15 seconds in a 2,000°F Mach 2 environment with a maximum temperature of 115°F reached on the face of the fiberglass (ref. 31).

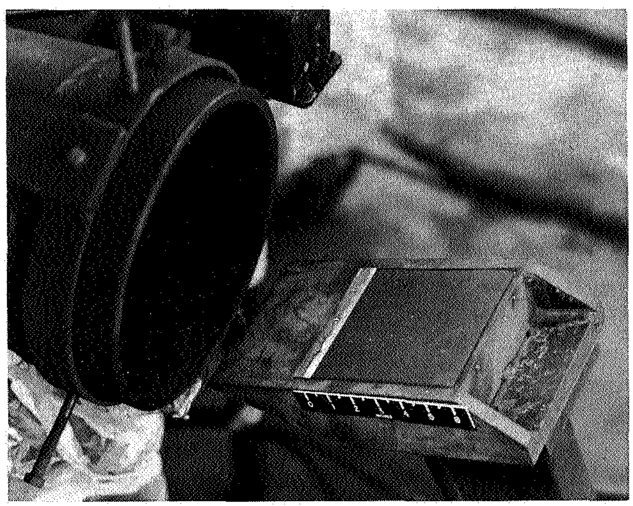


FIGURE 431. Panel in Wallops Ethylene Jet for heat-protection test of Thermolag, August, 1959.

The conical afterbody above the fiberglass compartment was constructed of corrugated inconel 0.05-inch thick, while the adjoining cylindrical section was made of 0.03-inch corrugated inconel. The antenna housing or canister, located on top of the cylindrical section, was removable. It housed the 6-foot drogue chute and covered the antennas for the beacons used as part of the recovery aid system. This section was made of 0.03-inch corrugated inconel. A conical fiberglass shield protected the canister from the exhaust of the escape rocket.

The escape tower and rocket motors were taken from the Mercury capsule production. Figure 432 shows the tower being attached to the capsule. The escape rocket was a Grand Central 1KS52000 motor with three canted nozzles. The tower-jettison motor was an Atlantic Research Corporation 1.4KS785 motor. This was the same design as that tested in a beach-abort exercise, shown in figure 430, and had the offset thrust line used in the beach-abort test to ensure that the capsule would get away from the booster in an emergency. The escape system weighed 1,015 pounds, including 236 pounds of ballast for stability.

FIGURE 432. Technicians attach escape tower to prototype Mercury capsule prior to assembly with Little Joe launcher, August 20, 1959.

The Little Joe booster was assembled at Wallops in a vertical attitude on its special launcher. The booster is shown in the background in figure 432, with the work platform in place. The launcher was located on a special concrete slab in Launching Area 1. The capsule was lowered onto the booster by a crane, as shown in figure 433. After assembly was completed, the scaffolding was disassembled and the launcher was pitched over to its normal launch angle of 80 degrees, as shown in figure 434. Little Joe had a diameter of 80 inches and an overall length, including the capsule and escape tower, of 48 feet. The total weight at launch was about 43,000 pounds. The overall span of the stabilizing fins was 21.3 feet.

A destruct system was added to Little Joe for ground safety during launch. The system was designed to be activated by a radio command from the ground which in turn would explode an annular-shaped charge mounted on the headcap of each of the four main rocket motors.

An automatic control system was installed on each one of the last several capsules. The system consisted of a Minneapolis-Honeywell autopilot that could sense and respond to angular attitudes as well as angular rates about the pitch, roll, and yaw axes. Control was provided by reaction jets located on the periphery of the pressurized compartment near the base of the capsule.

Instrumentation of the capsule was quite extensive, with onboard recorders as the main source of data, supplemented by a 10-channel telemeter. Accelerations, attitudes, and angular motions of the capsule were recorded, as well as the time for the many events scheduled to occur during a flight. Internal temperatures, skin temperatures, and surface pressures were measured. A tape recorder was used for noise measurements. A Geiger-Müller rate measuring instrument gauged radiation, and four onboard cameras recorded events.

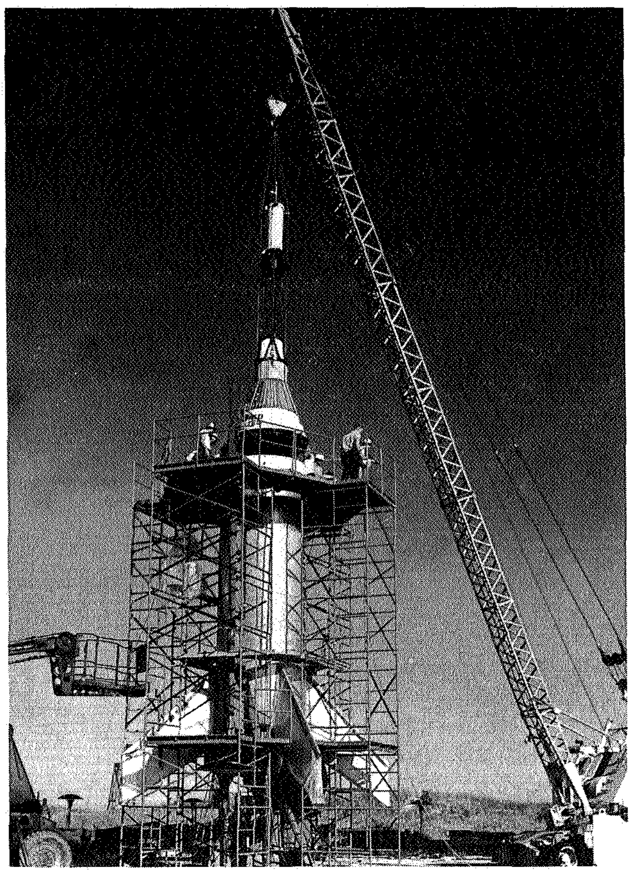


FIGURE 433. Prototype Mercury capsule and escape tower being lowered onto Little Joe booster for launch on August 21, 1959.

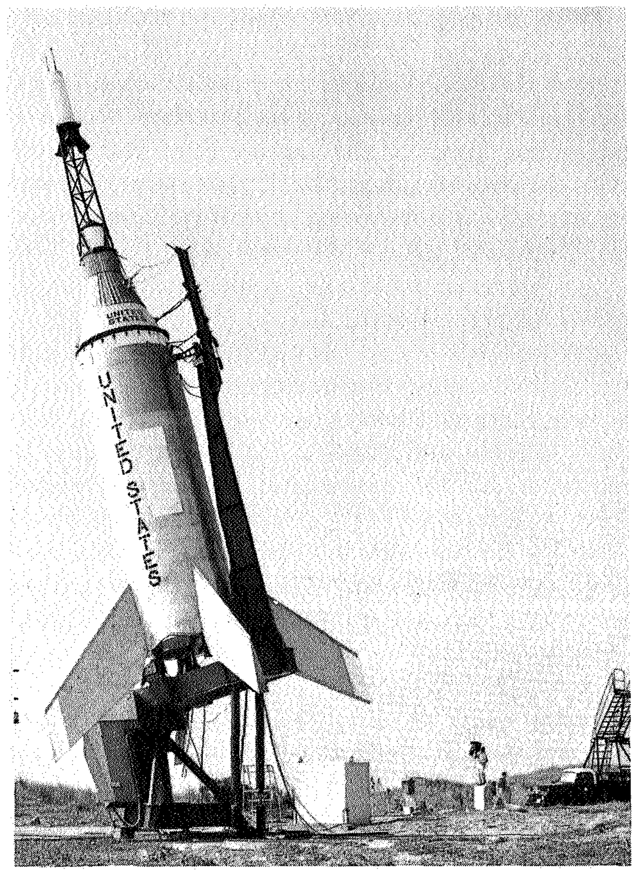


FIGURE 434. First Little Joe vehicle (LJ–1) with prototype Mercury capsule, ready for launch at Wallops, August 21, 1959.

Although the Little Joe project was the responsibility of Langley, it was conducted for the Space Task Group. For this reason, STG watched all operations closely and contributed specialized services, particularly in the field of recovery. Another contribution was in developing a rapid method for estimating the launcher setting for Little Joe to allow for the effects of winds on the trajectory of this unguided vehicle (ref. 32).

In January 1959, a launch schedule prepared for the Mercury Project showed the first Little Joe launching to be in July 1959, the first Mercury-Redstone in October 1959, and the first Mercury-Atlas in November 1959. The first manned orbital Mercury flight was shown to take place in April 1960. Of these three large vehicles, only Little Joe came close to its schedule. The first Little Joe was ready for launching on August 21, 1959, about a month late, whereas MA-1 was 8 months late and MR-1 was late by over a year. The first manned orbital flight was almost 2 years late (ref. 33). There were many events that contributed to the failure to meet the schedule, but during the construction and preparation of the first Little Joe, the schedule was thought to be realistic and Langley was determined to live up to its commitment. To do this despite the unexpected complications and the many additions to the project required a much greater effort than planned. For assembly and launch preparations, Langley sent a large number of men to Wallops to supplement the crew there. Since the first launch was a month late, the men worked around the clock with little sleep, some working as much as 40 hours without sleep. Although this devotion to the project was commendable, the failure to detect a faulty electrical circuit design during the countdown in the early morning hours of the first launch was later blamed, in part, on the overworked crew. Unlimited overtime pay was available, and this method of operation was thought to be more efficient than attempting to train three separate crews.

The failure of the first attempted launch of Little Joe on August 21, 1959, has been described earlier in Chapter 8 as one of the few major accidents at Wallops. In the final countdown at minus 30 minutes, during the charging of the onboard batteries, the rapid-abort sequence was activated and the designed events for this sequence took place. The Marman band holding the capsule to the booster fired at the same time as the escape motor, and the capsule and tower were pulled rapidly away from the booster, still resting on its launcher. At burnout of the escape motor, the explosive clamp holding the escape tower to the capsule fired along with the small separation motor, pulling the tower away from the capsule. Next, the drogue parachute was opened to begin the recovery sequence, but the main parachute was not ejected. Apparently there was not enough of a charge in the battery to activate this last event, and the capsule sank offshore. Although the capsule was recovered from the bottom of the ocean, it was of no further value, and no usable data were obtained because none of the instruments had been turned on.

A boilerplate capsule was quickly made ready for a flight to qualify the Little Joe booster since, in the first attempt, the booster was not fired. This uninstrumented capsule, designated LJ-6, was launched about 6 weeks later, on October 4, 1959. The only flight event planned other than the boost phase was the activation of the destruct system by ground command. The capsule was attached to the booster with a Marman clamp, but the escape motor was merely a ballasted empty case. This flight was made with four Pollux and four Recruit motors in the booster case. The launching was normal, and the Little Joe booster flew a stable trajectory, but there was a premature firing of two of the Pollux motors. In the Little Joe system, either the four large motors could be ignited at launch or they could be fired in two stages to provide different flight conditions. In this flight, two Pollux motors were ignited along with the four Recruit motors at launch, and the other two Pollux motors were programmed to fire 24.5 seconds afterward. In the actual flight, however, one of the second set of motors fired at 9 seconds and the other at 18 seconds after launch. It was concluded that circulation of the hot exhaust gases within the base area of the booster melted the polystyrene nozzle pressure seal closures and then ignited the motors. The destruct system was activated by radio command 170 seconds after launch, and the system apparently worked as planned (ref. 34).

The second attempt to launch an instrumented capsule with a Little Joe booster was made on November 4, 1959. This capsule was designated LJ-1A as a repeat of the first test. The purpose of the flight was to test the escape system under the maximum dynamic pressure conditions of an Atlas flight, about 1,000 pounds per square foot. For this test, only two Pollux motors were used, along with the four Recruits. The escape rocket igniter was fired right after burnout of the Pollux motors as planned but, for some unexplained reason, the Grand Central escape motor had a "hangfire" and did not begin thrusting until 12.7 seconds later. By this time, the vehicle had gained considerable altitude and lost some velocity, with the result that the actual escape took place at a dynamic pressure of only one-tenth the planned value. Except for this, the recovery sequence was followed as planned, and the capsule was picked up by a Navy ship about an hour later (ref. 35).

This failure to test the escape system at maximum aerodynamic loads was a disappointment to STG but, rather than repeat this test, Donlan decided to proceed with the planned high-altitude test, LJ-2, with a rhesus monkey, named "Sam," as a passenger. The flight, on December 4, 1959, was a complete success. This time, four Castor motors were used in the booster along with four Recruits. Again, the big motors were programmed to fire in two stages, and this time they fired as planned with a 5-second overlap between burnout of the first two motors and ignition of the second two. To prevent premature ignition of the second two motors in flight, the nozzles of these two motors were covered with 1/8-inch steel plates, and the general area of the base was covered with a thin coating of silicone rubber (ref. 36). The vehicle is shown in figure 435. The maximum altitude capability of Little Joe with this firing program of the four Castor motors was critically affected by the initial launch angle. For example, with a launch angle of 80 degrees, the altitude capability was calculated to be 69 miles. With a 70-degree angle, this was reduced to 10 miles; and with an 88-degree angle, an altitude of about 140 miles could be reached (ref. 37). In the actual flight, an altitude of 53 miles was reached, and a range of about 200 miles was achieved. This altitude was somewhat less than planned, because the wind changed just before launching, and last-minute corrections to the launcher setting were not made.

The Air Force School of Aviation Medicine, San Antonio, Texas, provided the biological package (biopack), including Sam, the primate. Sam was fitted into his own special contoured couch and

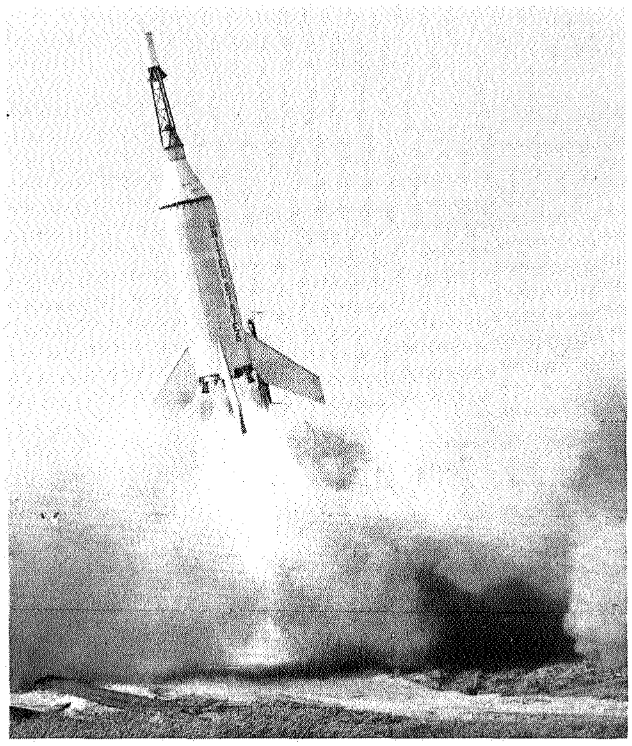


FIGURE 435. Launch of Little Joe 2 with prototype Mercury capsule, December 4, 1959.

restraining harness within the biopack. The biopack was sealed and had its own life-sustaining atmosphere. In addition to Sam, the biopak contained many other specimens such as insect eggs, larvae, bacteria cultures, and cell tissue. All were included for study under conditions of zero gravity and radiation. An 11-channel oscillograph recorder within the spacecraft provided a record of data pertaining to the physiological reactions of the monkey. These included electrocardiographs and recordings of nystagmus, respiration rate, air temperature, pressure, and humidity. A psychomotor-test monitor also was included. A motion-picture camera was aimed at the monkey's face. Sam came through the flight with flying colors and withstood the forces with no apparent harm (ref. 38). Without a hitch, he performed his duty assignment of pulling a lever when a light came on.

The flight was tracked by three radars—the MIT Millstone Hill radar and the Mod II and FPS-16 radars at Wallops. The FPS-16 provided the longest coverage, for 210 seconds, well beyond the apogee. Three Air Force T-33 photo planes were employed to record the launch and spacecraft separation sequence. In addition to the normal cameras at Wallops, a 320-inch tracking telescope with a 35-mm camera (see figure 436) was set up 18 miles south of the island. At burnout of the second set of Castor motors, the vehicle had reached a Mach number of 5.7 and an altitude of 95,000 feet. The escape rocket and Marman clamp were fired at this point, at a dynamic pressure of about 700 pounds per square foot. The capsule and escape system were stable, and after the vehicle had coasted to 130,000 feet, the second marman clamp and the tower-jettison motor were fired away from the capsule. The automatic control system in the capsule limited angular motions to a low rate until it was turned off at an altitude of 166,000 feet, when a deceleration of 0.05 g was reached. The capsule was found to be statically stable, base forward, throughout the reentry, and it aligned itself generally along the flight path down to about an altitude of 100,000 feet. Dynamic instability was indicated by oscillations of increasing amplitude estimated as 25 degrees in each direction at 90,000 feet, and increasing to nearly 100 degrees at 40,000 feet. The oscillations were damped considerably after the drogue chute was opened at the design altitude of 20,000 feet. This wild oscillatory motion was quite similar to that to be encountered in 1962 by John Glenn during his reentry from earth orbit. In Glenn's case, the drogue chute opened at 30,000 feet to end the motion. Early in the Mercury test program, Gilruth wanted to open the drogue chute at an altitude as high as 60,000 feet and a Mach number of 1.5, corresponding to the point of calculated beginning of difficulties from oscillations of the spacecraft. He therefore

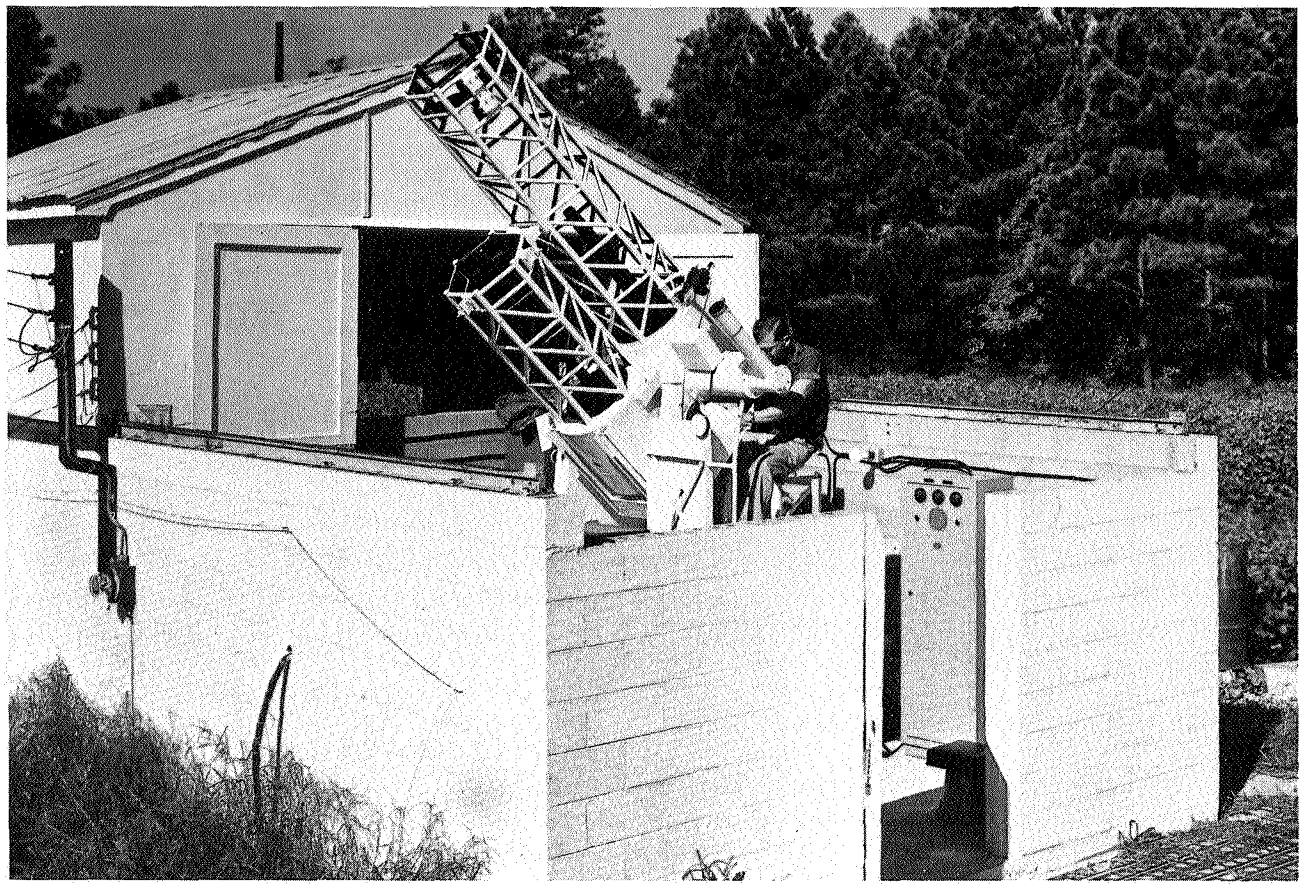


FIGURE 436. Long-range T−5 camera installed at Locustville, Virginia, for photographing Little Joe and other space vehicles, September 22, 1959.

initiated a flight test program at the High-Speed Flight Research Station (Edwards) to qualify the parachute for this condition. When the parachute failed to meet this requirement, the lower altitude had to be accepted (ref. 39).

The main parachute opened as planned at 10,000 feet, actuated by a pressure switch, and lowered the spacecraft to the ocean at a rate of descent of 35 feet per second, low enough for a nondestructive impact. (The load-relieving bag and detachable heat shield later to be used on Mercury capsules were not employed in the Little Joe tests.)

Recovery of the spacecraft was assigned to Destroyer Flotilla Four, Norfolk, Virginia, and two P2V *Neptune* airplanes, four helicopters, two destroyers, one LSD, and a seagoing tug were used. Two of the helicopters were stationed at Wallops. Several recovery aids were provided by the spacecraft. Two SARAH beacons, activated at deployment of the main parachute, served as homing transmitters to locate the spacecraft while it was still airborne, but they were also operative after splashdown. The telemeter signal was also available as a backup to the SARAH beacon. Two sofar bombs were provided, one released at main parachute deployment and set to detonate at a water depth of 2,800 feet, and the other within the spacecraft, also set to detonate at 2,800 feet in case the spacecraft sank. Two bags of fluorescein colored the water a bright green after impact. In addition, a flashing light was activated at main parachute deployment. One of the P2V airplanes received a SARAH signal at a distance of 94.5 miles from the spacecraft and obtained a fix on its position. The airplane then radioed this position to the destroyer *Borie*, which went to the location, sighted the dye marker, and lifted the spacecraft aboard, 1-3/4 hours after launch.

Aerodynamic heating of the spacecraft during the boost phase was rather severe, although not excessive, on the thin inconel sections. Temperatures as high as 700° F were reached. For this high-Mach-number test, the fiberglass shell, forming part of the conical afterbody of the capsule, was coated with a layer of Thermolag for added thermal protection. This was found to have a thin char layer after recovery. The ablative material around the camera pods was charred all the way through to the basic structure. The heat shield appeared to be charred black over its entire exposed surface, because of reentry heating. Measurements of noise within the spacecraft showed a maximum level of 142 decibels, again indicating a need for insulation to protect the astronaut (ref. 40).

The overall conclusion from this test was that the system concept for escape was sound at hypersonic speeds, the loads and motions were well within safe limits for a man, and the recovery system was excellent. Undoubtedly, this was the largest and most exciting launch of any made so far at Wallops. Sam certainly added to the excitement and interest of the news media and made the public more aware of the existence of Wallops Station. Sam had the distinction of being the first animal to ride in the Mercury capsule, and demonstrated that at least the Langley version of the spacecraft was airworthy.

On January 21, 1960, a successful test of the escape system was made with Little Joe 1B, under the maximum design dynamic pressure condition. As with LJ-1A, two Pollux motors plus the four Recruits were used. This time the escape motor fired as scheduled and pulled the capsule away to a safe landing in the ocean about 12 miles from shore. A helicopter returned the capsule to Wallops. This capsule also contained the biopack with Sam's female counterpart, Miss Sam (see figure 437), on board to test reactions to high-stress situations. Miss Sam was disturbed by the firing of the escape rocket but otherwise performed her assigned chore. This spacecraft was recovered in such good condition that it was to be used later in a Mercury-Redstone development firing in March 1961.

FIGURE 437. **Dainty-fingered monkey, Miss Sam, gazes forlornly from her contoured couch prior to flight test from Wallops in Little Joe 1B, January 21, 1960.**

Once the general concept of the Mercury system had been proven sound, the time had come tc qualify the actual spacecraft designed by McDonnell. Originally scheduled for a December 1959 launching, the test designated LJ-5 was not made until November 1960, because of delays at McDonnell. Preparations for the first Mercury-Atlas launching on July 29, 1960, no doubt interfered. The fact that this first Atlas flight was a failure contributed further to the delay. For the LJ-5 test, Langley personnel assisted in the assembly of the booster, but all of the spacecraft operations were handled entirely by STG. Now, a new set of people had to learn by experience. This test was to be similar to LJ-1B, with the escape system activated at maximum dynamic pressure. The launch started as planned, but about 16 seconds ahead of time both the escape rocket and the tower-jettison rocket fired. The spacecraft did not separate from the booster, however, but remained attached to impact and its destruction in the ocean. Investigation indicated that the trouble lay in excessive deflection of the Marman clamp under airloads that initiated the firing sequence. A need was indicated for a change in the basic spacecraft attachment before any more tests were made, either at Wallops or Cape Canaveral.

The next attempt to qualify the production capsule at high dynamic pressure was made on March 18, 1961, with LJ-5A. By this time, there had been a failure of the first Mercury-Redstone on November 21, 1960, followed by one successful firing on December 19, 1960, and another on January 31, 1961. These successful Redstone flights still did not qualify the escape system under maximum loads. Neither did a successful Mercury-Atlas flight on February 21, 1961, so the Little Joe test was still necessary. Unfortunately, however, this second qualification test of the production spacecraft also failed. In this test, two Castor motors were used instead of two Pollux, for a closer duplication of Mercury-Atlas flight conditions. Again, the capsule escape rocket fired 14 seconds early, without the capsule's separating. Eventually, the capsule did separate, but too late for the planned test. There remained only one more Little Joe booster out of the seven produced by north American. This one was readied for flight test, and on April 28, 1961, a successful test was finally made. (By this time the Little Joe launcher had been moved to Launch Area No. 4, north of the cafeteria.) The test was more severe than planned, because of a delayed ignition of one of the Castor motors. The dynamic pressure at separation of the capsule was 1,920 pounds, about twice the intended value. Thus, the production system was amply qualified. The success was attributed to a change in the circuitry and a redesign of the clamp installation (ref. 41). Although the escape system was never to be needed in the later manned flights, the fact that its ability to pull the spacecraft to safety in an emergency had been demonstrated was well worth the effort.

Another series of rocket-model flights in support of Mercury was planned to measure aerodynamic heating over the base and afterbody at high Mach numbers. A Sergeant five-stage launch vehicle was selected to provide data to a Mach number of 18, the highest value attainable at Wallops at this time. The initial flight test of this vehicle on June 27, 1958, prior to Mercury, has been described in Chapter 15. In this test, a Mach number of 17.8 was reached, but data were limited to Mach 15.1 by a telemeter failure. This test determined aerodynamic heating of a blunt spherical segment, quite similar to that selected for Mercury. The data were of value in the design of the heat shield for the capsule, but by February 1959, similar information on afterbody heating was desired. Even though the heating rate on the afterbody was known to be only a fraction of that on the heat shield, it was necessary to know the rate just as accurately, because the structure was designed with a close margin. Two flights with Sergeant five-stage systems were planned, therefore, in direct support of Mercury. A 0.07-scale model of the capsule was supported from the front of the last stage by a short conical sting. Funds for these vehicles were transferred from STG to Langley. The rocket motors were procured from Thiokol and Grand Central, and the vehicle hardware, exclusive of the test model, was constructed by Aerolab Development Company. The test models were constructed in the Langley shops and were instrumented by IRD. C. B. Rumsey of PARD was the project manager. This was one of several rocket model programs discussed with STG and McDonnell personnel on February 19, 1959 (ref. 42).

The first Sergeant five-stage vehicle with a Mercury capsule attached was flown on January 8, 1960. It is shown in figure 438. The flight plan was the same as that of the vehicle discussed in Chapter 15, with the Sergeant motor providing the velocity to take the upper stages to an altitude of 116,000 feet for a reentry firing after going over the top. A telemeter receiver was placed on a ship stationed about 40 miles downrange. Unfortunately, this firing was a failure because the entire fifth stage broke off from the Recruit stage during burning of the third stage, at a Mach number of only 6.

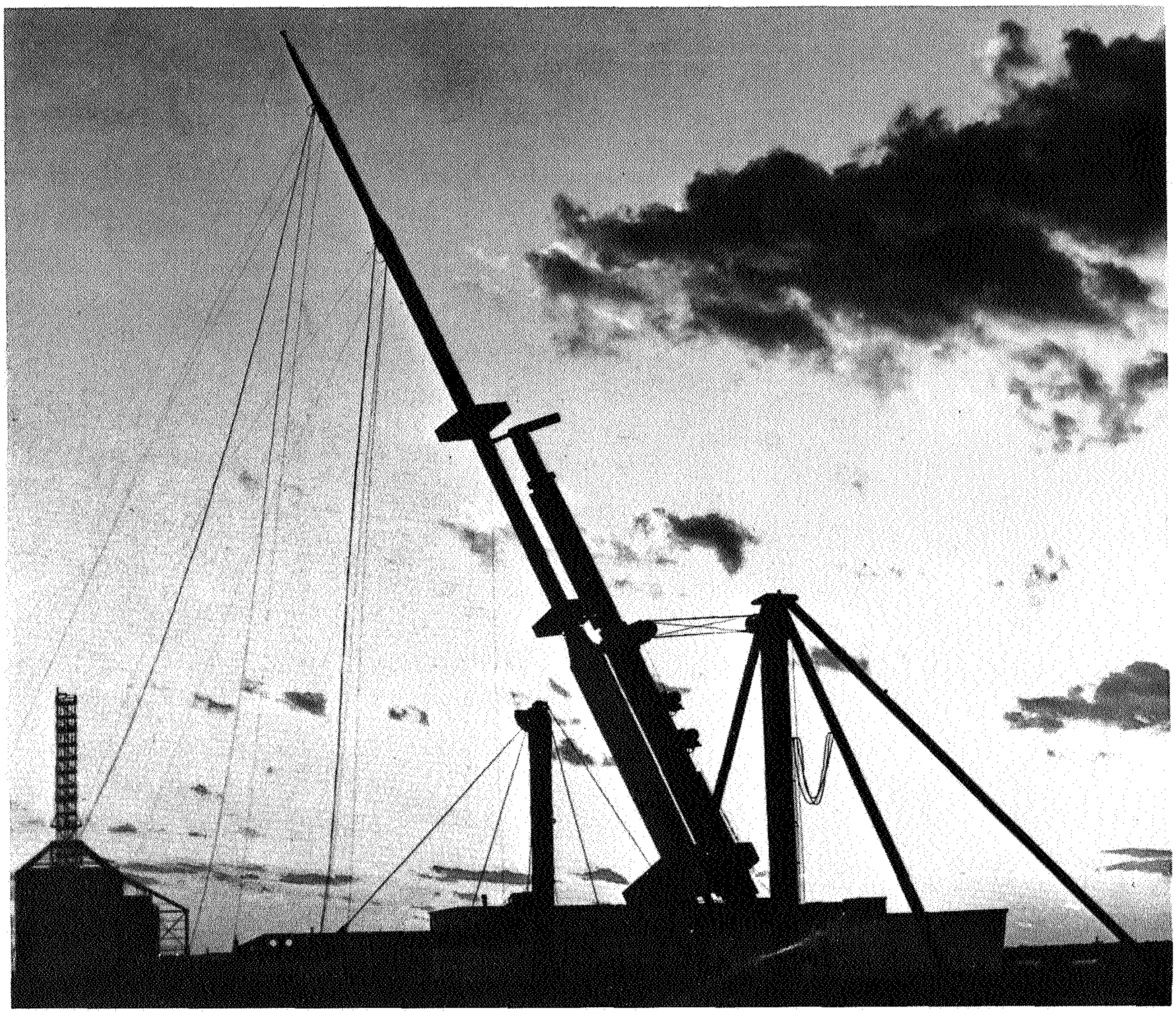


FIGURE 438. Sergeant five-stage vehicle with small model of Mercury capsule on tip for heat-transfer test, January 8, 1960.

The second attempt to obtain heat transfer data at high Mach numbers was somewhat more successful. In this test, on March 24, 1960, the last stage again broke off but not until after fourth-stage ignition at a Mach number of 10. Heating of the thick copper base of the capsule was too small at this time to allow analysis, but extensive data were obtained on heating of the afterbody, constructed of inconel. Analysis of the data indicated a maximum heating rate on the afterbody of about 6 percent of the theoretical heating rate at the stagnation point of the base. The highest heating on the afterbody was on the side of the antenna canister. The flight results were transmitted to STG for use in capsule design (ref. 43).

Rocket model tests were also requested by STG to determine pressure distribution on the afterbody during reentry, to provide data necessary for the design of a baroswitch to trigger parachute deployment. Dynamic stability tests at Mach 10 were also desired. The pressure distribution tests were canceled when the interference problem with the wind-tunnel sting support was solved. The dynamic stability tests, however, were performed. Two 1/7-scale models for this program were constructed by McDonnell for tests with a four-stage Honest John-Nike-Nike-Recruit propulsion system. After the first test, on September 9, 1959, was successful, the second flight test was canceled.

The flight test plan for a dynamic stability test was to adjust the weight and trajectory of the model so that the test simulated the deceleration during reentry between Mach numbers of 10 and 2. An over-the-top trajectory was selected as the best compromise. The model, shown in figure 439 on its booster, was instrumented with five accelerometers and a total pressure tube. The desired Mach number was

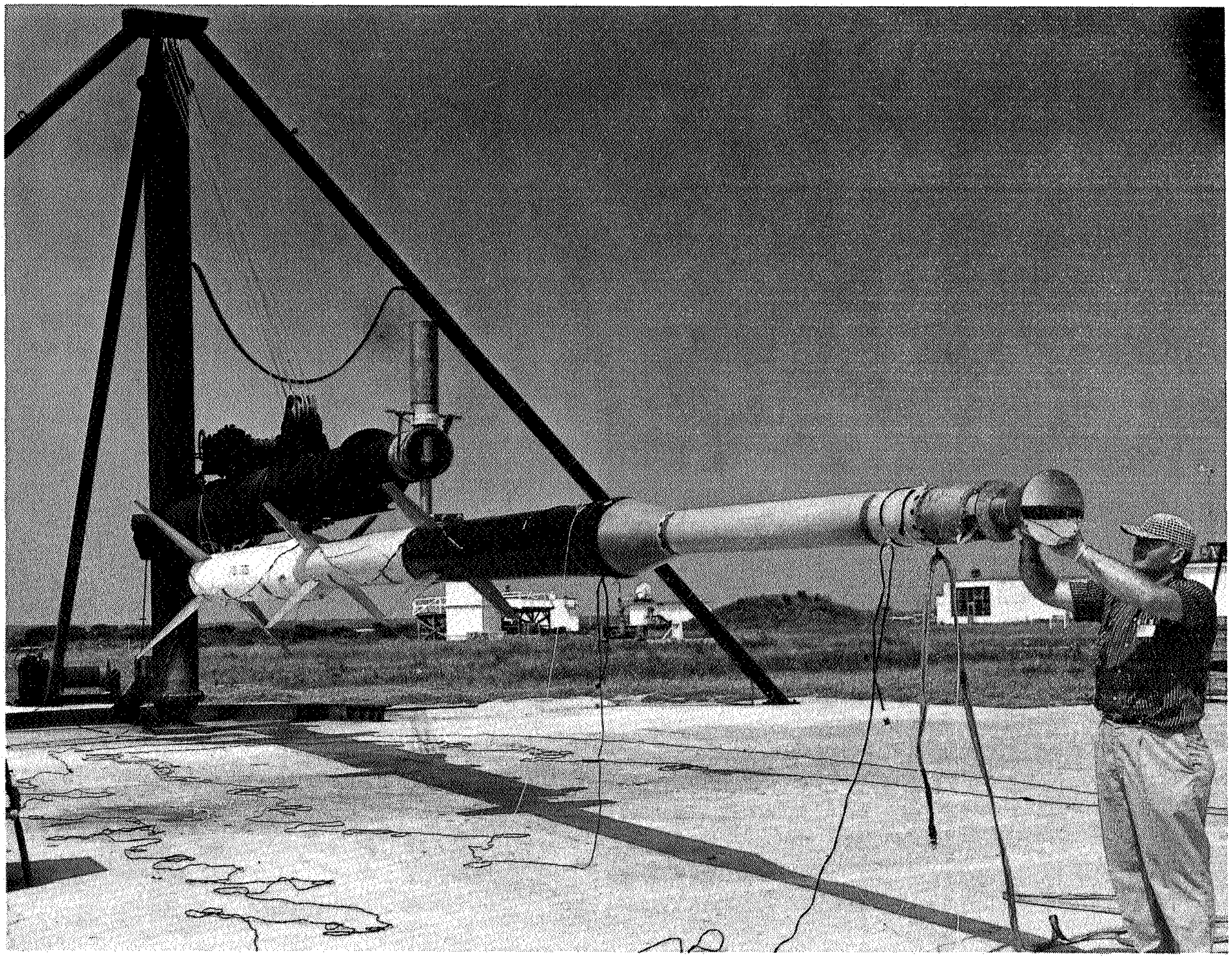


FIGURE 439. Technician checks model of Mercury capsule on Honest John-Nike-Nike-Recruit vehicle in preparation for dynamic stability test, September 9, 1959.

obtained, and dynamic stability data were obtained over the speed range, although the trajectory did not correspond exactly to that of Mercury. The data indicated a continual rolling motion, plus oscillations in pitch. The data were transmitted to STG for use in Mercury design.

The difficulties encountered with the drogue parachute in withstanding the opening loads at high speed and high altitude led STG to examine other landing systems. One system examined was the flexible wing paraglider, invented by F. M. Rogallo of Langley (ref. 44). PARD researchers P. R. Hill and J. H. Judd had also been intrigued by the simplicity of the Rogallo paraglider and initiated a few rocket-model tests of one at Wallops during 1959. Although these tests were not specifically for Mercury and did not use a model of the Mercury spacecraft, they were watched with interest by STG. The rocket-model tests were carried out by Judd with two boost systems. Two tests with each system were made, all successful. The paragliders were prepared by D. R. Croom and his associates of the Langley 7-foot by 10-foot tunnel, and had a rigid keel and rigid leading edges, with a flexible wing surface which could be folded into a tube. The first system used a 3.25-inch rocket motor with the intent of verifying the ejection technique. The folded paraglider and test model, a simple weighted cylinder hung from the paraglider with a bridle, were packaged inside a tube strapped to the rocket case and ejected rearward by a powder charge. In the first test, on October 6, 1959, the glider was ejected at an altitude of 1,500 feet and a speed of about 200 feet per second. It opened as desired and glided back toward the island, landing on the beach. In the second test, on November 25, 1959, a Nike-Cajun booster, as shown in figure 440, was used for a test at high altitudes. The model was ejected from its carrier tube at an altitude of 150,000 feet and a Mach number of 2.0, and although it could not be seen because of the cloud cover, the FPS-16 radar observed the target at the correct time, and it was assumed to have opened.

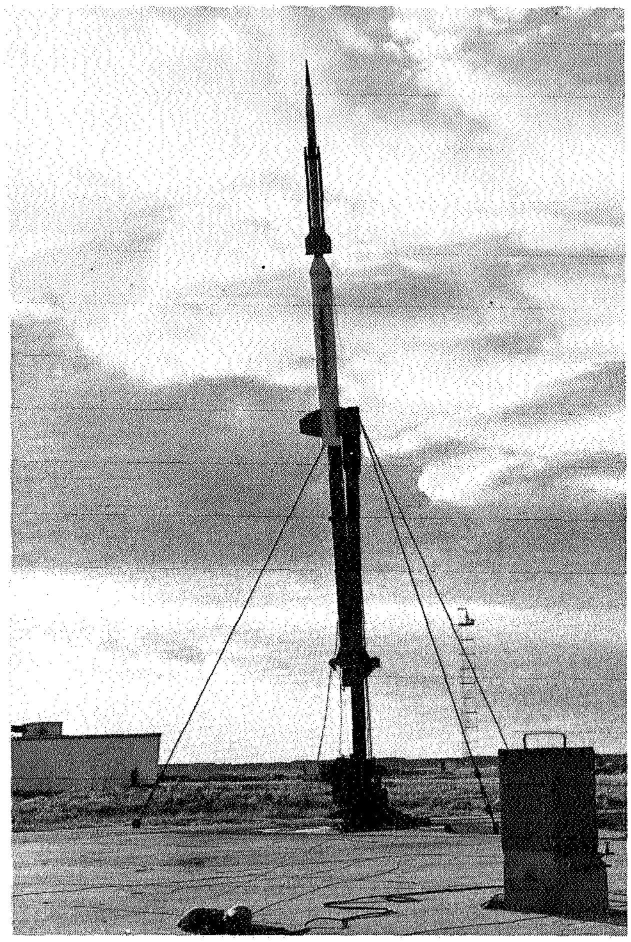


FIGURE 440. Nike-Cajun test vehicle with strapped-on carrier tubes for supersonic test of paraglider at high altitudes, November 25, 1959.

A second test with a Nike-Cajun booster was made on December 7, 1959, in clear weather. This time, the paraglider was ejected at 151,000 feet and the FPS-16 radar followed it to an altitude of 210,000 feet before losing track. In the next and most successful test, the length of the paraglider was increased from 5 feet to 8 feet for a total wing area of 45 square feet. In the test of this larger model, on February 2, 1960, the FPS-16 radar tracked the paraglider for over an hour from an altitude of 200,000 feet down to an altitude of 10,000 feet. These were the first tests to be made at supersonic speeds with a paraglider, and indicated sound operation after ejection from a tube in flight.

The problem of separating a high-drag test model from the front of a booster after burnout of the booster motor received serious attention at PARD. One of two schemes was usually used. The first was to increase the drag of the booster stage either by adding a drag flap to the motor case or by increasing the size of the stabilizing surfaces. The second scheme was to provide a separation rocket in the base of the model. This was the general scheme used in the Mercury project. In some cases, however, it was found that the empty booster stage would overtake the test model and bump it after separation. Another scheme for solving this separation problem was to use a "tow booster," developed by W. S. Blanchard, Jr., of PARD. Blanchard's idea was to tow the test model behind the rocket motor and simply cut it loose when the desired speed was reached. The booster now became a tractor, and its motor nozzles were canted to clear the model in the same fashion as were the nozzles of the escape rockets on the Mercury spacecraft. Blanchard tried such a propulsion system with a simple test body with four fins, and then with a complete airplane configuration; but the application that attracted the most attention was a test on March 10, 1959, of a model of the Mercury capsule towed by two 3.25-inch rocket motors, as shown in figure 441. This photograph of the unique test system appeared on the cover of *Aviation Week*, June 22, 1959. Some consideration was given to using a tow booster to measure pressure distribution on a full-scale capsule in flight to Mach 2.0 (ref. 45). This idea was abandoned, and further consideration was not given to a tow booster test because the system was generally limited to single-stage rocket motors and the maximum speed attainable was limited to the supersonic range.

FIGURE 441. Project engineer W. S. Blanchard, Jr., examines tow-booster for flight test of Mercury capsule model, March 10, 1959.

COOLING AND ABLATION

Chapter 10 has discussed some investigations made in the Wallops Preflight Jet of cooling schemes to combat the aerodynamic heating problems of hypersonic flight. These tests had included ejection of water, helium, or nitrogen from porous surfaces of a sharp cone and a 40-degree wedge wing model, and the ejection of water from the nose of an 80-degree cone. Now some preliminary measurements were made of the effectiveness of ejecting water upstream from a tube extending forward of a flat nose, a hemispherical nose, and an 80-degree conical nose. The measurements were made at the PARD rocket test area at Langley, with small models mounted in the exhaust of a rocket engine (ref. 46). The tests showed that under the 4,000° F condition of the jet, the water vaporized and provided a vapor shield around the test model. This simple scheme, although very effective, was more wasteful of water than the porous systems. Another effective scheme studied in this facility was the slow extrusion of a Teflon rod from the stagnation point of a model. The extrusion rate was adjusted to equal the sublimation rate. Again, the model was bathed in a relatively cool vapor. Additional tests were conducted at Wallops in the Ethylene Jet with helium ejected through a porous leading edge of a slab wing, and with nitrogen ejected through a porous conical surface in flight as well.

The slab wing model had a chord of 6 inches and a constant thickness of 1 inch. In figure 442, it is shown mounted in the Ethylene Jet. The leading edge was made of 1/16-inch-thick porous stainless steel. Helium was ejected through this porous leading edge to determine the effect of the cool gas in blocking heat transfer to the downstream surfaces of the wing. The tests were made at 0-degree, 5-degree, and 15-degree angles of attack. The results of the tests correlated very well when they were expressed in terms of a wall-cooling parameter and a cooling-flow-rate parameter at all angles of attack. A comparison of these results with a previous correlation of data for a completely porous wall indicated a need for more gas flow for the case of indirect cooling from gas ejected only from the leading edge (ref. 47).

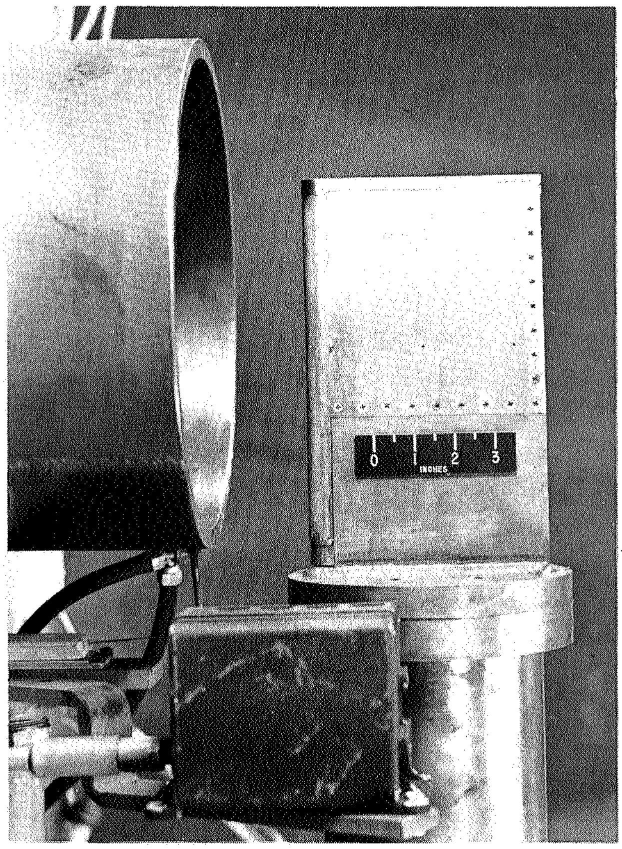


FIGURE 442. Wing model mounted in Ethylene Jet for cooling test, July 1958. In the test, helium was ejected through the porous leading edge.

The flight test of a rocket model with a porous 25-degree cone was made on April 26, 1960. It had been in the planning stage since 1955. Initially, a flight test was planned for the "demand" system of water ejection proposed by Convair for an early version of the Atlas missile nose cone. In this system, the cone was covered with a large number of independent orifices or jets, out of which coolant would be ejected in response to a temperature rise. This system was abandoned after tests in the Ethylene Jet indicated numerous operational problems; and the simpler porous wall model was substituted. The model, as flown, is shown in figure 443. It was propelled by an Honest John-Nike-Gosling boost system with the test model attached to the front end of the Gosling. The extreme tip of the nose was solid, while one half of the remaining cone, approximately 21 inches in length, was covered with 1/8-inch porous stainless steel. The vehicle was launched at an elevation angle of 77 degrees. A coast period of 33 seconds was programmed following burnout of the Honest John stage. At ignition of the second stage, a small explosive charge was energized to start the coolant flow. At burnout of the second stage,

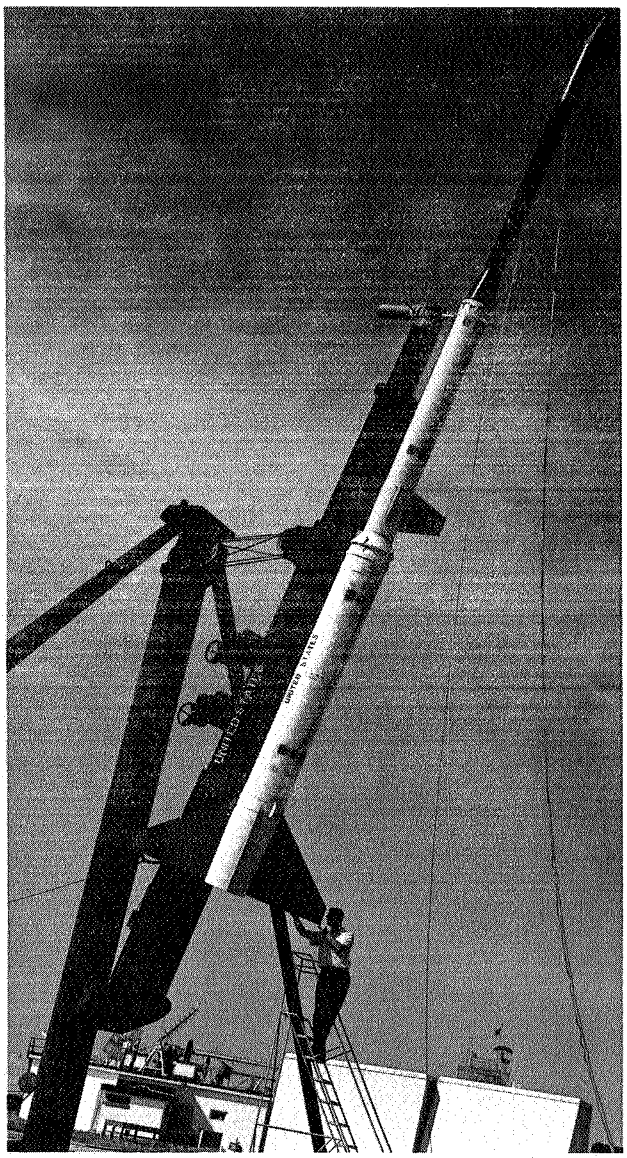


FIGURE 443. Project engineer Bernard Rashis examines fin on Honest John-Nike-Gosling booster in preparation for flight test of a porous 25-degree cone, April 26, 1960. Cone was used to test transpiration cooling.

the third stage was ignited and separated through collapse of a diaphragm connector. The flare-stabilized Gosling stage began to oscillate shortly after ignition and separation, and the telemeter failed shortly after, limiting the data to a maximum Mach number of about 4. Temperature measurements on the solid half of the cone indicated turbulent flow from the 4-inch station rearward. The amount of data obtained with coolant being ejected was much less than planned, because of failure of the third stage, but the data obtained correlated well with supplemental data obtained in tests of a 1/2-scale model in the Ethylene Jet, shown in figure 444 (ref. 48).

The unsuccessful attempt to obtain flight data on ablation for the General Electric ICBM nose cone has been discussed in Chapter 15. The research on the ablative shield for Mercury has been discussed earlier in this chapter. In the flight tests of the GE models, difficulty was encountered in breakup of the last stage of the PARD five-stage vehicle, but there was also a need for a continuous ablation sensor. Attempts continued at IRD to develop a sensor to measure ablation rates in flight. Finally, a sensor was developed which worked quite well in Teflon and provided continuous measurements of ablation (ref. 49). A most successful flight test of the ablative properties of Teflon at hypersonic speeds was made on December 1, 1960, with a five-stage Honest John vehicle, shown in figure 445. A maximum Mach number of 13.1 at an altitude of 78,000 feet was obtained in an over-the-top trajectory. The test model was a cylinder with a spherical segment as the nose. Under conditions of high aerodynamic heating, Teflon sublimes to a vapor, and its action is similar to that of an expelled gas. It was found that the ablation rate as determined in flight agreed well with analytical predictions (ref. 50).

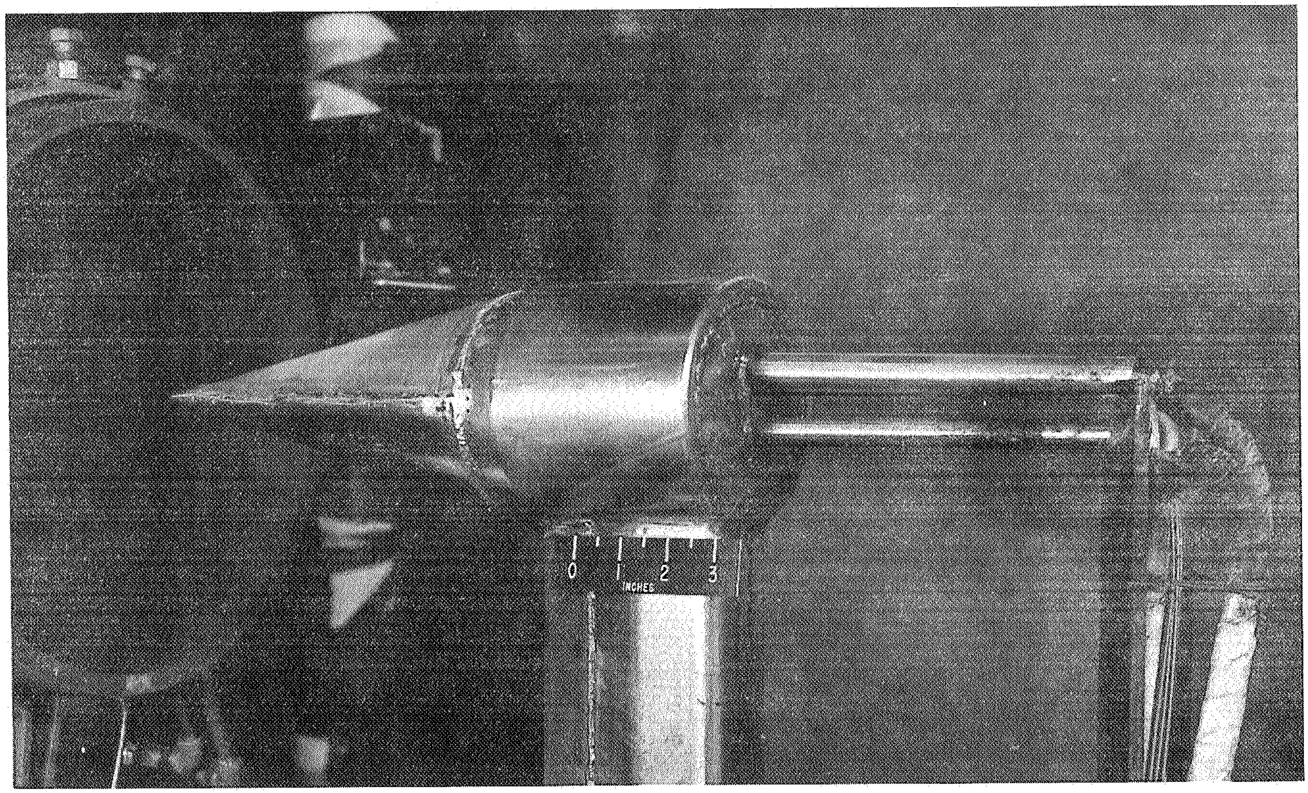


FIGURE 444. Porous 25-degree cone installed in Ethylene Jet for transpiration cooling test, March 19, 1959.

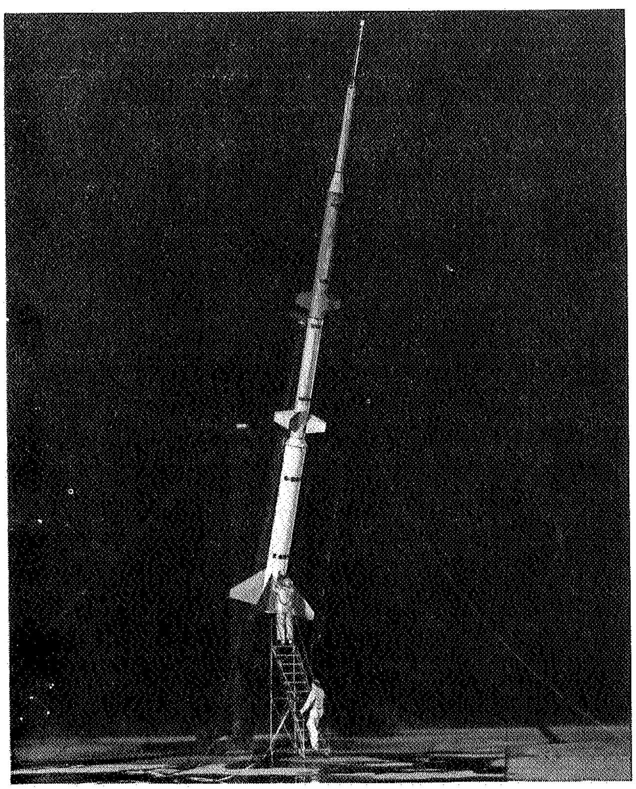


FIGURE 445. Five-stage Honest John vehicle ready for flight test of ablative properties of Teflon at hypersonic speeds, December 1, 1960.

GENERAL ELECTRIC ATLAS ICBM DATA CAPSULE

Wallops was called upon to provide assistance in many development projects because of its unique capabilities and willingness to provide the service with a minimum of red tape. One example of such assistance occurred in connection with development by the General Electric Company of a spherical data capsule for use with the Mark 2 nose cone flight tests at Cape Canaveral. Because of the blackout of communications with such a nose cone during a critical part of reentry, GE dared not rely solely on telemeter transmission of data, for a failure of the heat shield during reentry would prevent playback of any data recorded during the blackout period. GE's solution was to develop a separate data capsule with an onboard tape recorder to store the desired scientific data. The capsule then could be ejected from the nose cone and recovered from the ocean after reentry. The data capsule had a reentry heat shield and flotation capability. It was equipped with a dye marker, sofar bomb, electronic beacons, and stroboscopic lights to be used as location aids after the capsule impacted the ocean. The data capsule was used quite successfully in the Mark 2 nose cone tests (ref. 51).

The first contact the NACA had with GE regarding the spherical capsule was a telephone inquiry by F. T. Brent of the GE Special Defense Projects Department on June 29, 1956. Brent asked W. J. O'Sullivan, Jr., for information on drag coefficients for spheres at high altitude and high Mach number. He also asked about the possibility of making some sphere water-impact tests at Wallops, with the drops to be made from a helicopter (ref. 52).

According to the data capsule design, the heat shield was to break apart at impact, exposing the flotation sphere and the recovery aids. Proper opening of the heat shield at impact required that the sphere descend with a preferred orientation. To achieve this, a sort of drogue chute was made by separating a 6-inch-diameter cap from the top of the sphere and having it trail behind the sphere with a suitable bridle and towline. The length for the bridle and tow line was determined from tests in the Langley Spin Tunnel with a sphere 20 inches in diameter. In the tests at Wallops, both this 20-inch sphere and a sphere embodying the GE 18-inch design were dropped.

The GE 18-inch capsule weighed 108 pounds and contained a thick lining of foamed plastic to provide flotation and absorb the shock of impact. On March 10, 1959, the 20-inch spin-tunnel version was dropped at Wallops from a helicopter at an altitude of 10,000 feet. Although it was tracked by Wallops radar and appeared to perform as it did in the spin tunnel, the sphere was not located after impact. Two GE drops were made on April 7, 1959, from an Aero Commander airplane furnished by GE. In the first drop from an altitude of 10,000 feet, the drag cap did not operate correctly although the sphere was recovered. In the second drop, "everything appeared to function properly except possibly the beacon" (ref. 53). The sphere was recovered by boat.

DROP TESTS OF CONVAIR B–58 EXTERNAL FUEL TANK IN PREFLIGHT JET

Chapter 10 has already given some discussion of assistance provided the Air Force and Convair in development of the B-58 Hustler supersonic bomber by flight tests of rocket models. These tests covered several versions of the airplane, including one in which fuel was carried externally in a large pod hung below the fuselage. This large external fuel tank was used to extend the range of the airplane and was to be dropped from the airplane when empty. The external pod had two components—the fuel tank and a bomb mounted on a pylon attached to the bottom of the fuselage. The pod was recessed in its upper part to allow room for the bomb and its pylon. One area of concern was the motion of the fuel tank as it was released from the airplane. It was desired that the tank leave the airplane without endangering either the airplane or the bomb. The light weight of the empty tank made it particularly vulnerable to aerodynamic forces. At the request of the Air Force, scaled models of the tank were dropped from a 1/40-scale model of the airplane in the 27-inch nozzle of the Preflight Jet at Wallops. The tests were made in three phases in March, June, and September, 1959. The tests in September were the last made in the A jet. In fact, it had already been placed on a standby basis when the tests were requested.

The "heavy-model" technique of scaling the model for these tests was used because, in this method, the aerodynamically produced accelerations were accurately related to gravity acceleration.

In the first series of drop tests, emphasis was placed on controlling a stabilized tank as it left the airplane. Tests were made with three arrangements of tail fins: four-fin, three-fin, and two-fin designs. In the tests, a canard control surface was deflected by differing amounts to force the nose of the tank clear of the airplane at release. Tests were made at Mach numbers from 0.69 to 1.98, at simulated altitudes of 2,500, 26,000 and 36,000 feet. The tests indicated that the tank would clear the airplane safely if the proper control settings were used. A definite nose-down moment was required; yet, if too great a moment were applied, the tail would strike the airplane from the pitch rotation before the gravity fall would have produced the necessary clearance (ref. 54).

Although the canard controls provided safe release of the fuel tank, the fact that a different control setting was required for each flight condition prompted a search for a simpler solution. In September 1959, tests were made of a system in which neither canard controls nor tail fins were used; instead, the tail end of the tank was restrained by a specially hinged tail post. This hinge allowed a pitch-down rotation of -22 degrees before it released the tank and allowed it to drop free. As before, the tank was held at its center of gravity until release was desired. At release, the tank would first pitch downward and then drop away. This system produced a safe release in every case (ref. 55).

AMES HEAT-TRANSFER ROCKET MODEL

Chapter 7 has mentioned that attempts by Ames Research Center to engage in rocket-model testing were rejected by NACA Headquarters. Dryden felt that one rocket test range was sufficient, and passed the word that if Ames personnel had problems requiring rocket models for solution, they should transmit them to PARD. This did not end the attempts by Ames to become directly involved. As time went by and the interest in reentry research for missiles and spacecraft at higher and higher speeds began to dominate the hypersonic aerodynamic research field, Ames personnel again felt the need to engage in rocket-model research as the only way to stay abreast of the needs of the day. In April 1958, S. J. DeFrance, Director of Ames, expressed a desire to use Wallops facilities in a cooperative program with PARD to perform heat-transfer research.[18] DeFrance stated, in part,

> The staff of the Ames Laboratory is anxious to take advantage of the powerful research technique afforded by rocket flight-test facilities at the Wallops Island field station. In this connection we would like to plan, build, and aid in the conduct of experimental projects in research areas wherein we have exhausted the capabilities of our ground-based equipment.

He asked for detailed information about specific rocket launch vehicles and instrumentation used. C. L. Gillis of PARD prepared a comprehensive reply in which, in addition to providing the requested information, he pointed out some of the problems encountered by new groups entering rocket model testing, and the need for close cooperation with Langley personnel to ensure successful launchings at Wallops. Gillis also mentioned that Aerolab Development Company was one of the outside companies familiar with PARD design practices and instrumentation.

Ames decided to give it a try, and selected the Honest John five-stage vehicle. A contract was placed with Aerolab to construct the vehicle hardware from Langley drawings and to design and build the last stage containing the test model. Langley agreed to furnish the rocket motors from stock, and Ames agreed to fund the purchase of motors of equal value. For the initial tests, involving two models, Langley agreed to instrument the model and Ames agreed to assign a couple of men to IRD during the instrumentation period, for assistance as well as for training. The first model to be flown was to obtain heat-transfer data at Mach 15; the second was to study stability of a lifting body at Mach 5. This project was given the PARD designation F131 and, because the subject of the initial research was heat transfer, C. B. Rumsey of the PARD Heat-Transfer Section was assigned as PARD contact for the project. The first model was launched at Wallops on November 25, 1959, with only partial success, because the model apparently broke off from the last stage during fifth-stage burning. The second model was never flown.

18. Letter from S. J. DeFrance to R. R. Gilruth, Apr. 25, 1958, regarding capabilities of PARD rocket flights at Wallops Island.

The first Ames model was designed specifically to provide heat-transfer data on a typical ballistic missile nose cone under reentry conditions with complete turbulent flow. The ground-based facilities at Ames were such that only laminar flow could be obtained. The model is shown in figure 446. The general arrangement of the launch vehicle and the over-the-top trajectory followed PARD practice. The vehicle went over the top at an altitude of 86,000 feet and was then fired rather steeply downward. During the burning of the fifth stage, as the model reached Mach 11 at 58,000 feet, a structural failure was experienced, but the data appeared good to that point.

The test model was mounted on the front end of the T55 fifth stage, which was essentially a 6-inch-diameter cylinder with a flare for stability. The model itself also had a flare at its base. The model had a conical nose with a blunt spherical face and a cylindrical midsection ahead of the base flare. The nose was made of copper and the forward spherical area was roughened rather severely with many indentations made with a center punch to ensure turbulent flow.

The flight test results indicated that the desired turbulent flow was achieved and heat-transfer data over the nose, cylinder, and flare were obtained. Pressures over the model were also measured. The results were compared with predictions from various theories (ref. 56).

SONIC BOOM RESEARCH FLIGHTS

On September 23, 1958, the potential damaging effects of a sonic boom from a supersonic airplane were brought home to the residents of the town of Chincoteague, Virginia, when one of the plate glass windows in the Colonial Store was broken by the overpressure from a McDonnell F-101 airplane flying at Mach 1.22 at an altitude of 25,000 feet. This was the third pass made by the F-101 over the Wallops range on this day in a Langley flight program initiated to obtain scientific data on the sonic boom. In the earlier passes, at an altitude of 35,000 feet, the sonic booms were clearly heard, but the damage from them was insignificant. Although the overpressure generated at ground level during the damaging pass was measured to be much lower than the design pressure for the plate glass window, a real problem was exposed that was to plague development of a supersonic transport airplane for more than a decade.

During flight at supersonic speeds, the shock waves formed may extend to the ground. The passage of these shock waves past an observor results in rapid changes at atmospheric pressure, which are interpreted by the ear as explosive-type sounds, commonly referred to as "sonic booms." This phenomenon was encountered first in high-speed dives of military airplanes and, later, in steady-flight conditions with higher speed airplanes. The phenomenon of shock-wave propagation had been studied theoretically and experimentally by J. W. N. DuMond and his associates as far back as 1946 (ref. 57). The theoretical treatment of the case of small bodies at supersonic speeds had been analyzed by G. B. Witham in 1950 (ref. 58). This work was extended to the case of an airplane in 1957 (ref. 59), but measurements at ground level of pressures generated by airplanes at supersonic speeds had been made only for the case of airplanes in diving flight.

In 1958, a program was initiated by H. H. Hubbard and D. J. Maglieri of the Dynamic Loads Division of Langley, to measure actual ground pressures accompanying sonic booms. Again, Wallops was selected for the tests because of its relative isolation. One measuring station was installed on the island proper, and two on the mainland between Wallops and Chesapeake Bay. The Langley Flight Division handled the flight operations, and Langley pilots were used in all the tests except one for a Convair B-58 flight in 1959.

The program at Wallops was conducted in two phases. In the first phase, between September 23, 1958, and October 9, 1958, six passes were made over the ground stations with a McDonnell F-101 airplane (figure 447) piloted by J. B. Whitten, and a single pass was made with a North American F-100 airplane (figure 448) piloted by J. P. Reeder. The passes were made at Mach numbers between 1.13 and 1.40 and at altitudes between 25,000 and 40,000 feet. In the second phase, between July 23, 1959, and August 6, 1959, two passes were made with a Convair B-58 airplane flown by an Air Force crew (figure 449), and sixteen passes with a Chance Vought F8U-3 airplane (figure 450) with W. C. Alford as the pilot. In this phase, the passes were made at altitudes between 30,000 feet and 60,000 feet and at Mach numbers from 1.2 to 2.0.

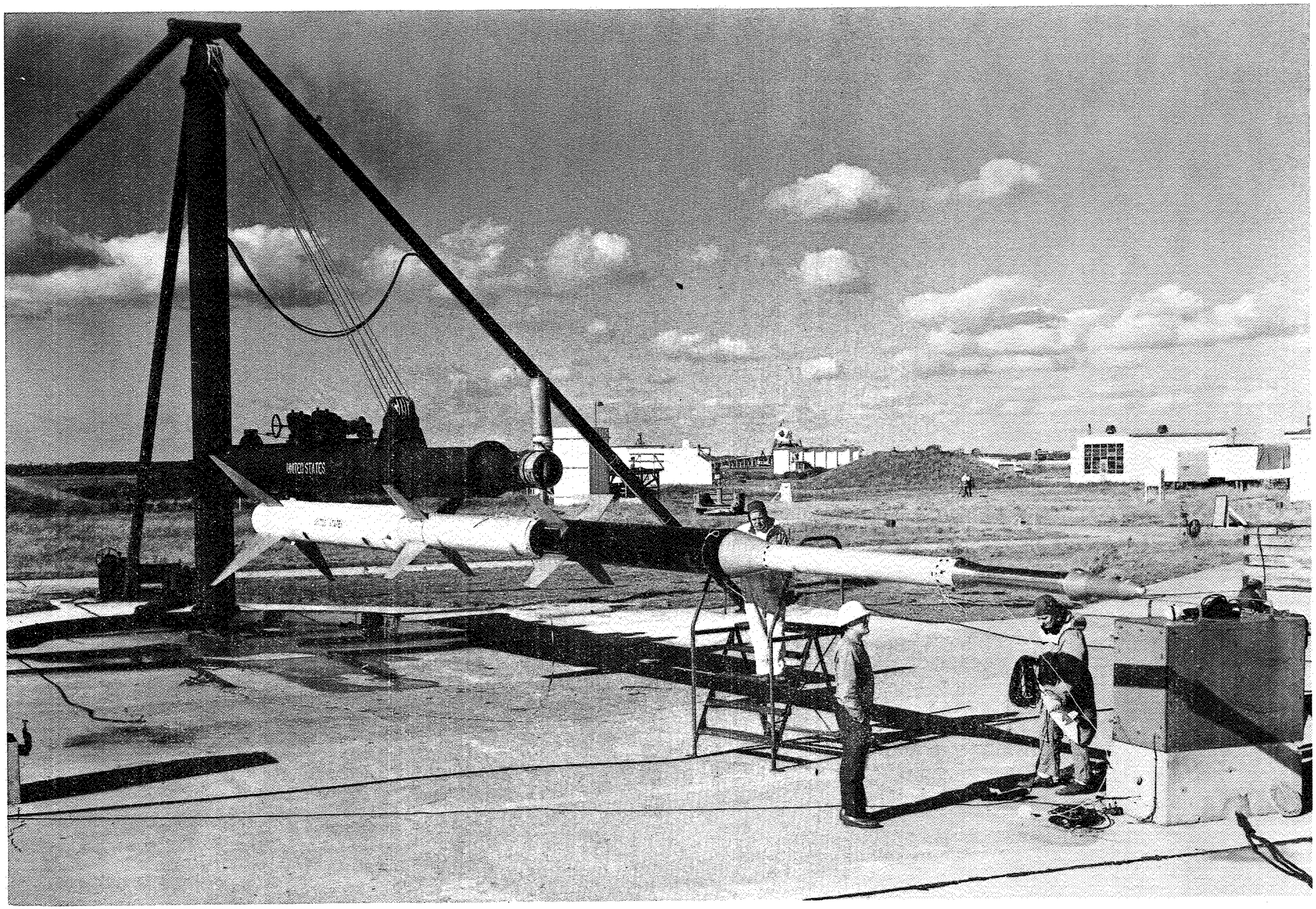


FIGURE 446. Engineer E. H. Helton examines Ames heat-transfer model on Honest John five-stage vehicle prior to elevation for flight test,November 25, 1959.

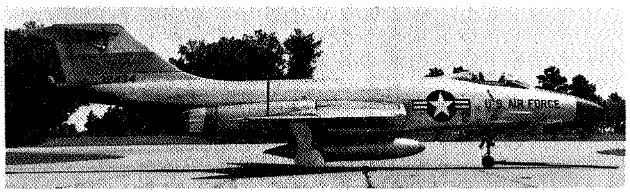


FIGURE 447. McDonnell F–101 airplane used in sonic boom investigation at Wallops, September–October 1958.

FIGURE 448. North American F–100 airplane used in sonic boom investigation at Wallops, October 7, 1958.

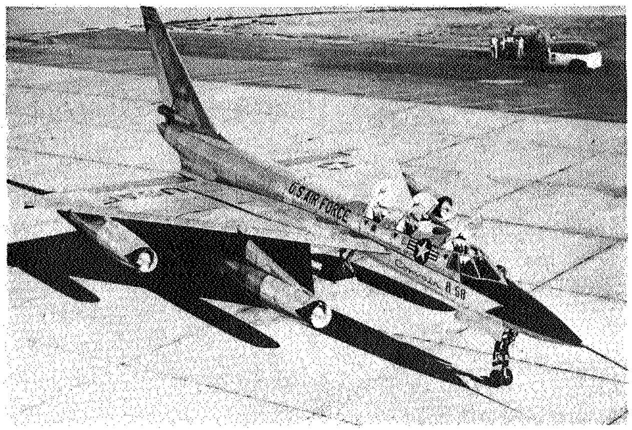


FIGURE 449. Convair B–58 airplane used in sonic boom investigation at Wallops, August 6, 1959.

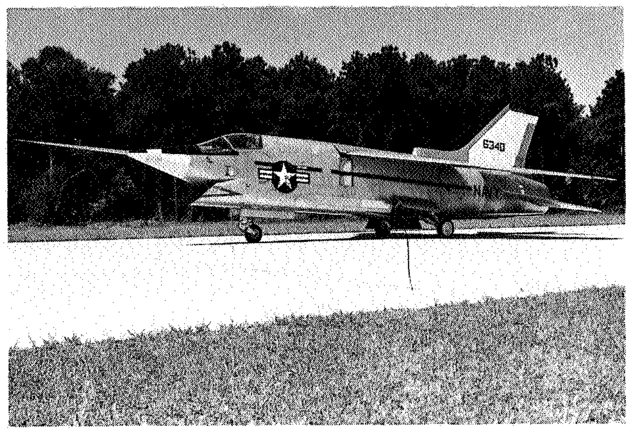


FIGURE 450. Chance Vought F8U–3 airplane used in sonic boom investigation at Wallops, June–August 1959.

Although the phenomenon is referred to as a sonic boom, the Mach number of an airplane at altitude must be greater than sonic for its effect to reach the ground. This situation holds true because of effects of the atmosphere. The fact that the velocity of sound is higher at sea level than at altitude causes a bending of the propagation path of the bow wave from the airplane. Wind velocity has the same effect; and in one flight at Mach 1.15 at 45,000 feet, no sonic boom was noted at the ground. A method of calculating the rise in pressure was developed which considered the size and shape of the airplane, the speed and altitude, and atmospheric conditions (ref. 60). Good agreement was obtained between measured and calculated values for locations near the flight track. The pressures were somewhat lower than calculated at locations remote from the track, because of diffraction effects. High tailwinds at altitude had a similar effect. The noise accompanying pressures above 1.0 pound per square foot was considered objectionable to ground observers, who likened the noise to close thunder.

During the third pass of the F-101 airplane at 25,000 feet (the pass that broke the plate glass window in the Colonial Store in the town of Chincoteague, Virginia) the Mach number was 1.22 and the measured overpressure was 1.75 pounds per square foot. The window was 90 inches by 128 inches and was made of 1/4-inch plate glass. The fact that similar windows adjoining this one did not break indicated a marginal condition (ref. 61). The manager of the Colonial Store called J. E. Robbins at Wallops on September 23, 1958, shortly after the window broke. After verifying that the time of breakage coincided with the time of the airplane pass over Chincoteague, Robbins assisted the manager in filing a claim for damages. NASA paid for replacement of the window the following June (ref. 62).

The interest in sonic booms was intensified with the proposal to build a supersonic transport to operate at Mach 3. It was possible to calculate a flight pattern from takeoff to landing, for which the overpressure at the ground would not exceed 1.5 pounds per square foot. Such a pattern involved a variable Mach number during the climb and descent phases. In order to obtain experimental data closer to the conditions than the data just discussed, the second series of flight tests at Wallops was made between June and August, 1959. These tests were made with the F8U-3 airplane at altitudes up to 60,000 feet and a Mach number of 2.0. In addition, to obtain data on the effect of airplane size, two passes were made with the B-58 airplane. In order to prevent further disturbance to the local communities, these passes were made over the ocean, parallel to the coast near Wallops. Instruments were placed both at Wallops and on two Navy ships stationed some 10 miles away.

The results of the second series of tests confirmed the earlier findings that the ground pressures could be calculated with good accuracy. In addition, the results showed that, during a climb maneuver, a higher Mach number at a given altitude could be tolerated for a given value of ground overpressure (ref. 63). Although these findings were encouraging to the proponents of supersonic transports, public opposition to flights of such airplanes over inhabited areas was still to be in evidence 10 years later.

TRAILBLAZER I REENTRY PHYSICS PROJECT: D58

The Trailblazer I reentry physics project originated from a need in the nation's antimissile program for a better understanding of the radar signature of a nose cone reentering the atmosphere at ICBM or greater speeds. In particular, knowledge of the radar enhancement of the target due to ionization of the flow around such a reentry body was needed for its accurate detection and discrimination. As a member of the Air Force Scientific Advisory Committee, R. R. Gilruth, Assistant Director at Langley, became aware of the importance of the problem. At a staff meeting at PARD in January 1958, he mentioned the need for a simple rocket vehicle that could duplicate ICBM reentry speeds at a range close enough to Wallops to allow a study of the reentry phenomena. A few days later, W. N. Gardner proposed a unique six-stage vehicle, which was to become Trailblazer I. The proposal was unique in that the upper three stages of the vehicle were mounted upside down in a "velocity package" and were programmed to be fired back toward the launching site at Wallops after being propelled above the atmosphere by the first three stages. The final stage, which could reenter at speeds between 19,000 and 26,000 feet per second, was a special spherical rocket motor 5 inches in diameter. This project was given the designation D58 by PARD and initially had the code name of "Meteor."

The Advanced Research Projects Agency (ARPA), created by the Department of Defense on February 7, 1958, was given responsibility for all DOD antimissile and space satellite activity. The detection of ICBM nose cones was a vital part of the antimissile assignment. Development of suitable radars for detecting the nose cones was assigned to the Lincoln Laboratory of MIT under an Air Force contract. On April 1, 1958, representatives of Lincoln Laboratory visited Langley, upon invitation, to learn about the proposed new reentry research vehicle. They were enthusiastic about the possibility of having a target available at reentry speeds. Their long-range radar at Millstone Hill near Boston, Massachusetts, was already making use of various inflatable spheres and "targets of opportunity" launched from Wallops, and, to take advantage of the new reentry targets, they proposed to locate a long-range S-band radar on the mainland across the marsh from Wallops Island (ref. 64). After the visitors returned home, Carl F. J. Overhage, Director of Lincoln, suggested to H. L. Dryden, Director of the NACA, "the establishment of a collaborative program between Langley and Lincoln Laboratory on reentry experiments at Wallops Island."[19] J. W. Crowley replied for Dryden on June 13, 1958, that the NACA would be pleased to cooperate with Lincoln Laboratory in "the study of radar returns from objects entering the atmosphere at ballistic missile speeds."

In September, after the Trailblazer I vehicle had been designed and construction of the first test unit was well along at Langley, Gardner and D. G. Stone requested that NACA Headquarters solicit the aid of ARPA in procurement of 12 flight vehicles as an extension of the program initiated at Langley. This was done because ARPA would be the main beneficiary of this anti-ballistic-missile endeavor (ref. 65). A sketch showing the complete vehicle, the velocity package, and the trajectory was provided for the information of ARPA, as shown in figure 451. This request was not sent to NACA Headquarters until October 10, 1958, however, because the NACA was changing to NASA and there was some question about the position of the new agency with regard to ARPA. The situation was straightened out by Overhage, who wrote T. K. Glennan, NASA Administrator, that the Lincoln Laboratory contract with ARPA included procurement of necessary flight vehicles, and he would be glad to purchase the 12 vehicles requested by Gardner. The estimated cost was about $60,000 each.[20] Crowley accepted the offer for Glennan on November 4, 1958.

19. Letter from Carl F. J. Overhage to H. L. Dryden, June 6, 1958, regarding a joint reentry program at Wallops Island.
20. Letter from Carl F. J. Overhage to T. K. Glennan, Oct. 21, 1958, regarding procurement of 12 reentry vehicles for the D58 type.

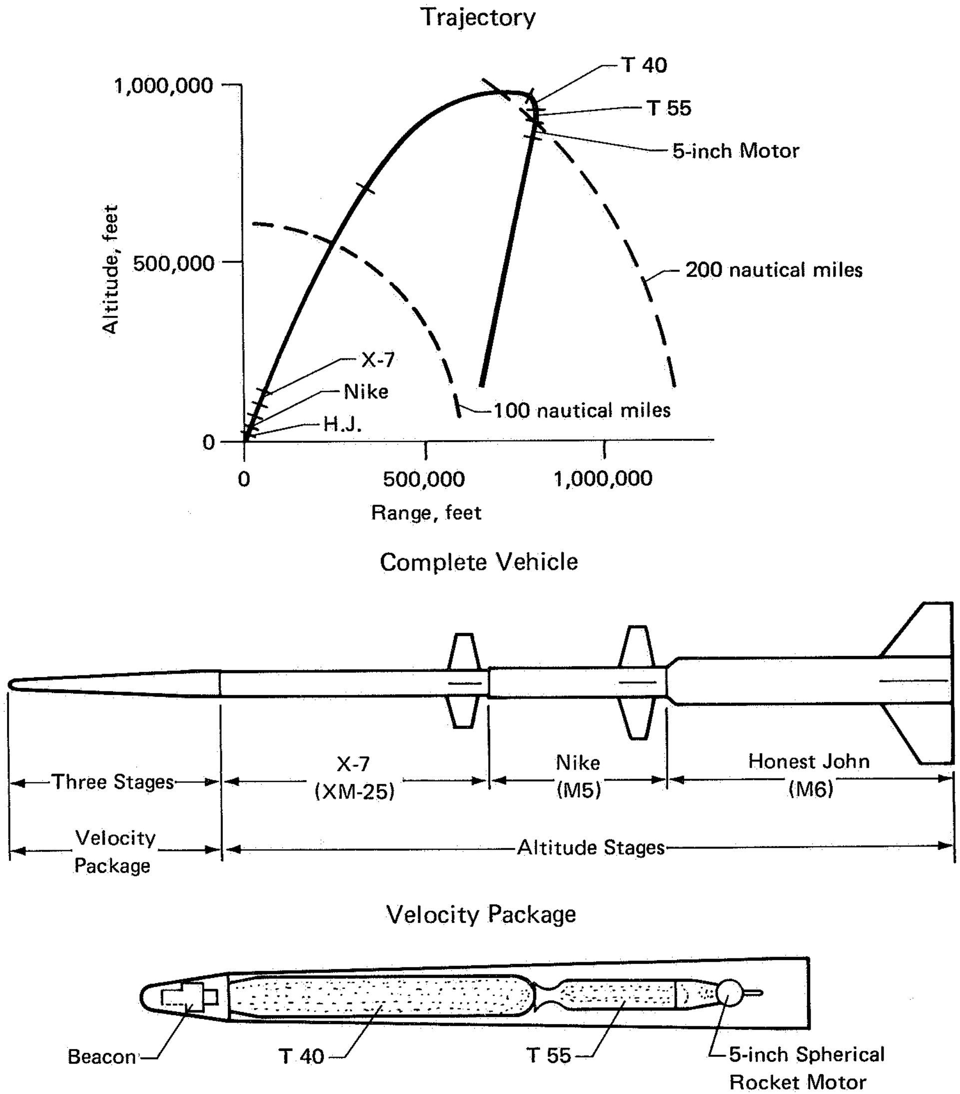


FIGURE 451. Sketches showing the trajectory, stages, and velocity package of the Trailblazer I vehicle.

During a visit of Lincoln Laboratory and ARPA representatives to Langley on November 12, 1958, plans were finalized for procurement of the 12 D58 vehicles. The plan was for Lincoln Laboratory to place the contracts and for Langley to be the technical manager.

From the first contact with Lincoln, Gardner learned of interest in a reentry body much larger than the 5-inch sphere planned for Trailblazer I. During January 1959, Gardner analyzed a similar but larger vehicle which could return a 15-inch-diameter sphere at ICBM speeds. This was to be developed later and designated Trailblazer II. In February 1959, after hearing about this advanced version, Lincoln decided to procure the first vehicles in two lots of six each to allow a change of plans whenever the advanced version became available. At this same time, Lincoln proposed to transfer $600,000 to Langley and let Langley handle all procurement.[21] This offer was rejected by Langley, and the original plan was insisted upon, with Gardner serving as Project Engineer and having authority to approve all specifications and contracts.[22] Gardner was assisted at Langley by C. A. Brown, Jr., and R. R. Lundstrom of PARD as vehicle coordinators, by I. W. Ramsey in engineering design, and by R. M. Dickerson in optical instruments.

21. Letter from Lincoln Laboratory to Langley, Feb. 18, 1959, regarding financing of D58 models.
22. Letter from H. J. E. Reid to H. W. Fitzpatrick, Lincoln Laboratory, Apr. 10, 1959, regarding procurement of D58 vehicles.

Aerolab Development Company was awarded the contract to construct all hardware for the first six D58 vehicles funded by Lincoln. The rocket motors were procured through the appropriate military agencies. The six rocket motors used in the D58 vehicle were, in order of stages, Honest John, Nike, Lance, T40, T55, and 5-inch sphere. Langley agreed to supply the 5-inch motors and the T40 motors since these were special, and difficult to obtain. Lincoln supplied nine additional T55 motors to reimburse Langley for the T40 and 5-inch motors used in the six vehicles. While these vehicles were being procured, Langley constructed three vehicles. Later, six additional vehicles were procured by Lincoln. These 15 Trailblazer I vehicles were all flown from Wallops in a continuing program covering a 4-year period. The first firing was on March 3, 1959, and the last, on February 16, 1963.

The second Trailblazer flown is shown in figure 452. The first three stages (Honest John-Nike-Lance) were fin-stabilized, while the upper three stages were contained within a shell to form the "velocity package." As was mentioned earlier, these motors were upside down in the package. (See figure 451.) The T40 motor, which was the fourth stage to be fired, was actually located at the top of the vehicle. The fifth-stage T55 motor was just below it, and the 5-inch sphere was at the bottom of the package. Spin was imparted to the vehicle by giving the fins a small angle of incidence. Sufficient spin was given the velocity package to ensure that after separating from the third stage it would retain its attitude as it went over the top of its trajectory at an altitude of 200 miles. The three rockets inside the package were then to be fired in quick succession out of the bottom of the package and back toward Wallops. The vehicle was to be launched along a rather southerly course so that the reentry event could be tracked from special stations along the coast south of Wallops.

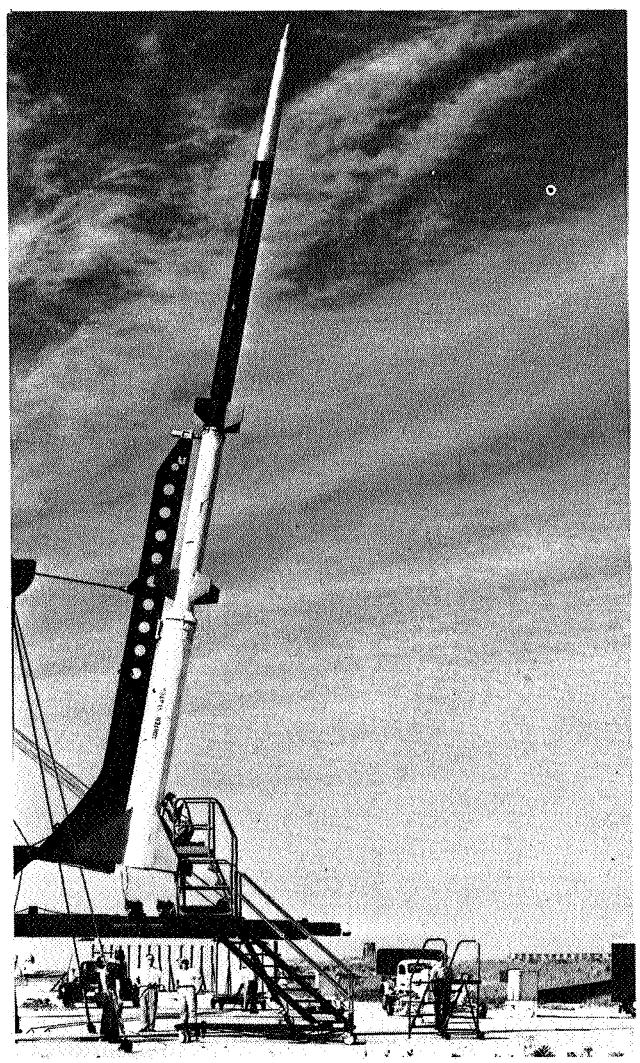


FIGURE 452. Engineers W. N. Gardner and C. A. Brown, Jr., check operations as Trailblazer Ib is readied for flight, June 4, 1959.

At launch, small rocket motors, strapped to the first stage, imparted a spin rate of one revolution per second to minimize dispersion. This spin rate was maintained by giving the fins on the first stage an angle of incidence of about 0.5 degree. At burnout of the first stage, it separated from the vehicle by the operation of drag forces. The second stage was ignited a short time later and, after burnout, remained attached to the vehicle for a coast period of about 20 seconds. The third stage was fired away from the second stage by the rupturing of a thin blowout diaphragm connecting the two stages. The fins on the third-stage motor were canted sufficiently to impart a spin rate of about 10 revolutions per second to ensure attitude stability of the velocity package. While the second stage was attached, no appreciable spin was imparted to the vehicle by the cant of the third-stage fins, because the induced loads on the fins of the second stage (downwash) nullified the effect. The burned-out third stage remained attached to the velocity package until an altitude of about 400,000 feet was reached, whereupon a powder charge was used to rupture the connecting diaphragm and force the two components apart at a rate of 10 feet per second.[23] By the time the velocity package was ready for firing, the empty third stage was out of the way. A maximum altitude of about 165 miles was reached approximately 100 miles downrange. About 20 seconds later, the three rocket motors were fired out of the velocity package in quick succession. The empty third stage continued on a normal ballistic trajectory to impact about 230 miles downrange. Because of the attitude of the velocity package (approximately 70 degrees), the three internal stages, after firing, followed different trajectories, with the final stage traveling back toward Wallops on a trajectory about 11 degrees back from vertical, to a calculated impact point about 100 miles downrange.

In selecting the spin rate of the different stages, it was important to avoid resonance either with any structural frequency or with natural pitch frequency. It was found that if the spin rate crossed the natural pitch rate rapidly, resonance problems were avoided.

The fourth-stage T40 motor was locked inside the shell of the velocity package with a thin blowout diaphragm and was supported along its sides by guide rails which it rode as it was fired out of the package. Small vent holes had been made in the outer shell to minimize pressure buildup inside the shell after ignition. Regarding the fifth and sixth stages, each likewise was attached to the connected stage with a blowout diaphragm. Because of the geometry of the sixth stage, a spin rate of 30 revolutions per second was required for stability. This was achieved by replacing the regular T40 nozzle with seven small canted nozzles arranged in a circle around a small central nozzle. The velocity package and its components were dynamically balanced at Wallops in a vertical balancing machine, as shown in figure 453.

The Trailblazer I vehicle was about 56 feet long and weighed approximately 7,600 pounds at launch. The velocity package was about 10.5 feet long and weighed 270 pounds.

All three of the stages fired downward out of the velocity package gained additional velocity from gravity acceleration until drag forces exceeded the weight. Typically, the speed of the T40 stage increased from 5,600 feet per second at burnout to a maximum of 8,500 feet per second. The T55 stage increased from 10,700 to 12,300, and the 5-inch last stage, from 16,900 to 18,700 feet per second. During reentry, only the last two stages were heated aerodynamically enough to be visible, with the 5-inch stage, of course, being the brightest. The maximum velocity obtained depended upon the weight added to the last-stage motor. The minimum weight at reentry was that with only the empty case, about 0.5 pound. In each one of the first two tests, a radio beacon in the form of a spike weighing 0.3 pound was added on the front of the motor, as a tracking aid. The motor and beacon are shown in figure 454. For the remainder of the tests, the beacon was added around the nozzle as a torus weighing 0.9 pound (see figure 455). The reentry velocity of the last stage varied from 19,000 to 26,000 feet per second, depending upon the reentry weight.

The D58 vehicles were all launched at an elevation of approximately 80 degrees and on an azimuth of about 150 degrees. As shown in figure 456, the ground track of the trajectory was almost parallel to the coast. Optical tracking stations were located at several places along the coast, as shown. In addition to Wallops Island, stations were located near Eastville, Sandbridge, and Langley Field, Virginia, and at Edenton, Cape Hatteras, and Coquina Beach, North Carolina. A typical arrangement of cameras for

23. Initially this separation altitude was about 650,000 feet. Then it was reduced to 125,000 feet, before the decision was made regarding the final separation altitude to be used.

FIGURE 453. Technicians W. R. Holloway, Jr., and J. L. Miller install velocity package of Trailblazer I vehicle in dynamic balancing machine at Wallops, January 10, 1961.

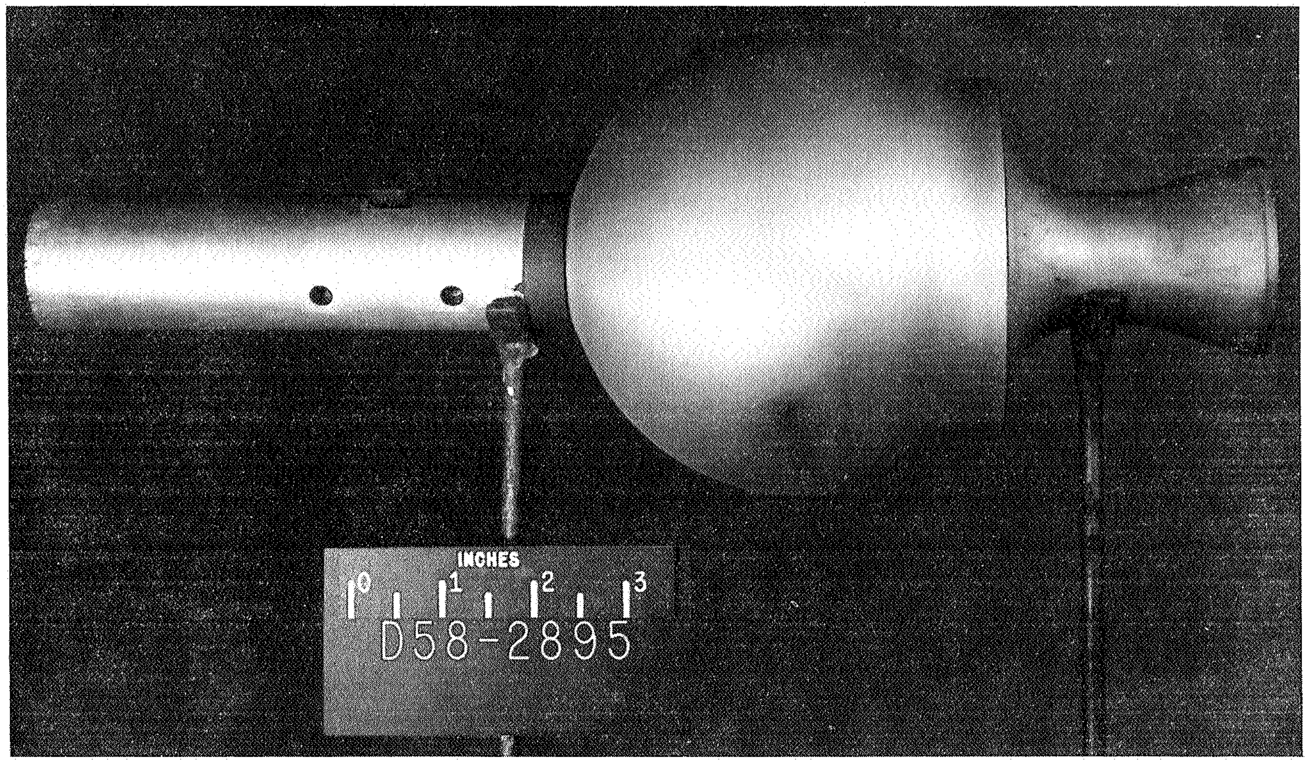


FIGURE 454. Spherical 5-inch rocket motor with spike radio beacon as used in first Trailblazer I vehicle, March 3, 1959.

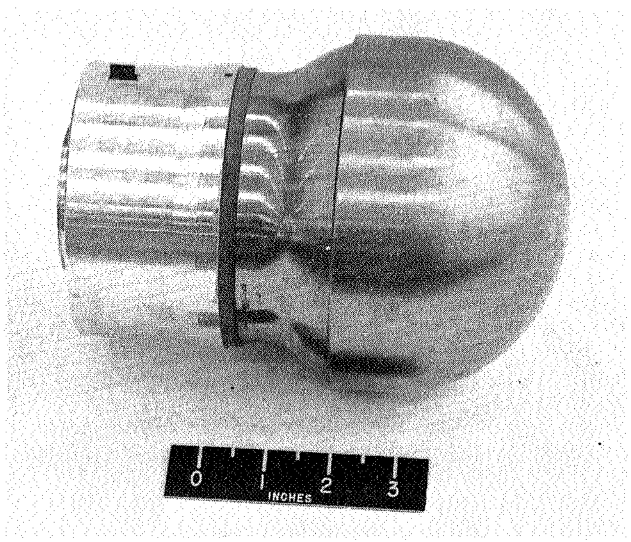


FIGURE 455. Spherical 5-inch rocket motor with radio beacon mounted as a torus around the nozzle. View shows motor as used in Trailblazer I vehicles.

photographing a reentry is shown in figure 457. In addition, some observations were made from aircraft in the area. All launchings were made on clear, moonless nights, and the reentry streaks of the last stage were recorded on film in fixed cameras against a background of stars. Wallops, Eastville, Sandbridge, and Coquina Beach were the principal locations used because they were on the ocean in rather isolated areas having a minimum of unnatural light in the sky to interfere with optical observations. Some of the cameras had rotating shutters to chop the reentry streak, to aid in velocity determination. One of the reentry photographs is shown in figure 458. In some tests, a spectrograph also was used. The background of stars was useful in defining the reentry path. The radio beacon on the last stage allowed trajectory determination by tracking from four ground stations, using a Doppler method (ref. 66). An S-band radar beacon was in the nose of the velocity package as a tracking aid. A four-channel telemeter in the third stage provided information on accelerations and events during the early part of the flight.

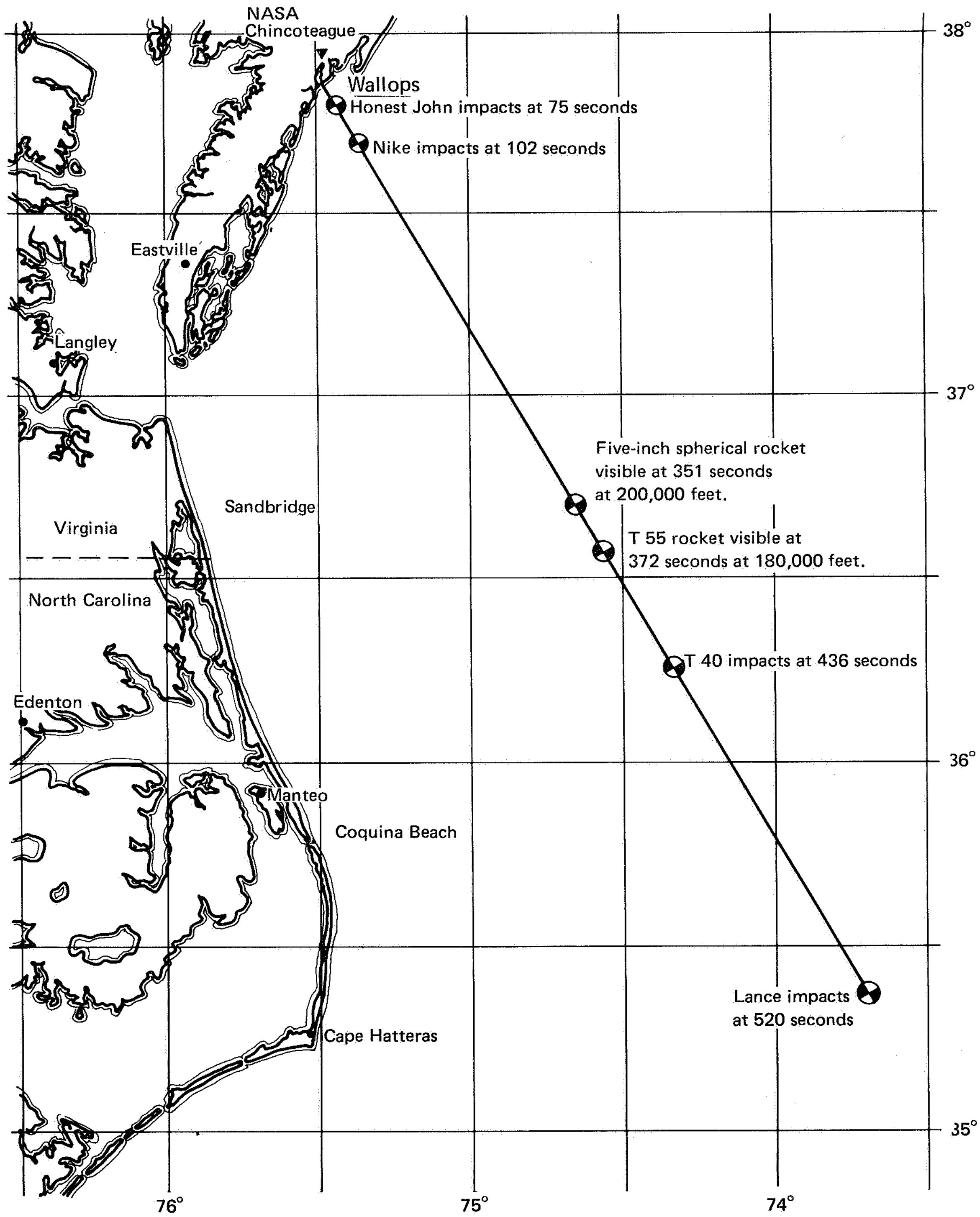


FIGURE 456. Map showing ground track of typical Trailblazer I trajectory parallel to coast of Virginia and North Carolina.

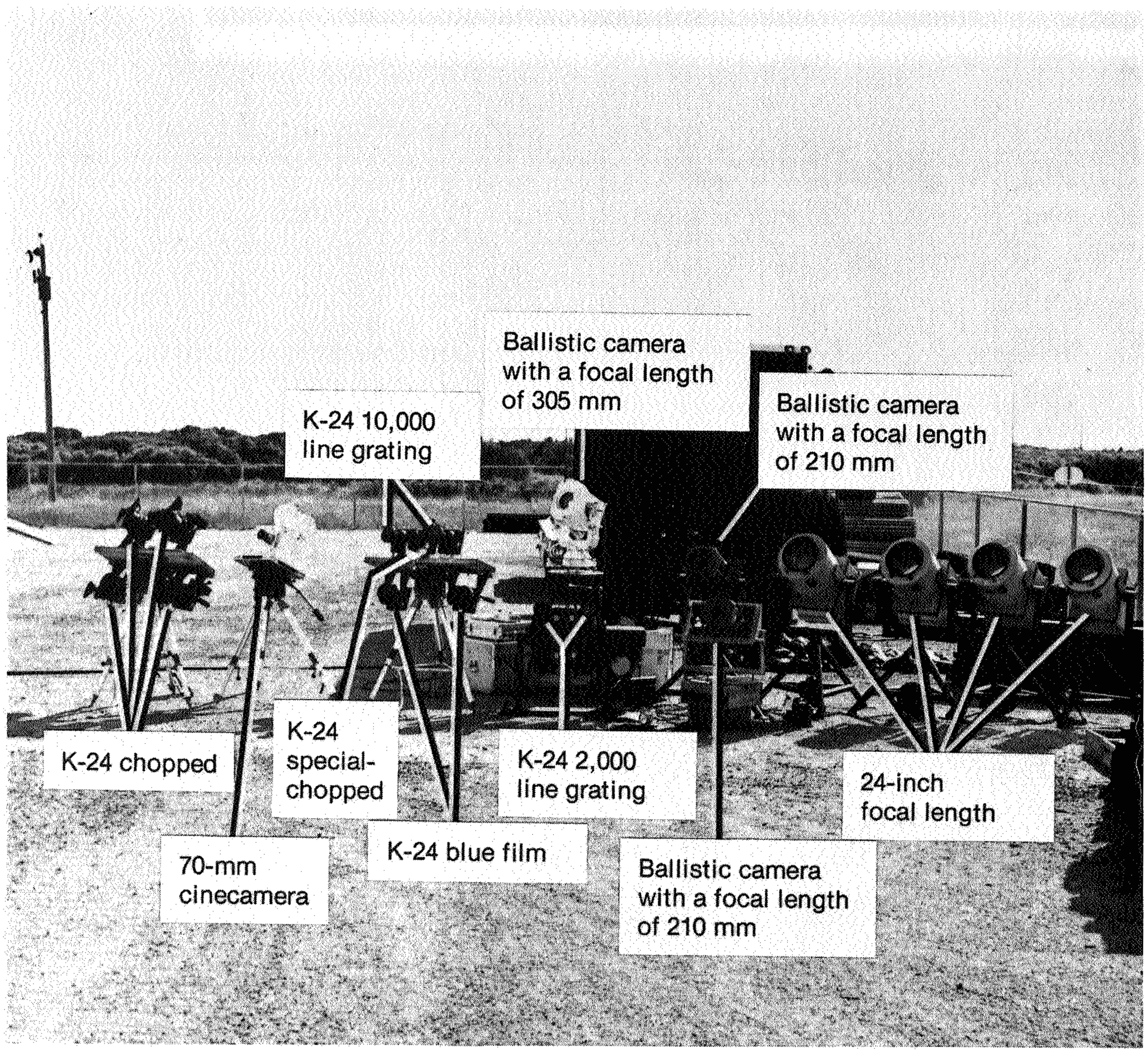


FIGURE 457. Equipment arranged for photographing reentry of Trailblazer I components at hypersonic speeds.

Although the Wallops radars tracked the Trailblazer stages as far as possible, and the Millstone Hill radar attempted to obtain data, the most useful radar data were obtained from two large radars located on the mainland across the marsh from Wallops Island. These are shown in figure 459. They were installed and operated by Lincoln Laboratory. Both had 60-foot radar dishes. One was an S-band tracker, while the other was a dual UHF and X-band radar. Lincoln Laboratory performed the analysis of data from these radars and from the one at Millstone Hill. The MIT radars at Wallops were not in place until late in 1959 and did not participate in the early firings.

The main variable in the flight tests was the material on the front of the sixth stage exposed to reentry conditions. The basic material was aluminum for the rocket motor case and, in two tests, phenolic nylon and copper were placed over the front of the case as a cap. In other tests, the material of the case was changed to either steel or titanium. There was a very significant enhancement of the radar target during reentry of the copper-covered motor case (refs. 67, 68, and 69).

In the first flight test of the Trailblazer I vehicle, on March 3, 1959, all parts of the system performed as planned except the sixth-stage motor. It was concluded later than the motor exploded at ignition. The reentry of the fifth stage was observed as a reddish-orange streak in the sky. The motor problem was corrected in additional ground firings at Langley and the second flight test, at 11:15 p.m.,

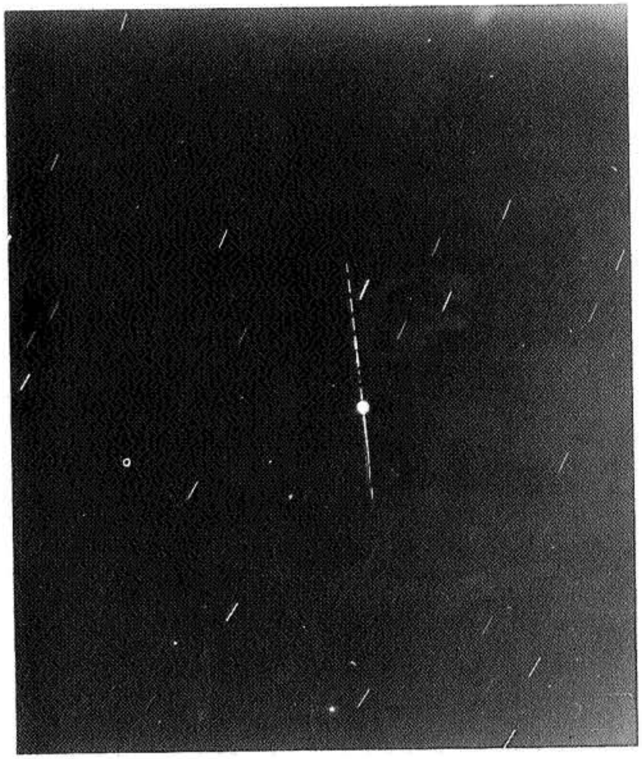


FIGURE 458. Reentry of Trailblazer I with titanium motor case, as seen from Coquina Beach, North Carolina, August 28, 1960.

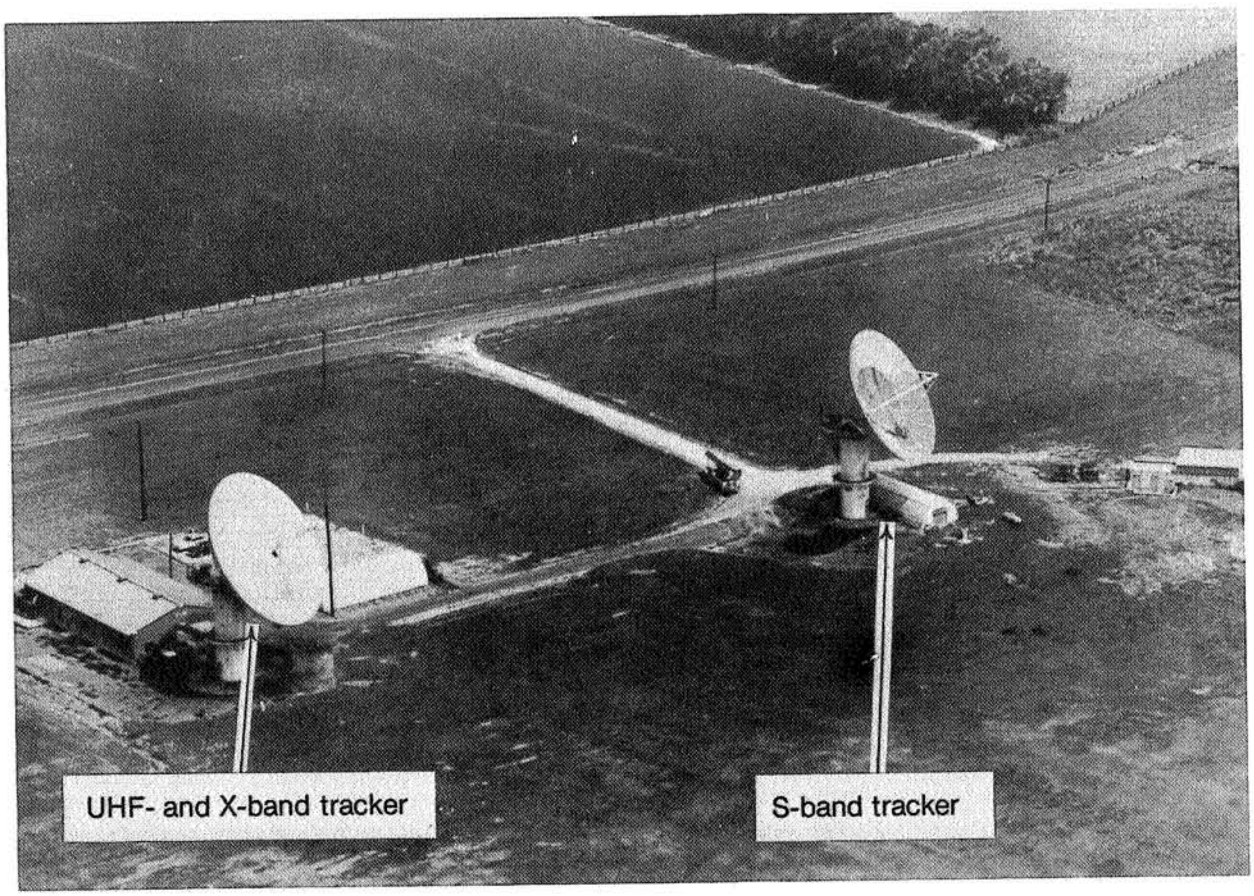


FIGURE 459. MIT Lincoln Laboratory radars on mainland near Wallops Island.

on June 4, 1959, was successful. The reentry was tracked optically from Wallops and Coquina Beach, and by a Lockheed F-80 airplane at an altitude of 30,000 feet. Velocity was determined by triangulation from four ground stations at Wallops, Langley, Cape Hatteras, and Edenton. The maximum reentry velocity was about 25,000 feet per second, and apparently the entire stage burned up during reentry. The Millstone Hill radar also tracked through reentry. Both the fifth and sixth stages produced a flash at reentry (ref. 70). The pilot of the airplane, D. L. Mallick of Langley, observed (ref. 71):

> The first object appeared first as a faint light which as it traveled downward gained in intensity until it was many times brighter than the brightest star. Its color was distinctly blue-green. While gaining in intensity, the object left a clear trail. It terminated in a larger and brighter flash and few if any visible objects continued on downward.

Barnes Engineering Company volunteered to participate in the D58 program by installing some of their instrumentation at Wallops for recording reentry trails. These items were to be a standard Barnes R-4K1 radiometer, two special ballistic cameras, and a 35-mm spectrometer with high-speed infrared film.[24]

In September 1959, plans were made to add flares to the second stage as a visual tracking aid. When R. M. Dickerson and C. A. Brown, Jr., visited the Army's Picatinny Arsenal at Dover, New Jersey, arrangements were made to procure some Daisy photoflash devices. These could be ejected at a velocity of 140 feet per second, and with a weight of 1.5 ounces would produce a fireball 9 feet in diameter at an altitude of 80,000 feet (ref. 72).

In the third test, on December 1, 1959, a failure during the coast period after the third-stage burnout prevented the velocity package from igniting. Large lateral loads were recorded, and it was concluded that the velocity package broke away from the third stage during the long coast period. Several structural elements were stiffened for the next flight and, in addition, the altitude of separation of the velocity package was reduced from 650,000 feet to 125,000 feet, to decrease the time during which a divergence might develop. The fourth flight, on March 29, 1960, also resulted in failure, this time at fifth-stage ignition. Analysis indicated marginal stiffness and also high temperatures at the rear of the shell of the velocity package. Aerodynamic heating was found to be responsible for the high temperatures.

The connectors for the last three stages were stiffened, and an ablative insulating coating was applied to the rear half of the velocity package shell. In the fifth test, on June 26, 1960, the radars tracked the vehicle to an apogee of 965,000 feet and through the reentry phase; but, unfortunately, the sixth stage failed to fire. The spin rate was measured to be 56.5 revolutions per second, and subsequent tests showed that such a high rate could affect ignition and burning. In all subsequent vehicles, the cant of the torque nozzles in the T40 motor was reduced to provide a spin rate of about 30 revolutions per second.

At this time, the reliability record of the D58 vehicle was very poor, with only one successful flight out of five attempts. The vehicle crew were confident, however, that all causes of failure had been determined and corrective measures taken. This proved to be the case, for the next 10 Trailblazer I vehicles all performed as planned, without any malfunction. One of the vehicles is shown in figure 460.

In the first successful flight in which the reentry object, the empty sixth stage, was made of steel, a visible trail was created and was accompanied by a large enhancement of the radar image; but the object apparently did not burn completely because it was tracked by radar down to an altitude of 94,000 feet, at which time it had slowed to a velocity of only 2,000 feet per second.

On August 6, 1959, Gardner and other representatives from Langley visited Lincoln Laboratory to discuss further plans for the reentry physics program. One item introduced was to have a far-reaching effect on the course of later experiments of this type. R. E. McCroskey of Harvard Observatory discussed the need for a controlled reentry experiment at natural meteor speeds, the photographs of which could serve as a calibration to allow interpretation of the information contained in more than 200 spectral photographs of natural meteors. The desired objective was a measurement of the relationship between the size of a meteor trail on a photograph and the actual mass of the reentry object. It was

24. Letter from G. N. Nelson, Barnes Engineering Company, to E. C. Draley, Langley, Sept. 23, 1959, regarding participation in Project Meteor (D58) by supplying radiometer.

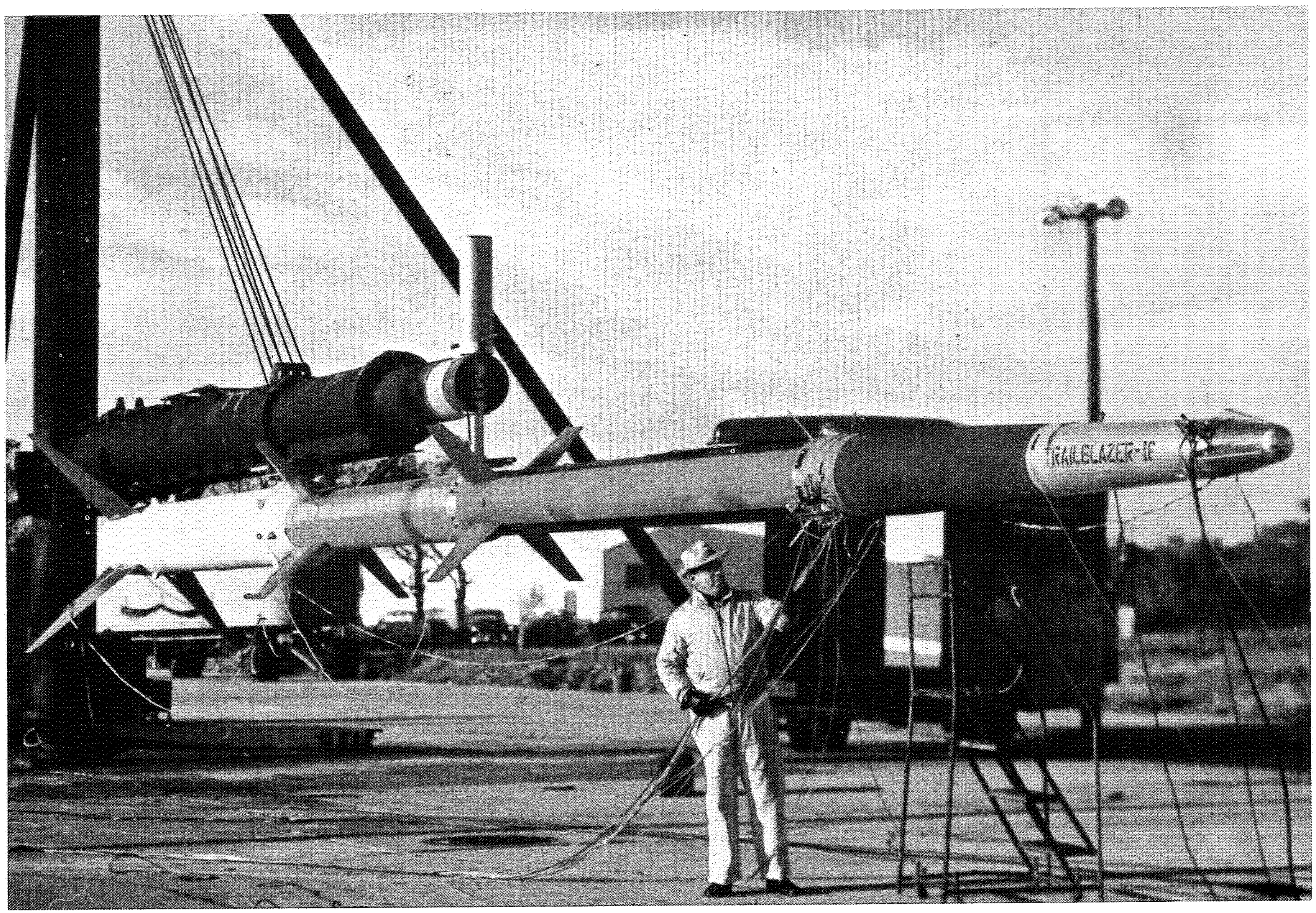


FIGURE 460. Project engineer C. A. Brown, Jr., adjusts wiring to Trailblazer I on launcher for firing, January 17, 1961.

proposed to mount a "suitable pellet launching gun" on the front of the final stage to provide the near-meteor velocities. Lincoln Laboratory agreed to undertake the development of such a gun for possible use in a later series of Trailblazer firings (ref. 73).

The first flight test with the pellet gun was made with Trailblazer Ig, launched on April 21, 1961. The gun, as developed by the Air Force Cambridge Research Laboratory, is shown in figure 461, attached to the front of the sixth-stage 5-inch spherical rocket motor. The gun was 1.5 inches in diameter and 10 inches in length. The pellet, made of stainless steel, was about 0.8 inch in diameter and 0.1 inch in thickness, and weighed 5.8 grams. In the test, the gun propelled the pellet to a velocity of 32,100 feet per second as the seventh stage of Trailblazer. This was a record velocity for Wallops as well as a record number of stages in a flight vehicle. "Optical data on the reentry pellet were obtained at three camera sites and yielded data necessary to compute for the first time the luminous efficiency of an artificial iron meteorite reentering the atmosphere" (ref. 74).

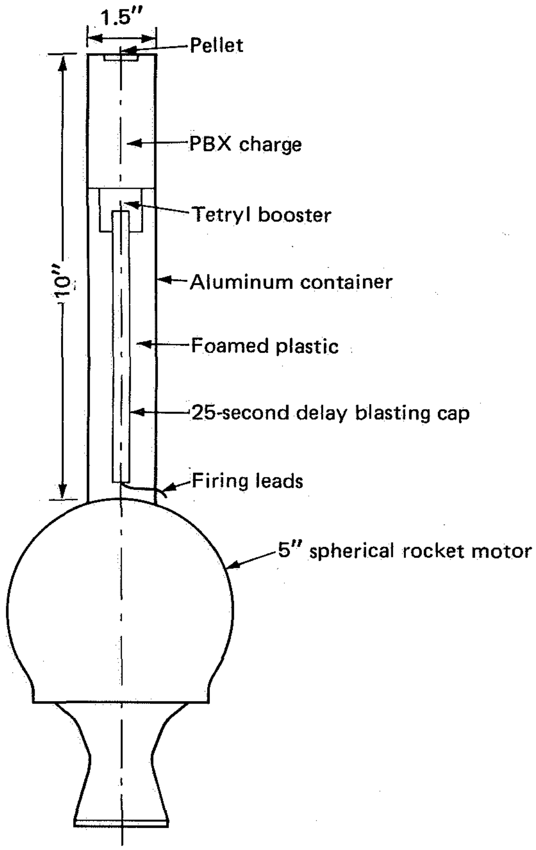


FIGURE 461. Drawing of shaped-charge pellet gun on sixth-stage 5-inch spherical rocket motor of Trailblazer Ig, launched April 21, 1961, for record velocity of 32,100 feet per second.

The Trailblazer I project provided information on the behavior of different materials under the extreme aerodynamic heating condition of almost vertical reentry; but the most valuable contribution was as an aid to the development of special radars to detect and discriminate between reentry nose cones, as a part of a continuing antimissile program of the Department of Defense.

TRUAX STEAM ROCKET

Admiral R. C. Truax of the Office of Naval Research had been involved with rocket engine development since the late 1930's. As a sideline interest, he invented a steam rocket as a possible answer to the need for an inexpensive and safe rocket for amateur and student scientists. The rocket was 6 feet 8 inches long and weighed 47.5 pounds with 30 pounds of water as the propellant. A propane gas burner was used to heat the water to a high temperature and pressure prior to launch. It exhausted from the rocket nozzle as steam. Truax had interested Experiment, Inc., of Richmond, Virginia, in developing the rocket, which they then offered for sale for $225, plus $275 for a launcher. A parachute recovery system for the payload was provided (ref. 75).

In January 1959, ONR asked NASA for permission to launch some of the Truax rockets at Wallops Island to verify their calculated performance. ONR was interested in the rocket for use in cloud seeding for weather modification at altitudes up to 30,000 feet. The calculated altitude achievable by the steam rocket was stated to be between 50,000 and 75,000 feet.[25]

Krieger was interested in this unique rocket approach for amateurs and recommended that the requested assistance be provided. He assigned a PARD designation of B20 to the vehicles because of their developmental nature. Figure 462 shows two of the three rockets prepared for launching on February 25, 1959. Under the direction of Admiral Truax, launch operations were carried out by representatives of Experiment, Inc., and ONR, with Wallops' assistance. The first rocket, launched at 1:48 p.m., left the launcher smoothly and appeared to be stable during and after powered flight. The performance, however, was disappointing. The altitude reached was only 5,000 feet, and the nose cone failed to open as planned, to deploy chaff. In the second attempt, the safety valve on the rocket opened during the heating cycle, and no launch was made. In the third attempt, at 4:04 p.m., the altitude reached was only 2,000 feet, and considerable wobble was noted in the flight. The parachute did not deploy (ref. 76). Despite this less-than-expected level of performance, the tests did demonstrate that steam could be used as a rocket propellant.

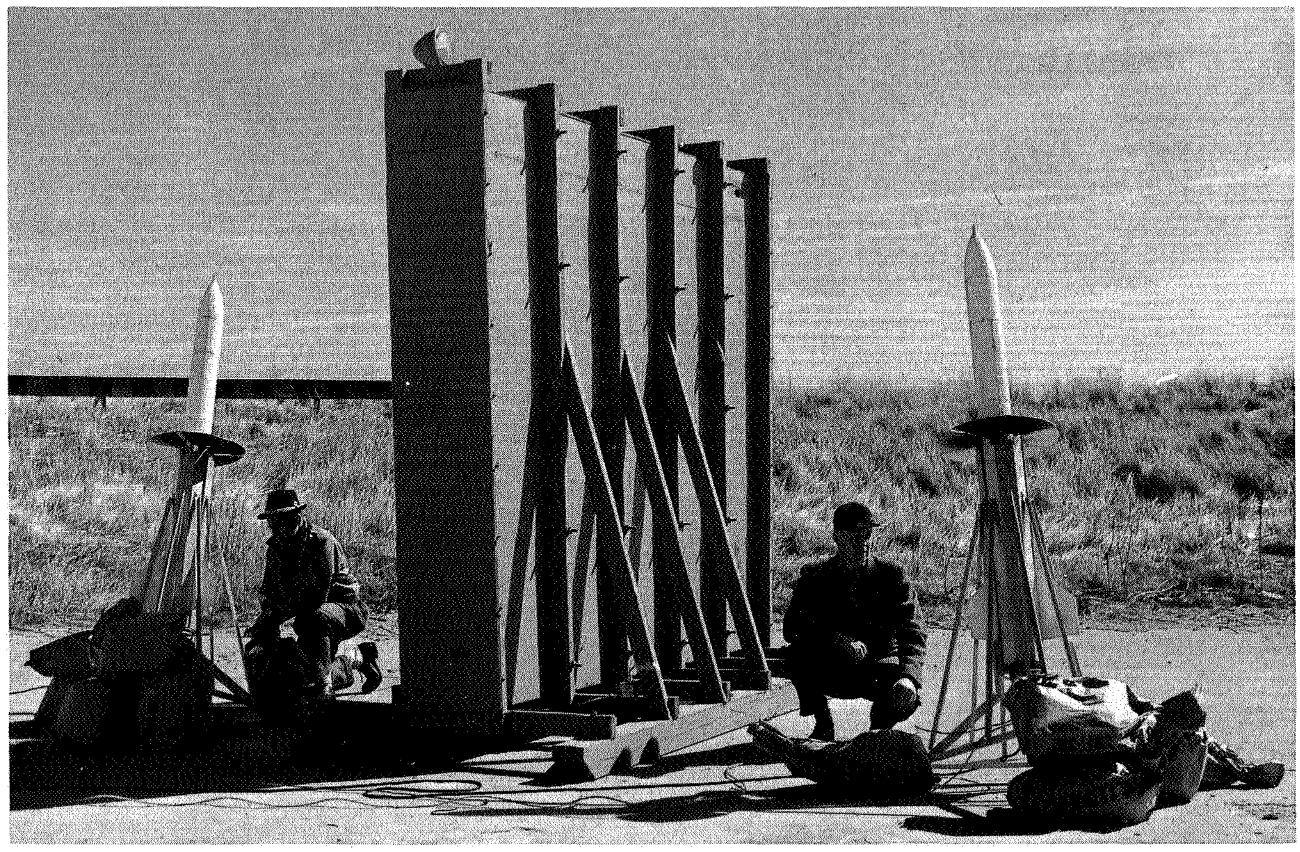


FIGURE 462. Truax steam rockets ready for launch at Wallops, February 25, 1959.

SHOTPUT AND *ECHO I* DEVELOPMENT

Chapter 15 has discussed the development of techniques for constructing one space-inflatable spherical satellite 30 inches in diameter, and another 12 feet in diameter. The 100-foot-diameter *Echo I* passive communications satellite was also developed by W. J. O'Sullivan, Jr., along similar lines and was for many years the largest object to be placed in earth orbit. It remained clearly visible in the night sky as it

25. Letter from G. G. Lill, ONR, to T. K. Glennan, NASA Administrator, Jan. 7, 1959, requesting permission to use Wallops facilities to launch the Truax Steam Rocket.

journeyed across the heavens on its predictable schedule. *Echo I*, the first satellite to be launched by the Delta launch vehicle, was placed in orbit on August 12, 1960, from Cape Canaveral. Prior to this launching, five suborbital flight tests of the Echo system were conducted at Wallops in the Shotput project, and made vital contributions to the success of Echo.

The idea of using a large inflatable sphere for space communications was first proposed in April 1955, by J. R. Pierce, Director of Electronics Research at the Bell Telephone Laboratories (ref. 77). Such a sphere was one of two schemes that he analyzed for providing long-range radio and television communications by satellite. In describing the two schemes he reported, "One consists of enough spheres in relatively near orbit so that one of them is always in sight at the transmitting and receiving stations. Another uses an active repeater located above the equator at an altitude of about 22,000 miles." Some of the advantages of the sphere were that it allowed the use of an unlimited number of communication channels, it could not be electronically jammed, and it allowed improvements to be made in the ground equipment without requiring corresponding changes in the satellite. Pierce proposed a 100-foot sphere to be constructed of 1-mil aluminum foil. Such a sphere would weigh about 400 pounds and "to keep the sphere spherical, initially one could inflate it gently." The 100-foot Echo satellite, made of 1/2-mil Mylar with an aluminized coating, weighed under 100 pounds, and the idea of "gentle inflation" was found to be a most important requirement for success.

The idea of a spherical communications satellite lay dormant until early in 1958 when the Killian Committee suggested to H. L. Drydan, Director of the NACA, that the technique developed by O'Sullivan for small inflatable satellites be applied to a 100-foot sphere for long-range communications. The committee indicated that possibly one of the ARPA satellite launch vehicles would be available for a test in October 1958. When J. W. Crowley visited Langley on March 31, 1958, in connection with the preparation of a space flight program, he also met with F. L. Thompson, J. A. Shortal, W. J. O'Sullivan, Jr., and E. C. Kilgore to learn whether Langley was interested in constructing a 100-foot sphere under conditions of the tight schedule proposed. Quick calculations indicated that the weight requirement of 100 pounds could be met, and Langley assured Crowley that it was not only interested but enthusiastic about the possibility of placing such a satellite in orbit, and that the schedule could be met. Consideration also was given to using the 100-foot sphere on a lunar probe to provide a positive means for visual identification. On April 18, 1958, Langley submitted to NACA Headquarters a proposed RA entitled "A Large Inflatable Object for Use as an Earth Satellite or Lunar Probe."

On May 8, 1958, NACA Headquarters approved the proposed RA as A12L145, and development of the sphere was initiated on a high-priority basis at Langley. It was planned to follow the same general construction techniques used for the 12-foot sphere. It was impractical and unnecessary, however to construct a hemispherical mold for forming the material. Instead, a long worktable the width of a single gore was used. A "clean" room was created by erecting a partially pressurized plastic half-cylinder about 200 feet long inside the large flight research hangar at Langley. Only a small compressor was required to restore the internal pressure lost from general leakage and use of access doors in each end.

The material selected for the sphere was Mylar film, 0.00025-inch in thickness, covered with a vapor-deposited molecular film of aluminum. The material was obtained from DuPont. Since it was planned to place *Echo I* in a 1,000-mile orbit, the external loads were expected to be extremely small, and the rigidity built into the 12-foot air-density satellite was not required. A contract was awarded General Mills for fabrication of the balloon.

By early August 1958, construction of the first 100-foot sphere had been completed. It was then inflated in the large balloon hangar at Weeksville, North Carolina. Figure 463 shows the inflated sphere in the hangar.

On August 18, 1958, a formal assignment of responsibilities for the Echo project was made. The project was the responsibility of the Space Vehicle Branch of PARD, under the direction of O'Sullivan. The detailed assignments agreed to in telephone discussions between Dryden, Gilruth, and O'Sullivan were as follows (ref. 78):

Project Coordinator	J. L. Mitchell
Electromagnetic Radiation	George P. Wood
Tracking and Orbit Determination	E. C. Buckley
Electromagnetic Propagation Test	M. Stoller

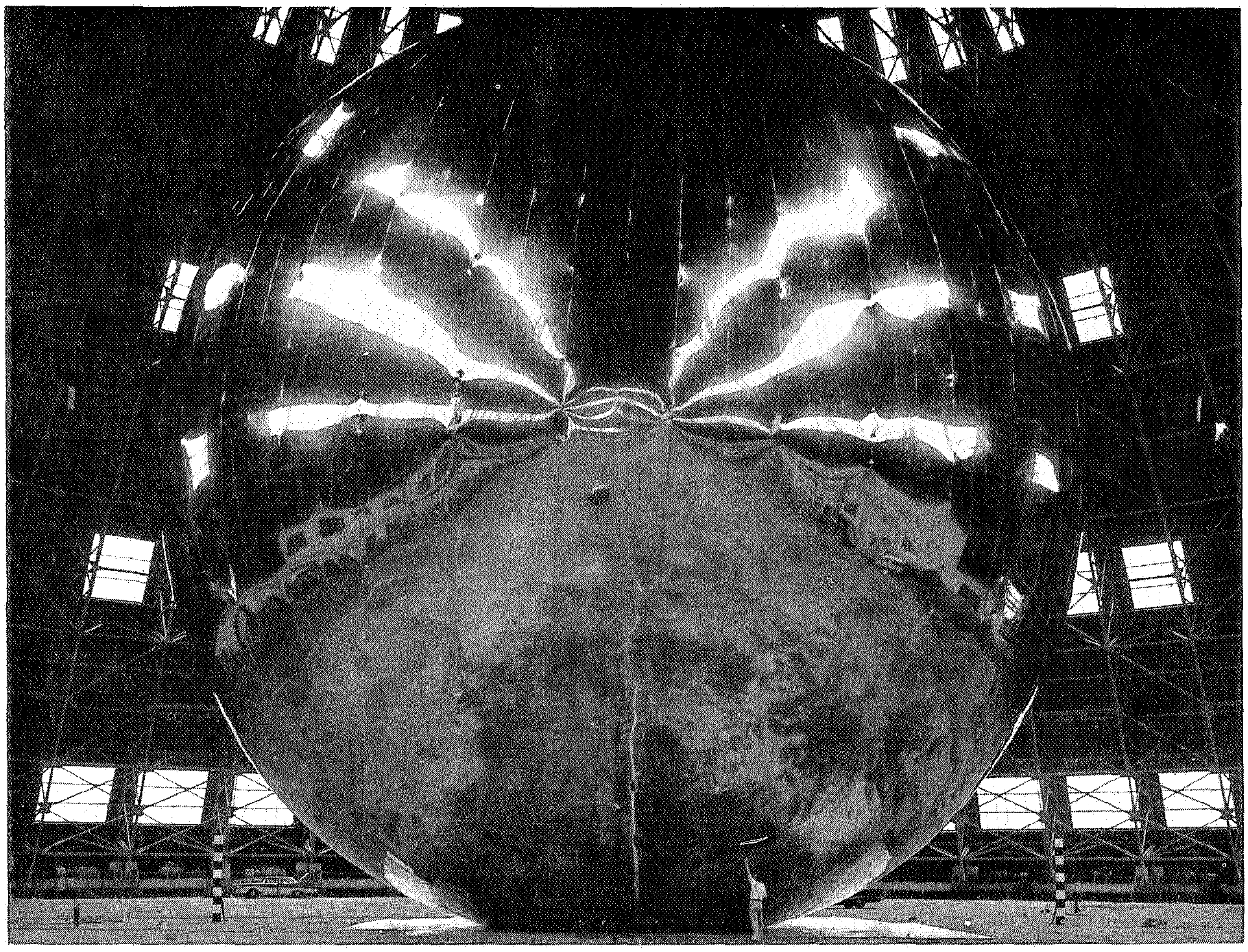


FIGURE 463. First version of Echo 100-foot sphere in Navy balloon hangar at Weeksville, North Carolina, for inflation tests, August 8, 1958.

Engineering Design and Tests	E. C. Kilgore
Sphere and Inflation Bottle	
Ejection System	Rene Berglund
Engineering Tests	
Launch Operations	R. L. Krieger
Satellite Launch Vehicle	ABMA and JPL
Vertical Shot Pre-Orbital Test	N. L. Crabill

The launch vehicle initially proposed for the 100-foot Echo spherical satellite was Juno II 19b, one of three new vehicles under development by ARPA. It was essentially a more powerful Jupiter C obtained by replacing the Redstone first stage by a Jupiter missile. The second new vehicle under development was the Douglas Thor-Able, an enlarged Vanguard in which the first stage became a Thor missile. The primary planned use for Thor-Able was as a lunar probe, for which mission a small fourth-stage rocket motor was added. The third vehicle was the Thor-Agena, an even more powerful vehicle obtained by adding to the Thor a new Agena stage, developed by Lockheed with the Bell Hustler engine. The primary use of the vehicle was in the military satellite program, initially the Discoverer series.

On September 2, 1958, a complete description of the sphere as inflated successfully was sent to NACA Headquarters. By this time, the plans to convert the NACA to NASA were practically complete, and all of the nonmilitary space projects of ARPA were to be transferred to NASA. Among these were the Thor-Able and Juno II launch vehicles tentatively considered for Echo. When Jupiter C49 failed structurally while attempting to place a 12-foot inflatable sphere in orbit on October 23, 1958, Langley knew that Juno II would be inadequate for the much larger Echo, and from that time all plans were centered around the use of a Thor-Able. With this in mind, Langley designed Echo for packaging inside a spherical container of the type normally used on the X248 stage of Vanguard and Thor-Able. Unfortunately, all of the Thor-Able vehicles were assigned as lunar probes, and Echo had to wait.

O'Sullivan persisted in his contacts with NASA Headquarters and was successful in having Echo placed high on the list of new projects and scheduled for the first launching of Thor-Delta, the NASA-developed follow-on to Thor-Able. The assignment of Echo to Thor-Delta imposed harsh demands on the vehicle because Echo required a 950-mile altitude. This requirement necessitated a 23-minute coast period between burnout of the second stage and ignition of the third. In addition, a larger heat shield had to be developed to suit the Echo payload.

By February 1959, the project had received official approval from NASA Headquarters, and funding for development of the satellite had been requested. A series of five suborbital launches at Wallops with a Shotput vehicle was planned to ensure proper operation of the payload package at simulated orbital insertion. As was discussed in Chapter 15, the 30-inch subsatellite and the 12-foot inflatable satellite were still awaiting flight test, and the combined workload was more than O'Sullivan could handle with only his Space Vehicle Group. Consequently, on February 18, 1959, the project organization of August 1958 was dissolved and replaced by a special Task Group to handle all three inflatable-sphere projects. The major effect of this action was to make C. L. Gillis assistant head of the group, directly under O'Sullivan. Furthermore, any additional assistance required at PARD to support the Space Vehicle Group was now available from Gillis' Aircraft Configuration Branch (ref. 79). N. L. Crabill of this branch continued as Project Manager for the pre-orbital Shotput tests. Mechanical design and assembly of this launch vehicle was under the direction of K. S. Bush, with the assistance of W. Taub, both men being from the Dynamic Model Engineering Section.

With the establishment of Echo as an official NASA space flight experiment, ample funding became available for extensive contracting. In NASA Headquarters, Echo was assigned by Silverstein to the Office of Space Sciences, and Leonard Jaffee, Chief of Communications Satellites, was the principal contact for O'Sullivan in that office. Funding for the project was handled by Jaffee and was transferred through the Space Task Group at Langley to the Langley Research Center for expenditure. The Office of Aeronautical and Space Research under Crowley in NASA Headquarters now had little to do with the execution of the project. In effect, the part of Langley working on Echo was really working for the Office of Space Flight Development under Silverstein. To complicate matters even more, the entire Space Vehicle Group was, for a time, carried on the rolls of the Space Task Group. The fact that the funds were routed through the Space Task Group did not cause any difficulty, however, inasmuch as the Langley Procurement Division actually handled procurement for this group as well as for the entire center.

Jaffee left the development of the 100-foot sphere to O'Sullivan and the Langley crew while he concentrated on getting a communications experiment in readiness. The two 85-foot antennae of the JPL at Goldstone, California, were to transmit signals at 2390 mc and receive signals at 960 mc. The Bell Telephone Laboratories were to make available at Holmdel, New Jersey, a 20-foot by 20-foot horn-fed parabolic receiver at 2390 mc and a 60-foot antenna for transmitting at 960 mc. A 60-foot antenna at NRL also was engaged for receiving the JPL transmissions at 2390 mc. Jaffee secured approval from the FCC for use of these frequencies for the Echo experiment. In addition, he attempted to create an interest in the general scientific community for conducting independent experiments with Echo (ref. 80).

At the second Project Echo planning meeting on October 13, 1959, it was announced that Echo project management responsibility had been assigned to the Goddard Space Flight Center, with R. J. Mackey as the "action officer." Goddard had responsibility for making all arrangements for the launch at Cape Canaveral, since the Delta vehicle was already a Goddard development. Goddard also had responsibility for tracking the satellite and providing the communications experimenters with pointing information. The assignment of overall responsibility for Echo to Goddard was in line with the NASA Headquarters policy of centering all space projects there (ref. 81). Actually, it had no effect on the effort at Langley.

Organization of the project at Langley was announced officially, at the insistence of Silverstein, on March 25, 1959, as follows (ref. 82):

Project Director	W. J. O'Sullivan, Jr.
Assistant	C. L. Gillis
Payload Development	W. E. Bressette
Instrument Research Support	H. H. Youngblood
Shop and Engineering Support	Rene A. Berglund

On March 28, 1960, Silverstein informed Langley of the responsibilities of Goddard in the NASA Communications Satellite Program. These included management of Project Echo as well as research on follow-on projects and studies. The Director of Goddard appointed R. J. Mackey Manager of Project Echo, and Silverstein stated, "Working arrangements between Goddard and Langley will be established by the Project Manager."[26] As it worked out for *Echo I*, Langley was responsible for development of the Echo spacecraft, while Goddard was responsible for integration of the spacecraft with the Delta launch vehicle, and planning and execution of flight operations and the communications experiments. Langley was quite disturbed over the assignment of overall responsibility to Goddard because, although it would have no effect on the immediate Echo project, Echo was considered to be but the first in a long series of large satellite experiments under the jurisdiction of Langley.

The plan for the Echo project was to flight test five Shotput vehicles at Wallops, and to conduct as many satellite firings at Cape Canaveral as would be required to achieve a successful orbit. Because of the requirement for prototype testing and spare components, the number of complete units required was considered too great for construction in the Langley shops. Units included the actual sphere as well as the associated hardware. All design work, however, was carried out at Langley.

Following competitive bidding, contracts were let as follows:

100-foot Sphere	G. T. Scheldahl Company
Spherical Container	Kaiser-Fleetwings Corporation
Upper Stage, excluding Sphere and Container	Douglas Aircraft Company, Tulsa
Shotput Hardware, excluding Payload	Aerolab Development Corporation

With the exception of three Sergeant motors available from the Polaris project, the rocket motors were procured by Langley with Echo funds. The Delta satellite launch vehicles were funded under the development program for this vehicle. Langley personnel performed all assembly and preflight testing, including folding and packaging of the sphere inside its container. The folding and packaging were done in the special "clean" room in the hangar. Langley personnel also went to Wallops to assist in the preparations for launching of the Shotput vehicles. By the time Echo was in orbit over 200 people at Langley had worked on the project.

The only major change in the sphere after it became a NASA project was that the thickness of the Mylar was increased to 1/2 mil, and the Mylar was covered with a layer (approximately 2,200 angstroms) of vapor-deposited aluminum. It was found that the Delta vehicle could handle the additional weight, and the added strength was highly desirable to facilitate fabrication without tearing the material.

Many people questioned whether, even in space, such a frail object 100 feet in diameter could travel 18,000 miles an hour, while being subjected to the relatively unknown environment of space, and maintain its spherical shape as required for the communications experiment. An analysis was made by W. E. Bressette and C. W. Coffee, Jr., of the SVG in May 1959 to determine the gas leakage from the satellite due to meteoroid puncture in space, and the possibility of the sphere's collapsing from external forces (ref. 83). They made the assumption that the sphere would remain spherical as long as the internal pressure exceeded the forces of external collapsing pressure. At this time, four pounds of water were planned for pressurization. Bressette and Coffee concluded that the sphere would retain sufficient pressure to remain spherical for at least 7 days, but pointed out that "An additional pressurization process such as the sublimation of solid materials at a low pressure value in the 100-foot sphere, above the collapsing pressure, will extend the time considerably." Despite the fact that the water

26. Letter from NASA Headquarters to Langley, Mar. 28, 1960, regarding Goddard responsibilities in NASA Communications Satellite program.

was replaced by subliming solids before Echo was placed in orbit, the figure of 7 days for the expected lifetime remained as the "official" life expectancy. Actually, Echo was to retain its sphericity much longer than expected, and the external collapsing pressures, including solar radiation, acted more to change the orbit of Echo than to collapse the sphere.

For a realistic environmental test, Shotput was made to duplicate the operation of Echo on Delta, in all respects except that of velocity. The Delta vehicle had a Thor first stage, an Aerojet liquid-rocket second stage, and an ABL X248 solid-rocket motor third stage. The second and third stages were similar to the same stages on Vanguard. In operation, the first and second stages were automatically guided to lift the third stage to the desired orbital altitude of 1,000 miles, ending on a trajectory parallel to the earth and providing part of the necessary orbital velocity. The third and last stage was unguided but was stabilized in the desired attitude by spin imparted to it by small Atlantic Research Corporation Pet motors mounted on the last stage to fire tangentially. This spinning stage was mounted on the front end of the second stage on a special spin table that restricted the spinning motion to the last stage. At launch and during flight through the atmosphere, the last stage was protected by a clamshell type of heat shield that was discarded in space before orbital altitude was reached. After the third stage attained its necessary spin rate (120 revolutions per minute) and the 1,000-mile altitude, the X248 motor was fired away from the spin table and on into orbit.

The X248 rocket motor was developed by ABL for the Vanguard vehicle and had a very high propellant mass fraction, obtained by the use of a wound fiberglass case. The motor had a diameter of 18 inches, a length of 4.9 feet, and a weight of 515 pounds, with 456 pounds of double-base propellant. It provided a thrust of 2,820 pounds for about 41 seconds. The propellant mass fraction was 0.89.

After the X248 motor burned out and the stage was in orbit, the spinning motion was eliminated by the firing of additional Pet motors in the reverse direction. Next, the spherical container was separated from the empty rocket motor. Then the container was separated into two halves, and the sphere was allowed to inflate.

The effectiveness of some of these steps could be determined from tests in the 60-foot vacuum sphere at Langley; but the critical phase, actual inflation behavior, could not. The Shotput tests were aimed primarily at this event, although the other events also were evaluated.

In the Shotput tests, all of the components forward of the second stage of Delta were duplicated, including the spin table, the X248 motor, and the clamshell protective shield. The last stage with the shield removed is shown in figure 464. Prior to installation on the launch vehicle, the stage mounted on the spin table was dynamically balanced with a live motor in a special machine located inside the rocket test cell at Wallops. The first stage of Shotput was a Sergeant motor, which was large enough, in combination with the X248 stage, to carry the payload to an altitude essentially outside the atmosphere for a sufficiently long time to test all events, including inflation of the sphere. A maximum altitude of 240 miles and about 8 minutes of time above 400,000 feet were provided. Two Recruit motors were strapped to the Sergeant to provide additional acceleration at launch. The Shotput series of vehicles was designated E60 by PARD.

The first Shotput vehicle, launched at Wallops on October 28, 1959, is shown in figure 465. The nozzles of the Recruit rockets were canted so that their thrust would act through the center of gravity of the complete vehicle. The vehicle was about 32 feet long and weighed 11,200 pounds. The Sergeant and two Recruits, which were ignited simultaneously at launch, provided a combined thrust of 124,000 pounds. The four wedge fins on the Sergeant were canted 1.9 degrees to provide roll of the vehicle for dynamic stability. The fins, constructed by Aerolab, were those originally intended for the Lewis hydrogen-fluorine engine flight test discussed earlier in Chapter 15. The second stage, although mounted on the spin table in the same manner that Echo would be on Delta, was locked with a shear pin to ensure that this stage would have the same spin rate as the main vehicle. After burnout of the first-stage rocket motors, the vehicle was allowed to coast to high altitude before the X248 motor was ignited. During this coast period, the protective shield was cast off in two halves. At an altitude of 200,000 feet, the spin rate of the complete vehicle was approximately 286 revolutions per minute, about twice that necessary and allowable for the X248 stage. This stage, therefore, was despun from 286 to about 120 rpm by four Pet rocket motors, which also sheared the locking pin on the spin table.

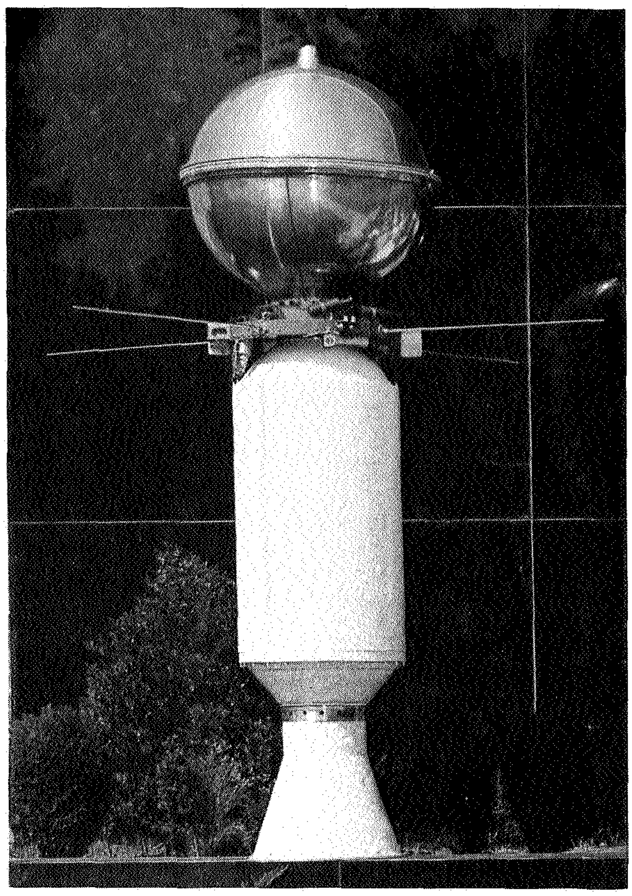


FIGURE 464. Third stage of Thor-Delta launch vehicle with packaged Echo spacecraft attached.

Immediately after this despin event, the X248 motor was fired away from the spin table. At burnout of this stage, the altitude was 375,000 feet, and three additional Pet motors were fired to bring the spin rate down to zero. Next, the payload container was released from the stage by an explosive Marman clamp and, by means of a spring, was pushed forward with a separation velocity of 6 feet per second. Immediately thereafter, six Pet motors, aligned to provide a retrograde impulse, were fired to slow the spent stage and prevent it from overtaking the sphere after its inflation. The 26-inch spherical container, composed of two halves, was then opened by the firing of a linear shaped charge fitted between the connecting flanges of the two halves. The firing of this charge not only opened the container but also pushed the two halves apart. In addition, the 100-foot sphere was expelled from the two halves by a tautly stretched rubber membrane lining the inside walls.

Upon release of the container, the sphere immediately began to inflate. When the sphere was packed into the container, both the sphere and the container were evacuated to about 5 pounds of pressure per square inch, to prevent excessively rapid inflation upon release in the vacuum of space. The residual air in the sphere, however, was counted on for initial inflation. In addition, four pounds of water were carried inside the sphere. It was calculated that 17 percent of the water would flash immediately into vapor, the remainder turning into minute ice particles that would evaporate later and maintain internal pressure. To sustain inflation even longer, 20 pounds of a subliming solid were to be carried in the Echo satellite. For the Shotput test, starch was substituted for this material for the sake of convenience, because the time of flight was not long enough for the proper material to sublime.

An eight-channel telemeter was mounted between the container and the X248 motor, and transmitted measurements of acceleration, spin rate, pressure, and timing of the important events.

The trajectory and dispersion of the spinning Shotput launch vehicle under different wind conditions were computed by R. L. James, Jr., and R. J. Harris (ref. 84), with the aid of a three-dimensional, six-degree-of-freedom computer program developed by James for the IBM 704 electronic data processing machine at Langley (ref. 85). This was the first instance at Wallops of

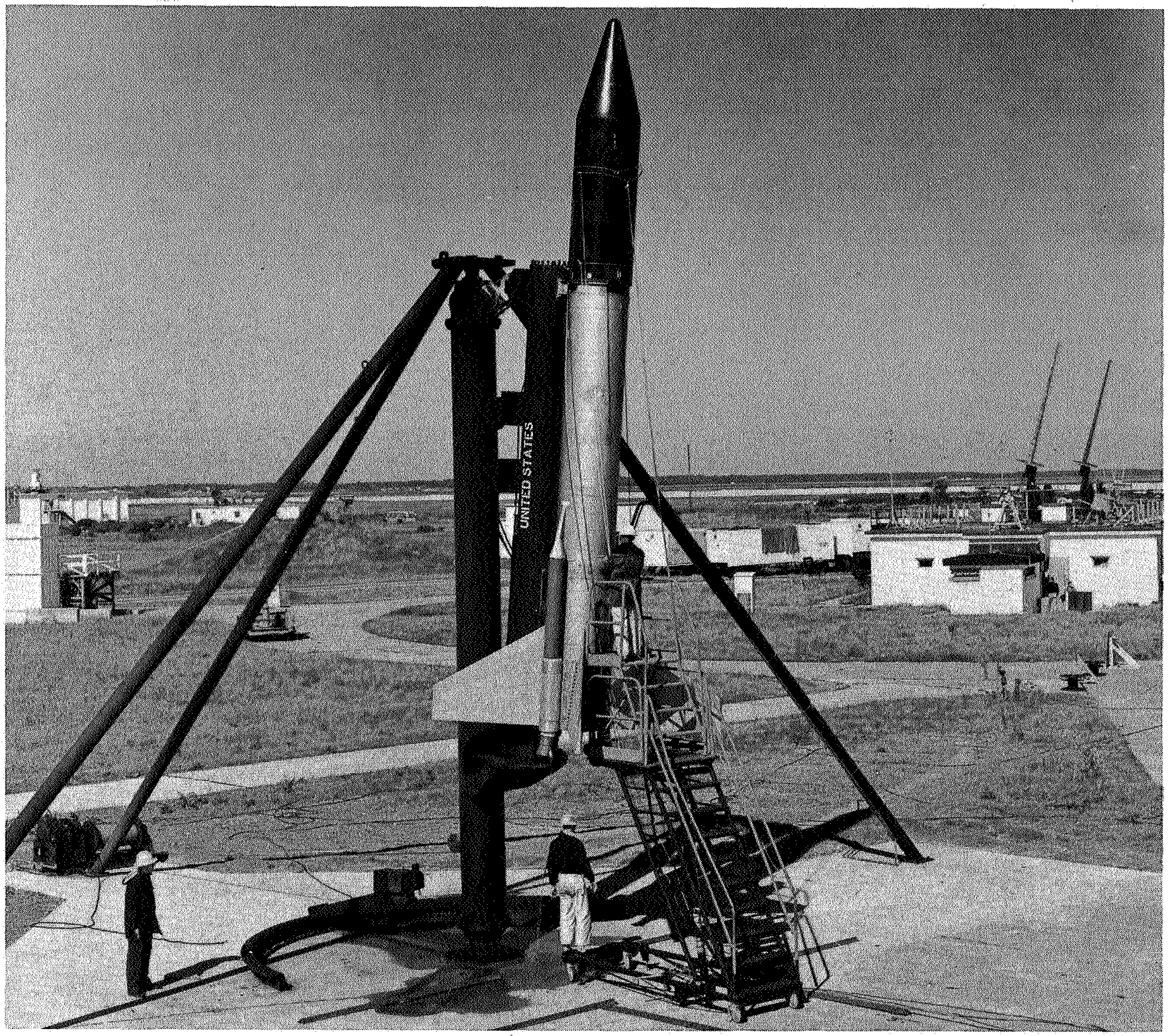


FIGURE 465. Hard-hat technicians ready first Shotput vehicle for flight test, October 28, 1959.

computing the motions and loads for design purposes by using normal shroud, fin, and thrust misalignments in the process. From this analysis, a unique spin program was developed, namely, to spin the complete vehicle very rapidly at launch, using canted tail fins, so that the roll-resonance region would be traversed at low altitude while dynamic pressure was still high enough to provide adequate pitch damping to limit angular deviations during the critical period. Later, at high altitude, steady conditions were assured at second-stage separation, because the vehicle was then well above resonance. The results of this analysis were presented at an AGARD conference in 1961 (ref. 86).

All available radars in the general area of Wallops were alerted to the Shotput firings. Several long-range radars were under development during this period, and different installations were available for the different firings. Although the SCR-584 and Reeves Mod II at Wallops were used in every firing, they were not considered long-range radars. The RCA FPS-16 radar at Wallops and the MIT Millstone Hill radars were the main long-range equipment used in the project, although both were out of operation for Shotput 1. For this test, an FPQ-4 radar operated by RCA at Moorestown, New Jersey, provided the only long-range radar data and was indispensable in the determination of the sequence of events at inflation. Radars operated by NRL at Washington, D. C., and North Beach, Maryland, as well as one operated by Bell Telephone Laboratories at Whippany, New Jersey, were invited to participate and were provided with launch times. In addition, the Shotput firings were made just after dusk so the inflated sphere would be illuminated by the sun as the sphere emerged from the earth's shadow. Various cameras, including motion picture cameras on loan from White Sands Proving Ground, were located at Wallops to record the inflation sequence. The cameras were of 175-inch and 320-inch focal length. (See figure 436.) In addition, ballistic cameras were also located at Grumman Aircraft Corporation, Bethpage, Long Island; at DuPont, Wilmington, Delaware; at Electric Boat Company, Groton, Connecticut; at NRL, Blossom Point, Maryland; and at BRL, Aberdeen, Maryland.

From the telemeter and radar records and the photographs of the first Shotput launching, it was possible to determine most of the events precisely. All of the events up to container opening went as planned. At the time of container opening, the altitude was 450,000 feet, and the velocity was 9,300 feet per second along a flight path angle of 58 degrees above the horizontal. The FPQ-4 radar at Moorestown recorded the inflation of the 100-foot sphere as occurring in only 0.7 second. Several objects were seen leaving the sphere as it inflated, and it was concluded that the sphere tore itself to pieces at inflation. The explanation was that the 5-psi residual air pressure inside the sphere was sufficient to rupture the skin at critical places in the folds of the sphere as it began to inflate (ref. 87). This was a very crucial finding, because preparations for launching the Echo satellite with the Delta vehicle were under way at Cape Canaveral, although Echo was not scheduled to be launched until March 1960. Plans were immediately made for additional tests in the vacuum tank at Langley, and for a reevaluation of the folding technique. Tests in the 41-foot vacuum sphere at Langley indicated that the container halves did not damage the sphere at separation. The folding method was changed for the next test.

In the second Shotput test, on January 16, 1960, the balloon did not have a chance to open correctly because the retrorockets which were supposed to separate the last stage from the sphere did not fire, and apparently repeated collisions occurred, first between this stage and the container, and then between this stage and the sphere, which was torn in the process. Nevertheless, the partially inflated sphere was tracked by the Wallops FPS-16 radar to an altitude of 257 miles and out to a range of 450 miles. The elapsed time during which it was tracked totaled 9.5 minutes. In this flight, the water for inflation was replaced by a subliming powder. Ten pounds of benzoic acid were provided for inflation, and 20 pounds of anthraquinone for sustaining the pressure after inflation. The powder could be distributed evenly and would not subject the balloon to tearing from a concentrated mass such as the water, previously used.

O'Sullivan selected anthraquinone to maintain the internal pressure in the satellite because its vapor pressure was sufficient to overcome the external collapsing pressure and produce a tensile stress of 20 pounds per square inch, sufficient to maintain the surface "smoothly spherical" (ref. 88).

The third Shotput was launched on February 27, 1960, with approximately the same arrangement as that of the second test except that a red fluorescein powder was placed inside the sphere, replacing the anthraquinone for the test to provide concrete evidence of any tearing of the sphere at inflation. In this test, there was evidence that the container halves did come in contact with the inflating sphere and rupture it, for the red dye was visible about two seconds after initial opening of the container.

Following the breakup of the sphere in Shotput 1, there was interest in recovering the next balloons to aid in determining the cause of any future failure. Captain Cecil D. Bailey, Air Force Liaison Officer at Langley, became intensely interested in this possibility and arranged with the Air Defense Command for downrange airplanes and ships to photograph the balloon and track it by radar. The reentry of the balloon was calculated to be at a velocity of 10,000 feet per second at a distance of about 400 miles due east of Wallops, near the location of picket ship Dessert. For Shotput 2, an object was tracked by the radar on the picket ship for more than 3 hours. It appeared to be 10 miles wide and 30 miles long. It was conjectured that this target was either the balloon torn into many pieces or the powder carried inside the balloon, which escaped when the balloon was torn during ejection and inflation. For Shotput 3, Bailey arranged for an aircraft to be in the vicinity of the reentry point, and he was on board as an observer. The balloon could be seen to inflate, and a reddish-orange comet appeared to form slightly behind it. Again, this balloon was one that had been torn and contained the red powder. The picket ship also picked up the balloon on its radar. Bailey concluded that with an additional aircraft and a high-speed destroyer, the balloon could be recovered (ref. 89).

Additional tests were made in the Langley 41-foot sphere after the failure of Shotput 3, and it was found that the balloon was inflating too fast and would overtake the two halves of the container. An increase in the power of the shaped charge was tried, to increase the speed of separation of the container halves. This was not fruitful, however, because the stronger charge damaged the container, and it was feared it would also damage the balloon directly. A solution was found in reducing the inflation speed of the balloon. This was done by puncturing the surface of the balloon with 240 pin-sized holes to allow reducing the internal pressure inside the balloon and the container after packaging. It was now possible to reduce this pressure to about one-third of the earlier value, and tests in the vacuum tank indicated a considerable slowing of the inflation process under the inflation of residual air (ref. 90). Since this technique appeared to be a solution to the problem, the next Shotput was prepared for a test of the system; and at the same time the packaged spheres at Cape Canaveral awaiting the Delta launch were opened and modified in the same manner. The total area of these small holes corresponded to about the damage calculated to occur during one day from meteoroid penetration. The subliming powder carried within the sphere could easily replace the corresponding loss in pressure for some time.

The fourth Shotput with the perforated balloon was launched at Wallops on April 1, 1960. Everything performed as planned, and good inflation was obtained.

The first attempt to place Echo into orbit at Cape Canaveral was made on May 13, 1960. The attempt failed because of several malfunctions in the Delta launch vehicle in this, its first flight test. The third stage did not fire, and the 100-foot sphere never had a chance to open.

Pending correction of the difficulties with the Delta vehicle, a fifth Shotput was launched at Wallops on May 31, 1960. This test was identical to the fourth except that RCA beacons were added to the skin of the satellite to aid tracking at times when the satellite would not be visible in sunlight. The beacons had been operating in the first Shotput test but were removed in later launches when it was suspected that these concentrated masses might have contributed to the tearing of the balloon during inflation. In the fifth test, the sphere inflated smoothly, and the beacons worked as planned. It was an extreme test of the system because the first despin motors failed to fire, and as a result the X-248 motor operated at a higher than designed spin rate. The sphere therefore was ejected and opened from a container spinning at 90 rpm instead of zero. The use of the beacons on the second Echo satellite scheduled at Cape Canaveral was recommended (ref. 91).

The second attempt to place Echo into earth orbit with a Delta vehicle was made on August 12, 1960. This time the vehicle performed as planned, and Echo was in orbit. Glennan congratulated O'Sullivan for the achievement and stated, "I am happy to share a small bit of your large budget of satisfaction over the first real communications experiment in space."[27] *Echo I* was clearly visible to the naked eye while illuminated by sunlight, and the beacons on the satellite made tracking possible in darkness. Communications experiments were successfully carried out between the Jet Propulsion Laboratory station at Goldstone, California, the Bell Telephone Laboratories station at Holmdel, New Jersey, and the Naval Research Laboratory station at Stump Neck, Maryland. Frequencies of 2,390 mc and 960 mc were used. Voice messages were transmitted, and continuous wave and other research techniques were employed.

During the first orbit, a previously recorded message by President Eisenhower was transmitted from the west coast to the east coast, with *Echo I* serving as a passive relay. This was followed by two-way telephone conservations, and then a signal was transmitted and received from France. No deviation from propagation theory was observed in the communications. During the first 14 days, the returned signal strength was within one decibel of theoretical calculation. Even after *Echo I* lost its internal pressure, it remained a useful communications relay because it retained essentially a spheroid shape, although there was some loss of signal strength. The Air Force's Rome Air Development Center also conducted communications experiments with *Echo I*, transmitting teletype and voice signals at 2,000 mc from the 84-foot radar dish at Trinidad, British West Indies, and receiving them with a 33-foot dish antenna at Floyd, New York. In September 1962, Echo was used as a relay for communications transmission from another satellite in polar orbit, *Alouette I*, at frequencies of 2 mc and 15 mc.

27. Letter from T. Keith Glennan to William J. O'Sullivan, Jr., Aug. 12, 1960.

In addition to providing verification of Pierce's analysis of a sphere as a communications satellite, Echo provided additional research information. Two items of particular importance were data on atmospheric density at an altitude of 1,000 miles, and information on the effects of solar pressure on the motion of satellites. Solar pressure acted to decrease the perigee and increase the apogee when the perigee was on the side of the earth facing the sun. The orbit was shifted dramatically from its original value of a 945-mile perigee and 1,049-mile apogee to a 580-mile perigee and a 1,365-mile apogee by the end of 1960, after which a reverse effect began. R. W. Bryant of Goddard found this change in orbit in excellent agreement with theory (refs. 92, 93, and 94). This information was to be of value in predicting the behavior and lifetime of other satellites. The greatest benefit of Echo, however, came from the fact that it was visible from practically the entire populated area of the earth for many years, and served as a constant reminder that the man-created Space Age had really arrived.

With the success of Echo, there was no need for the two Shotput vehicles remaining at Wallops. They were placed in storage and were later assigned to Lewis Research Center for possible use in a flight experiment to study the behavior of fuels in a zero-gravity environment.

One of the many honors accorded Echo was the issuance, by the U. S. Post Office Department, of a commemorative 4-cent stamp on December 15, 1960. The stamp was identified as *Echo I*, Communications For Peace. At a special ceremony in the Postmaster General's Office, F. L. Thompson and W. J. O'Sullivan, Jr., were presented autographed albums of the *Echo I* stamp. O'Sullivan also received a $5,000 award from NASA for his inflatable sphere concept.

ARCAS METEOROLOGICAL ROCKETSONDE

The purpose of the Arcas rocketsonde was to extend the data-gathering capability of radiosonde balloons to an altitude of 200,000 feet. With the support of the Navy, the National Bureau of Standards in 1936 began development of a radio meteorograph, later renamed "radiosonde," to be carried aloft by free balloons to provide data on pressure, temperature, and humidity at altitude for weather forecasting and flight planning. By 1938, such radiosondes were in regular use (ref. 95). Later, radar tracking of the balloons enabled determination of wind velocity. From the beginning of Wallops, radiosondes were used to provide environmental data for use in analysis of the rocket-model data. As the altitude requirements increased, the size of the balloons was increased until it was possible to obtain data to an altitude of about 90,000 feet. In 1955, the radiosondes were replaced by Rawinsondes with GMD-1 receiving equipment. This equipment, operating on a frequency of 1680 mc, contained its own tracking antenna and eliminated the need for separate radar tracking. During World War II, consideration was given by the Navy to the use of rockets instead of balloons to gain the desired altitude. A rocket equipped with a radiosonde was called a "rocketsonde." In fact, the original NRL upper atmosphere branch was named the "Rocket-Sonde Research Branch" in 1945 (ref. 96).

Plans were made to use the Deacon rocket as a rocketsonde, but its cost made use as a routine meteorological tool prohibitive. With a rocketsonde the desired data could be obtained faster than with balloons; and its use opened the possibility of measurements at higher altitudes. With a rocketsonde, the meteorological package would be ejected from the nose cone at altitude, and then would be lowered to the ground by parachute. Tracking of the parachute provided wind data. With the coming of ballistic missiles, knowledge of wind data at high altitudes was needed because wind loads could be important in structural design. Synoptic measurements at the different ranges were, therefore, desired to establish statistical wind profiles and gust data for vehicle design. An excellent summary of the situation and the PARD requirements was prepared by A. G. Swanson for presentation to a Meteorological Requirements Conference held at Washington, D. C., on July 6, 1959 (ref. 97).

In December 1958, the Army Signal Research and Development Laboratory (SRDL), Fort Monmouth, New Jersey, informed NASA and other Government agencies of its plans to develop an Arcas rocketsonde system to provide meteorological data to an altitude of 200,000 feet. The laboratory asked if NASA would participate.[28] The system would use the Atlantic Research Corporation's Arcas solid-fuel rocket motor and would contain "a radiosonde set suitably repackaged for rocket operation."

28. Telegram from Army SRDL to NASA, Dec. 22, 1958, regarding Arcas rocketsonde development.

Ground equipment was to be either a single GMD-2 or two sets of GMD-1 on a baseline. NASA indicated an interest in the system but declined to participate in the development.[29]

The Arcas rocket (shown in figure 466) was developed by Atlantic Research especially for rocketsonde use, and was essentially a scaled-down Arcon motor. It was 4.4 inches in diameter and 60 inches in length, and developed a thrust of 336 pounds, with a total weight of 65 pounds. It was an end-burning rocket that exposed the case to the combustion temperature except as inhibited by insulating lining. It was a low-acceleration rocket that should have minimized the design problem for the payload from considerations of shock load except for the fact that a high-acceleration booster also was required, to minimize dispersion from winds at launch. A special launcher tube was required, as shown in figure 467. The Army's SRDL had responsibility for the meteorological package, and Atlantic Research was responsible for the rocket. Each assumed that the other's component was fully developed, whereas in fact neither was; and as a result, Arcas had very low reliability.

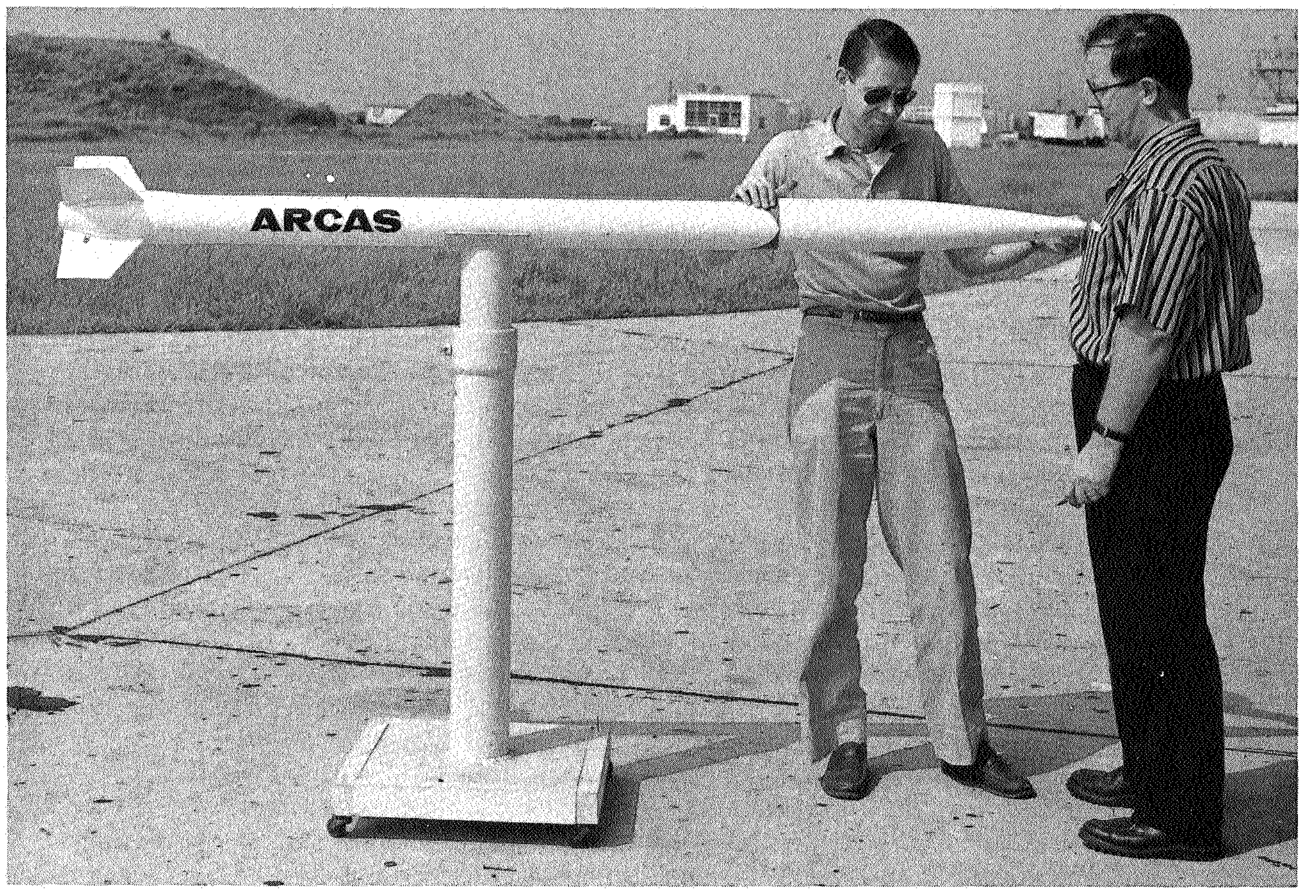


FIGURE 466. First Arcas meteorological rocket, shown at Wallops prior to flight test, July 31, 1959.

During 1959, three launchings of Arcas rockets were made from Wallops. People from the Army's BRL supervised the initial firings. The first firing, on July 31, 1959, was a complete failure; the rocket veered sharply at burnout and broke up. A second attempt on the same day gave the same result. The third attempt, on August 7, 1959, however, was successful. An altitude of 180,000 feet was reached, and a metallized parachute carrying a radiosonde was ejected as planned. The radiosonde apparently broke away from the parachute, however, as indicated by the fact that the GMD-1 at Wallops tracked a fast-moving radiosonde, while the FPS-16 radar remained locked on a slow-moving target for 19.8 minutes. Apparently, the slow-moving target was the parachute without its payload.

Despite failure in the first tests, the people involved were enthusiastic about the possibilities of the system, and its development was continued. Arcas was to be for many years the main meteorological tool for obtaining data at altitudes up to 200,000 feet. It was to be used in synoptic measurements as well as in direct support of high-altitude reentry tests.

29. Letter from R. V. Rhode, NASA, to SRDL, Jan. 6, 1959, regarding Arcas rocketsonde system development.

FIGURE 467. Lieut. Commander W. Houston checks elevation adjustment of special tubular launcher for Arcas rocket, July 31, 1959.

NIKE-CAJUN AND NIKE-ASP LAUNCHINGS DURING 1959

During 1959, five Nike-Cajun and five Nike-Asp sounding rockets were launched at Wallops. The five Nike-Cajuns were the last of the International Geophysical Year (IGY) series, while the Nike-Asps were the initial launchings of this sounding rocket at Wallops, under a NASA Headquarters contract. Goddard was assigned responsibility for sounding rocket activity, but it was not until 1960 that Goddard-sponsored launches began at Wallops. The one exception was provided by the Arcon launchings of 1959, discussed in Chapter 15, which were actually a continuation of a program begun at NRL by the same people.

Activities concerning the first three of the five Nike-Cajun sounding rockets launched at Wallops in 1959 were under the direction of L. J. Cahill of the University of Iowa, as a part of IGY and its continuation through 1959. As has been discussed in Chapter 14, the Nike-Cajun was developed by the University of Michigan from a PARD test vehicle, without the aid of a prime contractor. As a result, any other users had to learn for themselves what the limitations of the vehicle were. The first of the Iowa vehicles, shown in figure 468 and launched on May 20, 1959, failed after burnout of the Cajun. The maximum velocity reached was near the expected value, but shortly afterward the vehicle slowed rapidly and failed to reach its desired altitude. In fact, an altitude of only 36 miles was reached instead of 86. It was conjectured that the vehicle diverged and either turned sideways or tumbled. The exact cause was not indicated, although it was suggested that the fins on the Cajun might have been destroyed by aerodynamic heating. Iowa had elected to leave the inconel caps off the leading edge of the Cajun

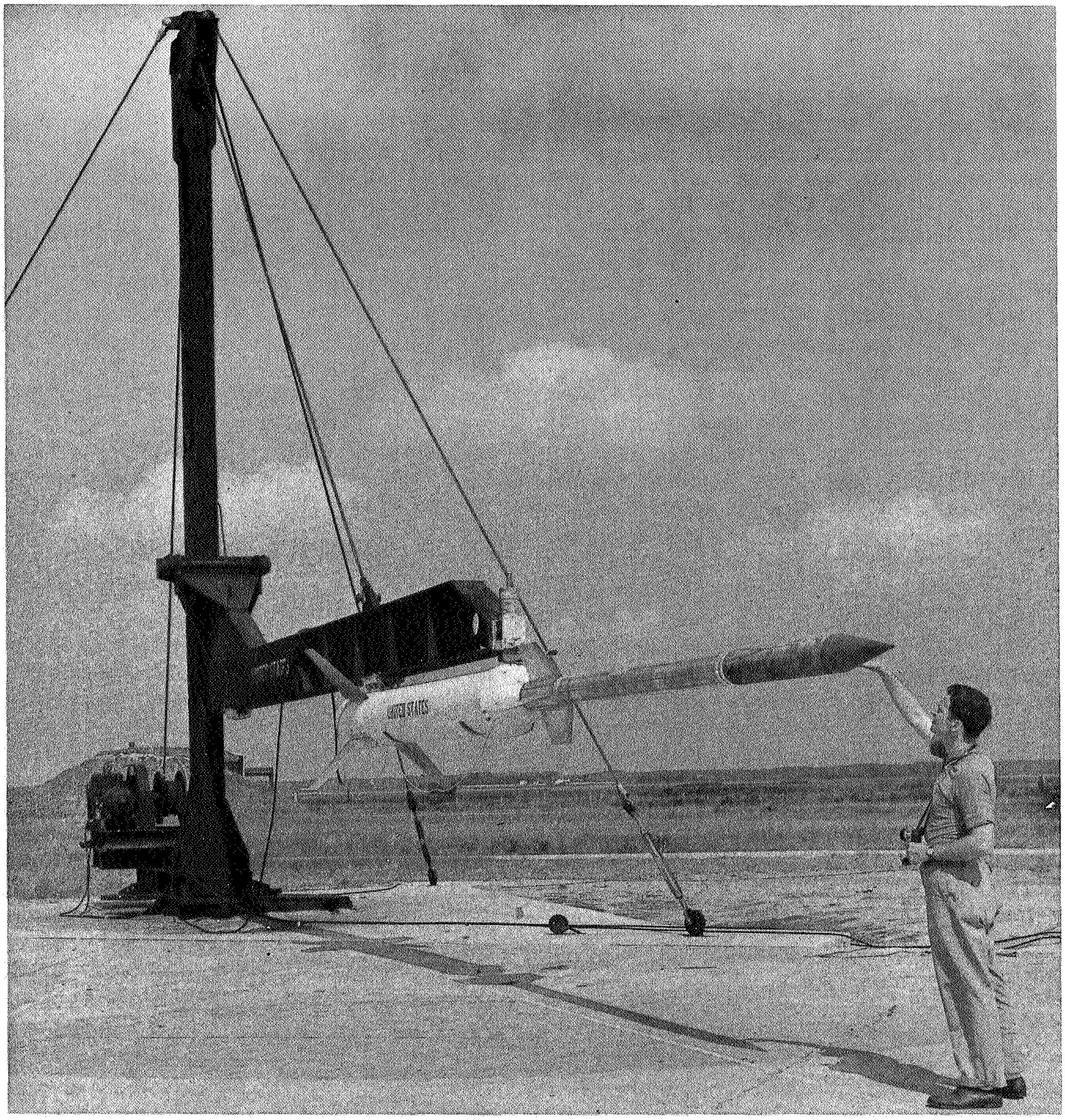


FIGURE 468. Nike-Cajun sounding rocket with University of Iowa payload on launcher at Wallops for flight test, May 20, 1959.

fins. On the second flight, on May 23, 1959, the model again went into a corkscrew flight path after Cajun burnout, and an altitude of only 40 miles was reached. This time, inconel caps had been added to the fins. For the third flight, on June 27, 1959, a double inconel cap was added to the fins, but again a divergence occurred at maximum velocity. The problem was taken to Langley where it was analyzed by DMES engineer R. L. Gungle, who found that the trouble was caused by structural divergence associated with excessive movement at the joint between the nose cone and the headcap of the Cajun (ref. 98). This analysis was later verified by a successful launching, on April 7, 1960, of a fourth Nike-Cajun with a redesigned connector.

Two Nike-Cajun sounding rockets were launched for N. W. Spencer of the University of Michigan on June 30 and July 1, 1959, as a part of the continued IGY program. Both of these tests were successful. These vehicles embodied the original design, which had already achieved a high record of success.

The Nike-Asp sounding rocket was adapted from the ASP (Atmospheric Sounding Projectile) which Cooper Development Corporation had designed for the Navy's BuShips, incorporating the Grand Central Rocket Company solid-fuel rocket motor developed by Grand Central as an improved Deacon and a competitor to Cajun. The Asp had four highly swept delta fins but otherwise was similar in appearance to the Cajun. It differed from the Cajun in that its case was made of steel and its performance was slightly superior. The addition of the Nike to the Asp was handled by Cooper under a Navy contract to provide a sounding rocket for IGY use. It was not used as extensively as the Nike-Cajun during IGY, although 12 were launched at the naval facility at Point Arguello, California, beginning in July 1959. A number of Nike-Asp sounding rockets were ordered from Cooper by the Navy transferees at NASA Headquarters and at Goddard in preference to Nike-Cajuns. In the Goddard numbering system for sounding rockets, Nike-Asp was assigned number 3, and Arcon was number 2. Nike-Cajun was restored to the inventory later and was assigned number 10. Nike-Asp never achieved the reliability of Nike-Cajun and was finally abandoned. By 1968, only 27 Nike-Asps had been launched by Goddard, compared with 301 Nike-Cajuns (ref. 99).

The first Nike-Asp launching at Wallops took place at 4:18 a.m. on August 17, 1959. The rocket and its launcher are shown in figure 469. In the Goddard numbering system, this vehicle was number 3.13, being the thirteenth launched. It was the first of five launched in 1959 by the Geophysics Corporation of America, under a contract with NASA Headquarters (NASw-25) monitored by Maurice Dubin of the Space Science Division of NASA Headquarters. Although the NASA scientist on this project was from Headquarters, it was identified by Wallops as a Goddard project. The purpose of these Nike-Asp launchings was to study winds at altitudes between 50 and 150 miles, by releasing sodium at twilight and analyzing the cloud movement. The first test was a complete success, with the payload reaching an altitude of 148 miles. The sodium vapor formed an immense cloud that was visible along the Atlantic coast for 700 miles. Remote photographic sites at Dam Neck and Camp A. P. Hill, Virginia, Andrews Air Force Base, Maryland, and Dover Air Force Base, Delaware, reported good visibility, and photographs were obtained for 40 minutes after the launching. This was to be the first of a continuing series of such experiments at Wallops over the next decade.

The successful test with this first sodium vapor cloud at Wallops brought a strong sense of satisfaction to the experimenters and Wallops personnel, but considerably disturbed the Commander of the Navy's Eastern Sea Frontier, who was considered to be the prime source of information for civil and military agencies along the eastern seaboard and who, in addition, took an active interest in evaluating all reports of unidentified flying objects. He had received queries from as far away as 700 miles, and requested that, in the future, Notices to Airmen (NOTAM's) of Wallops operations "describe

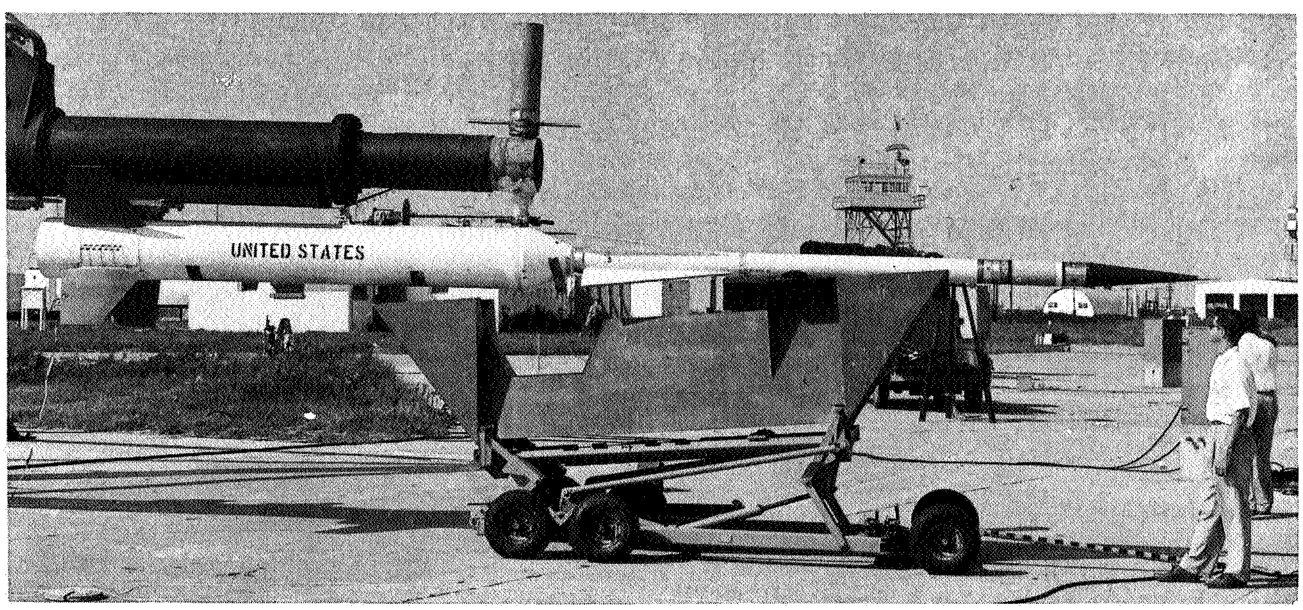


FIGURE 469. First Wallops Nike-Asp sounding rocket on launcher for flight test, August 18, 1959.

in detail the nature of the exercises, contingent upon National Defense security requirements."[30] There really must have been a hectic time in the Commander's office in the pre-dawn hours of August 17. Krieger assured Admiral Combs that his request would be carried out in the future, and said further,

> At the outset may I apologize for the inconvenience caused to your command by the flood of inquiries concerning our sodium flare experiment of August 17, 1959. Frankly we simply failed to foresee the amount of attention that would be attracted by this firing. In addition, the weather and seeing conditions turned out to be unbelievably good that morning.[31]

The second Nike-Asp launching was held at 7:12 p.m. on August 18, 1959, for an evening wind study, but the vehicle apparently broke apart at a range of 22,000 yards.

The final three launchings of this series took place in November 1959. On November 18, 1959, at 5:17 p.m., another very successful sodium cloud was created at high altitude. This time, other instrumentation sites in use were at Aberdeen Proving Ground, Maryland; DuPont Research Laboratory, Wilmington, Delaware; Grumman Aircraft, Bethpage, Long Island; Barnes Engineering Company, Stamford, Connecticut; Georgia Tech, Atlanta, Georgia; and Rome Air Force Base, New York. The following day, at 5:51 a.m., another launching was conducted and, although the vehicle appeared to perform satisfactorily, the sodium never ejected. Another attempt was made at 5:51 a.m., on November 20, 1959, but again the sodium was not ejected. Although disappointed by the three failures, Dubin was satisfied with the two very successful launches, and made plans for additional attempts.

UNIVERSITY OF MICHIGAN STRONGARM SOUNDING ROCKET

Chapters 12 and 13 have included a discussion of the role of the University of Michigan in development of the Nike-Deacon and Nike-Cajun sounding rockets under a contract with the Air Force Cambridge Research Center. A similar role was played by Michigan for AFCRC in development of the more powerful Exos sounding rocket, as has been discussed in Chapter 14.

During 1958, Michigan obtained a contract from the Army Ballistic Research Laboratory to develop a sounding rocket with a 1,000-mile-altitude capability for a 20-pound payload. This was about ten times the capability of Nike-Cajun, and three times that of Exos. Essentially the same personnel at Michigan were involved in the three projects—in particular, L. M. Jones, W. H. Hansen, and F. F. Fischbach. As before, Michigan personnel designed the new rocket vehicle around an existing PARD rocket system. This time, they selected the PARD Honest John five-stage vehicle as used in the JASON project, but with two seemingly minor modifications to the motors. The first three stages (Honest John-Nike-Nike in tandem) were left intact. For the fourth stage, the Recruit was replaced by a slower burning version of the motor named "Yardbird." This Thiokol motor burned for 3.4 seconds, compared with 1.5 seconds for the Recruit, and provided slightly more total impulse with lower acceleration loads. For the fifth stage, the T55 was replaced by the slightly larger Baby Sergeant rocket motor, which had more impulse. The name "Strongarm" was given to this five-stage sounding rocket. It was about 56 feet long and weighed 7,230 pounds at launch.

On December 19, 1958, Hansen and others from Michigan, along with W. W. Berning of BRL, visited PARD to obtain comments on the proposed vehicle and to solicit aid in its development and launching, as had been provided for the earlier vehicles. The visitors met with A. G. Swanson and J. T. Markley of PARD and J. W. Mayo of DMES. Swanson provided information on the performance of the system used in JASON, and Mayo provided drawings of the fins, couplings, and other hardware of the system. The purpose of the vehicle was to measure electron density at altitudes to 1,000 miles.

Swanson was disturbed that an Army agency was initiating a sounding rocket program with the same objective as that of the AFSWC program to which he was already giving assistance, and that the

30. Naval Speed Letter from Admiral T. S. Combs, Commander, Eastern Sea Frontier, to Director, Langley Research Center, Aug. 25, 1959, regarding sodium flare rocket launched at Wallops on Aug. 17, 1959.
31. Letter from R. L. Krieger to Admiral T. S. Combs, Sept. 3, 1959, regarding sodium flare experiment at Wallops on Aug. 17, 1959.

program was in a field of obvious interest to the new civilian space agency, NASA. He was also disturbed by the fact that the most qualified people in the development of solid-fuel sounding rocket systems, namely the Langley PARD, DMES, and IRD groups, were not given a more responsible assignment in the NASA program. In his report on the visit, he observed:

> The requests for assistance and information from PARD indicate that many of the vehicles used or planned by PARD for other types of investigations can and should be adapted to sounding rocket programs. It would seem that PARD should not only be allowed but should be encouraged to extend its capabilities in the field of sounding rocket vehicle development and should develop, in conjunction with IRD, the capability to conduct scientific experiments of its own. Such programs would, of course, be coordinated with the central office responsible for sounding rocket programs (ref. 100).

On July 15, 1959, Hansen and Fischbach returned to PARD and asked for PARD to check their trajectory, stability, and heating calculations for the vehicle, and to provide the assistance of a project engineer for test firing the vehicle at Wallops. One innovation used by the University of Michigan on this vehicle was to enshroud the entire nose cone with a shell of Teflon, in order to combat aerodynamic heating effects on the thin-walled fifth-stage motor as well as the payload. Douglas Aircraft Company provided assistance in the use of Teflon. Swanson recommended that the assistance requested of PARD be provided because of the general interest of NASA in the project (ref. 101). Before approving the request for assistance, the NASA Office of Aeronautical and Space Research at Headquarters sent a memorandum to Homer E. Newell, Jr., Assistant Director for Space Research in the Office of Space Flight Development, asking him if the project was important and worthy of support from the viewpoint of space science (ref. 102). After an affirmative answer had been received, an RA was issued to cover the requested assistance, and BRL was informed that NASA would be pleased to assist.

The first vehicle, shown in figure 470, was launched at Wallops on November 10, 1959. Everything about the vehicle seemed to perform as expected, and although the radars did not track the last stage to its maximum altitude, it was calculated—from the trajectory followed by the first three stages—that a maximum altitude of 1,120 miles had been attained. In the second launching, on November 18, 1959, the third stage failed to ignite. When this failure was traced to improper wiring that could be corrected easily, the vehicle appeared to be ready for use (ref. 103).

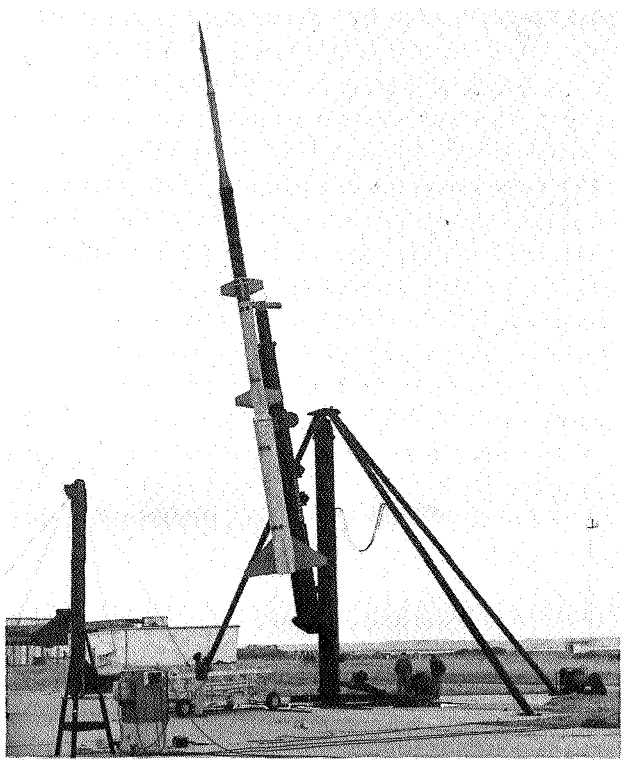


FIGURE 470. First University of Michigan Strongarm sounding rocket on launcher at Wallops for test, November 10, 1959.

Three additional vehicles were prepared. Two of these, launched on July 13, 1960, failed for the same reason—the fifth stage did not fire in either case. Again, on August 1, 1960, the fifth stage failed to ignite. An investigation of the failures indicated that the main trouble was most likely with the Yardbird motor. In one case, it appeared that the Yardbird failed to ignite and the Baby Sergeant fired early. In another, the Yardbird appeared to have diverged, possibly from a failure in the nozzle (ref. 104).

Two more attempts were made by BRL on February 14 and 17, 1961, with vehicles procured for research tests; but the same dire results followed. After six failures in a row, the project was canceled. It was generally agreed that the Yardbird rocket motor was the main cause of the trouble. The capabilities of Strongarm under different launch and weight conditions were computed by Chance Vought Corporation in the study of Strongarm as one of the sounding rockets analyzed for NASA (ref. 105).

AIR FORCE JAVELIN AND JOURNEYMAN PROJECTS

The Javelin and Journeyman projects were planned by the Air Force Special Weapons Command (AFSWC) as a follow-on to the JASON project discussed in Chapter 15. Whereas the five-stage sounding rocket in the JASON project provided an altitude capability of 500 miles, Javelin was to measure radiation at altitudes to 1,000 miles, and Journeyman, to 2,000 miles. Entirely new vehicles were required to achieve these altitudes, and AFSWC wanted PARD and Wallops to assist in their development and launching, as had been the case with JASON. Although development of the required launch vehicles was initiated, only the one for the Javelin project was ever flown by the Air Force at Wallops. With the creation of NASA and the transfer of many projects from ARPA to NASA, there was a realignment of the remaining projects at ARPA, and this one was terminated. The launch vehicles in the project had capabilities of interest to the new Goddard Space Flight Center, and their development was completed under the sponsorship of Goddard, with identification by the project titles "Javelin" and "Journeyman." Contracts between AFSWC and Aerolab Development Company, Inc., for construction of the vehicles were later replaced by Goddard contracts with Aerolab. Aerolab applied the designations Argo D4 to Javelin and Argo D8 to Journeyman vehicles.

In mid-September 1958, representatives of AFSWC visited PARD to discuss the possibility of launching a payload remaining from the JASON project. The launch would use a PARD five-stage Sergeant vehicle described in Chapter 15 and launched for the first time in June 1958. At PARD, the representatives talked with A. G. Swanson and J. T. Markley, who had been the two main contacts in the JASON project. It was the wish of AFSWC to launch the vehicle in November 1958. With conversion of the NACA to NASA imminent, both Swanson and Markley were reluctant to make any commitments as to launch date, particularly in view of the absence of the high priority carried earlier by the JASON project. Some encouragement was given to AFSWC by the information that, under NASA, an interest would probably exist for a Sergeant-type sounding rocket (ref. 106). In addition, Swanson agreed to make some heating and trajectory calculations for the Sergeant system as he had done for JASON.

In November 1958, AFSWC informed Langley that the Air Force had formally approved the firing of six complete Sergeant systems, and asked that Swanson be sent to Kirtland Air Force Base, new Mexico, for about 5 days in early December to work directly with AFSWC people on the project.[32] In preparation for this assignment and in appreciation of the need experienced by NASA for launch vehicles in its own sounding rocket program, Swanson made an analysis of the capabilities of some existing systems plus two new systems incorporating the ABL X248 motor (ref. 107). The calculated performance of each system, in terms of altitude reached with a 50-pound payload, is shown in the following table:

32. Letter from AFSWC to Langley, Nov. 4, 1958, regarding temporary duty of NASA personnel.

Vehicle	*Rocket Motors*	*Altitude (miles)*
Nike-Cajun	Nike-Cajun	80
Exos	Honest John-Nike-Recruit	300
JASON	Honest John-Nike-Nike-Recruit-T55	430
Sergeant, five stages	Sergeant-Lance-Lance-Recruit-T55	840
New (1)	Honest John-Nike-Nike-X248	910
New (2)	Sergeant-Lance-Lance-X248	2,020

The greater potential of the two new systems analyzed by Swanson, nearly 1,000 miles for one and over 2,000 miles for the other, prompted AFSWC to change its mind about using the PARD Sergeant five-stage system. Instead, the two new systems were adopted for the Javelin and Journeyman projects, respectively. During Swanson's tour of duty at AFSWC in December 1958, final decisions regarding these vehicles were made. Following informal discussions between NASA Headquarters and representatives of USAF Headquarters, the NASA Administrator informed USAF Headquarters on January 22, 1959, that he would be glad to assist and would arrange for seven firings at Wallops in the Javelin and Journeyman projects. This was "jumping the gun" somewhat for in the accustomed manner under the NACA, the official request for assistance, prepared by WADC's Trygve Blom, Air Force member, Aircraft and Missile Projects Allocation and Priority Group, was not made until February 26, 1959, over a month later. The request confirmed the plan for three Javelin firings and four Journeyman firings with two new vehicles incorporating the X248 rocket motor, as proposed by Swanson.[33] On March 23, 1959, NASA Headquarters informed WADC of its approval of the Javelin and Journeyman programs as outlined by Blom, and assigned RA A73L311 to cover the assistance.

Despite the apparent ready willingness of NASA to assist AFSWC in this new program, there was not, on the part of Langley, the same feeling of justification that had been present in the JASON nuclear explosion project. Even though AFSWC called the new program an extension of JASON, it appeared to Langley to be a general research study of radiation at high altitudes—a definite field of research planned for NASA in its own sounding rocket program.

Following the agreement of NASA to assist in the Javelin and Journeyman programs, AFSWC provided a formal Operation Plan (ref. 108). In this document, the following point was made:

> Although highly successful, Project JASON raised new questions of great scientific importance. A major residual question is the exact correlation of JASON sounding rocket measurements with Explorer satellite measurements. The objective of Project Javelin/Journeyman is to find answers to these new questions.

Three firings of Javelin to an altitude of 1,000 miles and four firings of Journeyman to an altitude of 2,000 miles were planned, with firings to begin on May 28, 1959. Wallops was to supervise assembly and launch and provide radar tracking and telemeter reception. The Millstone Hill radar was to provide additional tracking, and AMR was to record telemetered data. The Project Director was Lieutenant Colonel J. L. Beavers, and the AFSWC representative at Wallops was Major F. W. Korbitz. AFSWC personnel in the project were aware of the change between the status of this project and that of JASON, and recognized the difficulties with the FAA created by the JASON firings with respect to commercial air routes. They were also aware of the feeling of intrusion into the domain of NASA, for in the Operation Plan it was cautioned that,

> All things considered, AFSWC will be in a difficult and delicate position at Wallops Island. Extreme tact, diplomacy, and appreciation for the NASA's very real problems will be required.

In view of the assignment to ARPA of military space operations, and to NASA of all civilian space operations, there were rumors at AFSWC that NASA might even prohibit support of such military projects at Wallops.

33. Letter from Trygve Blom to NASA, Feb. 26, 1959, requesting assistance in connection with Javelin and Journeyman

The three Javelin sounding rockets were launched at Wallops; the first on July 7, 1959; the second on July 21, 1959; and the third on January 14, 1960. The first and third launchings were successful. By the time of the first Javelin launching, an agreement had been reached between Wallops, the Navy, and the FAA, as has been discussed in Chapter 15, and AFSWC let Wallops control the time of firing in accordance with the new agreements.

The success of the first flight was described by J. C. Palmer in the official firing log for July 7, 1959, as follows:

> Model F133-3079 was launched at 0715 with good results from cameras, radars, and Air Force telemeter receiver. The FPS-16 radar set a new record by tracking the model to 392,000 yards. The Mod II and SCR-584 radars tracked the model to between 60-70,000 yards before losing it.
>
> The ABL X-248 rocket motor seemed to perform as expected as did the first three stages. Millstone Hill radar tracked the model for 17 minutes and 40 seconds. Antigua tracked it - telemeter - for 21 minutes and 5 seconds. Patrick tracked the telemeter signal for approximately 18.5 minutes. Wallops lost the signal at 18 minutes and 15 seconds. The model flew very close to the calculated trajectory. In general it was a very satisfactory flight.
>
> Range clearance was provided by Patrol Squadron 56 of Norfolk. Some difficulty was experienced with FAA traffic, and bad weather in the third stage impact area delayed the firing 1 hour and 15 minutes.

The second flight, made on July 21, 1959, was unsuccessful because of failure of the X248 motor to ignite. The vehicles were identified by AFSWC as JV-1, JV-2, and JV-3. The PARD designation was F133.

The first Javelin to be fired is shown in figure 471. It was essentially the five-stage Honest John vehicle with the upper two stages replaced by an ABL X248 rocket motor. The first three stages (Honest John-Nike-Nike) propelled the system to an altitude of 150,000 feet, at which point the X248 motor was ignited. The maximum altitude reached was about 650 miles. The X248 stage was aerodynamically unstable and maintained its orientation through induced spinning at a rate of about 2 revolutions per second. The spin was imparted by having the fins on the third stage set at a small angle of incidence. A heat shield or shroud protected the last-stage motor and payload within the atmosphere, and was cast off prior to ignition of the X248 motor. The payload consisted of instrumentation to measure charged particles trapped in the earth's magnetic field, and was provided by Lock-

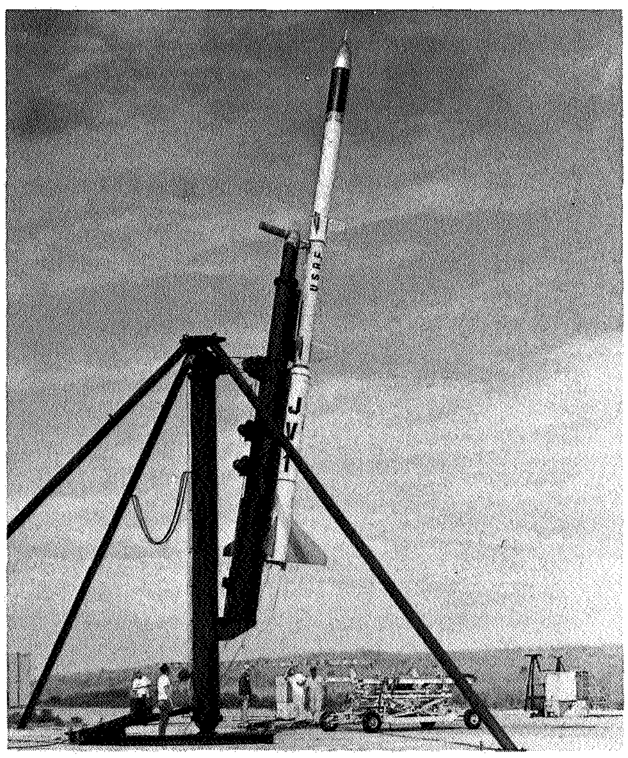


FIGURE 471. First AFSWC Javelin sounding rocket ready for flight test, July 7, 1959.

heed Missiles and Space Division under contract to AFSWC. It was generally similar to the payload used in JASON, and contained a standard FM/FM telemeter.

The principal item of instrumentation was a magnetic spectrometer for observing the flux and spectrum of electrons. A Geiger counter was also used. A Schonstedt magnetic aspect indicator was provided to indicate the instantaneous orientation of the spectrometer with the direction of the magnetic field. During the data gathering period, the payload developed a wobble of about 30 degrees with a period of 6 seconds, in addition to the original spin rate. The ascent trajectory of Javelin generally followed magnetic lines of force and was in the outer radiation belt. During descent, the payload crossed magnetic lines and passed through the gap between the inner and outer radiation zones. The measurements indicated that the natural radiation in the outer belt was composed almost entirely of electrons with energy of less than 1.5 mev (ref. 109).

Goddard considered the Javelin and Journeyman sounding rockets very desirable for continued space exploration. In September 1959, Langley sent Goddard all information available on the design of both vehicles and on the actual performance indicated by the Air Force launchings of July 1959 (ref. 110). Goddard contracted with Aerolab to supply both systems. Charles Campbell was the project manager at Goddard for the development program, and made many trips to Langley for consultation with PARD and engineering systems staff members. The main difference between the Goddard and Air Force Javelin was in the altitude of ignition of the last stage.

The first Goddard Javelin was flown successfully at Wallops on December 22, 1959. This was essentially a proof test, but some measurements were made of the vibrational environment created by the X248 motor during burning. This was the beginning of a continuing space flight program at Wallops with the Javelin vehicle. (See ref. 111 for additional description and data regarding performance capabilities of the Javelin vehicle.)

The Journeyman vehicle, as proposed by Swanson and adopted originally by AFSWC, was canceled by AFSWC before it was flown. Goddard, however, went ahead with development along the contemplated lines, and the first flight was made at the Pacific Missile Range on September 19, 1960, in the very successful nuclear emulsion recovery experiment (NERV I). Although this flight was successful, the Journeyman was not to become a "workhorse" like Javelin. The Journeyman vehicle consisted of the Sergeant or Pollux first stage, plus two Recruits strapped on the sides, with the second and third stages being Lance motors, and the last stage, an ABL X248. It was about 62 feet long and weighed 14,000 pounds. It could carry a 50-pound payload to an altitude of 2,000 miles. One Journeyman was launched at Wallops on September 22, 1962, as shown in figure 472. (See ref. 112 for performance summary.)

AFSWC canceled the Journeyman project in November 1959 because the development took longer than expected, and by the time it could be flown other probes had already surveyed the planned altitude range. AFSWC proposed to substitute a different launch vehicle for Journeyman, one that was calculated to attain an altitude of 30,000 miles. This vehicle, called Journeyman B, was to have the Sergeant and two Recruits of the original Journeyman for its first stage, but the upper stages were changed to an ABL X254 motor for the second stage, an Aerojet 30KS8000 motor for the third stage, and a 15-inch spherical motor for the fourth stage. The X254 motor was the one developed for the third stage of the NASA Scout vehicle and was a scaled-up version of the X248.

AFSWC asked Langley and Wallops to provide the same type of assistance in the development of Journeyman B as they had furnished for Javelin.[34] Langley agreed to provide this assistance, but by this time the agreement for the joint development of Scout by NASA and the Air Force had been signed, and Journeyman B became a part of this joint program. Under the joint Scout program, the Air Force Scout vehicles were called Blue Scout and the Journeyman B was called Blue Scout, Jr. Several were launched successfully at Cape Canaveral. The Journeyman B, as flown, had a Castor rocket motor for the first stage instead of the Sergeant, and a NOTS 17-inch spherical motor for the fourth stage instead of the 15-inch spherical motor planned. Unlike the earlier Sergeant vehicles fired at Wallops, the Journeyman B did not have two Recruits strapped on for extra acceleration at launch, but instead had strapped-on spin rockets

34. Letter from Lt. Col. J. L. Beavers, II, to E. C. Draley, Langley, Nov. 13, 1959, regarding reorientation of Journeyman Program.

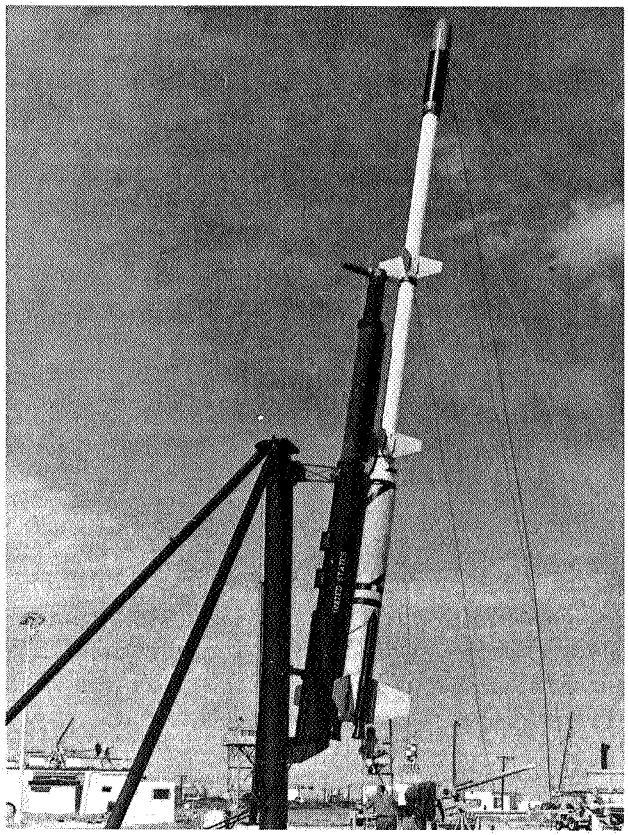


FIGURE 472. Journeyman 11.02 sounding rocket ready for launching at Wallops, September 22, 1962.

to spin the vehicle at launch to reduce dispersion during the low-acceleration period of flight—the system used earlier with the Lockheed X-17 vehicle. The Journeyman B was about 40 feet long and weighed 13,250 pounds. It had the capability of lifting a 30-pound payload to an altitude of 13,700 miles. Later, Langley was to employ the Journeyman B vehicle, without the fourth stage spherical motor, in the RAM flight program at Wallops, a program to study communications blackout during reentry.

SCOUT SOLID-FUEL SATELLITE LAUNCH VEHICLE

The NASA Scout four-stage solid-fuel satellite launch vehicle was a Langley development, initiated under the NACA as an extension of the hypersonic multistage rocket-model systems of PARD, and completed under NASA as a part of the space program. In 1957, after repeated success had been achieved with the Honest John five-stage vehicle at Wallops at a Mach number of 15, and the construction of the Mach 18 Sergeant five-stage vehicle was well under way, a study was initiated at PARD to determine the best method for extending the speed capabilities of solid-rocket systems at Wallops to ICBM and satellite reentry speeds. Appendix F presents a list of rocket propulsion systems developed at Wallops during the period 1945–1959.

A contract had been let to develop the Cherokee rocket motor, a high-performance motor to replace the T55 last stage of the five-stage vehicles, as has been discussed in Chapter 15, but this was known to be only an interim step since it would increase the Mach number only from 18 to 19 or perhaps 20 at the most. The successful development of a 10-inch spherical rocket motor with a high propellant-mass fraction, discussed in Chapter 14, led to calculations of the performance of a vehicle made up of several stages of such motors of different sizes. One promising configuration consisted of a Sergeant as the first stage and a 40-inch spherical motor for the second stage, followed by 25-inch and 10-inch spherical motors. This configuration was calculated to provide flight speeds in excess of the speed of escape from the earth. A contract was awarded Thiokol for development of the required 40-inch and 25-inch spherical motors early in 1958 as was discussed in Chapter 14, but it was known that their development would not be completed for over a year. The PARD team, notably P. R. Hill, J. G. Thibodaux, M. A. Faget, R. O. Piland, and W. E. Stoney, Jr., continued to evaluate other solid-rocket systems in an attempt to find a high-performance combination designed around existing motors. Only solid-fuel motors were considered because of the successful experience of PARD and Wallops with such motors. When it was learned that Aerojet-General Corporation had developed a very large solid-rocket motor, called Jupiter Senior, studies of the applicability of this motor to the PARD needs were immediately made.

The Jupiter Senior was the largest solid-rocket motor in existence at the time, and its development was related to the needs of the fleet ballistic missile program. It was developed by Aerojet as a part of the joint Army-Navy project to develop a solid-fuel IRBM. Two static firings at Sacramento, California—both successful—were made in March and April 1957. Experience with this motor led Aerojet to development of the larger solid motors for both the Polaris and Minuteman missiles.[35] Jupiter Senior had a diameter of 40 inches, a length of 30 feet, and a weight of 22,650 pounds, almost three times the weight of Sergeant. It provided a thrust of 100,000 pounds for 40 seconds with its propellant of ammonium perchlorate-polyurethane plus aluminum. This first design was to achieve an enviable record of 13 static firings and 32 flight tests without a failure.

At about the same time that PARD learned of the Jupiter Senior motor, it was also learned that Thiokol was able to improve the Sergeant motor by changing the propellant from polysulfide to a polybutadiene-acrylic acid formulation plus metallic additives. The possibility of a 20-percent increase in impulse was indicated for the improved Sergeant. Stoney analyzed a vehicle consisting of the Jupiter Senior as the first stage, an improved Sergeant as the second stage, and ABL X248 motors for the third and fourth stages. The X248 motor had already been developed for the Vanguard satellite vehicle. When analysis indicated the possibility of attaining satellite speeds with such a four-stage vehicle, it was immediately proposed for development because it was believed that it could be made operational ahead of the spherical rocket system. All of the motors were essentially on hand.

Two main problems faced this new four-stage vehicle. First, it was to be the most expensive vehicle ever developed by PARD, and no funds were immediately available. Second, as a satellite launch vehicle, it was in direct competition with the Navy's Vanguard and the Army's Jupiter C, as well as with the Air Force's Thor-Able, which was rapidly nearing a state of readiness. The main selling points for the PARD vehicle were its lower cost, operational simplicity, and, it was hoped, greater reliability. When I. H. Abbott emphatically informed PARD, early in 1958, that NACA Headquarters would not be receptive to a proposal for development of another satellite vehicle, the proposal lay dormant although design studies continued at Langley. As a satellite vehicle, it would differ from the existing PARD multistage launch vehicles in that a control and guidance system would be required.

An opportunity to propose the new four-stage vehicle came at the end of March 1958, when J. W. Crowley asked Langley to prepare a Space Technology program for the new space agency, as has been discussed in Chapter 15. Without any opposition, this vehicle was listed as a requirement of the program for the investigation of manned space flight and reentry problems. The sum of $4 million was listed to provide for five "small-scale recoverable orbiters" (ref. 113). It was proposed that preliminary orbital flights to study the problems of manned space flight be made with small models launched by this vehicle. It was referred to for a time as the "solid orbiter." A research authorization was requested on May 6, 1958, to cover the investigation of a four-stage solid-fuel satellite system capable of launching a 150-pound satellite in a 500-mile orbit. Further analysis of the system indicated the desirability of replacing the third-stage X248 motor with a larger motor of the same type. By this time, the vehicle was officially in the space program and the fact that this change required development of a new motor stirred scarcely a ripple on the management surface. The overall space plans for NASA were so grandiose when compared with NACA operations that cost was now a relatively minor item.

Before the orbiter received official status, Langley negotiated a contract with Thiokol, through Army Ordnance, for development and delivery of four improved Sergeant motors at a cost of $264,135. The money was available from an NACA 1958 supplemental appropriation of March 1958. Langley reasoned that the improved Sergeant would be useful in the Wallops multistage rocket

35. Letter (with enclosures) from J. R. Crooks, Aerojet General, to J. A. Shortal, Feb. 3, 1971, regarding history of Algol.

program even if the orbiter were not approved. It was fortunate that this step was taken because some unforeseen difficulties were to plague the rocket development, and the extra leadtime was welcome.

In the meantime, the Air Force was considering a new solid-rocket test vehicle for a 100-pound payload to be carried to an altitude of 2,000 miles. On June 4, 1958, representatives from the NACA, including M. A. Faget and R. R. Gilruth, met with General H. A. Boushey and his staff at USAF Headquarters to discuss the possibility of joint action to develop a common test system. The Air Force had received a proposal from Aerophysics Development Corporation for a vehicle incorporating the Aerojet 40-inch motor as the first stage, a 1/4-length 40-inch motor as the second stage, and a Vanguard motor as the third stage. The Air Force had $1 million to use in the initial procurement. Faget agreed to prepare specifications for the NACA system and to obtain the reaction of the NACA Director to a joint program (ref. 114). The chief Air Force agency considering the vehicle at this time was Holloman Air Force Base. As discussed earlier in this chapter, AFSWC was also interested in a high-performance probe vehicle for the Javelin-Journeyman program. At a later meeting on June 16, 1958, some of the details of a joint vehicle were discussed. It was agreed that a joint vehicle would have aerodynamic stabilization on the first two stages, with parallel development of reaction stabilization. The last stage was to have either spin or reaction stabilization. It was agreed that the vehicle would be developed so that two, three, or four stages could be used (ref. 115).

At a meeting on July 8–10, 1958, representatives of the NACA and the Air Force met at NACA Headquarters and drafted a mutually acceptable specification for the joint system. The NACA was represented by C. Wood, M. A. Faget, P. E. Purser, M. J. Stoller, W. E. Stoney, Jr., and J. G. Thibodaux. Now the NACA four-stage system was accepted with its Jupiter Senior first stage with fins, an improved Sergeant in the second stage with flare stabilization, a new 2,200-pound motor with reaction controls as the third stage, and a Meteor motor with reaction jets as the fourth stage. The system was to be capable of placing a 100-pound payload in a 400-mile polar orbit. A total of eight vehicles was to be considered for the initial order for the Air Force. It was agreed that at least the first three vehicles would be test fired at the NACA's Wallops test site.[36]

Nothing more was done on this joint plan until NASA was created. One of the understandings reached between DOD and NASA was that NASA would proceed with development of a solid-rocket test vehicle to meet its requirements, and the Air Force would then consider modifying the vehicle to meet its requirements. A joint team would coordinate the work of the two organizations (ref. 116).

Langley proceeded to develop the orbiter vehicle in the usual manner. Rocket motors and hardware were to be procured, with Langley acting as overall system manager. W. E. Stoney, Jr., of PARD was assigned overall responsibility. Stoney applied the name "Scouts" to the vehicle as an acronym for Solid Controlled Orbital Utility Test System. The name was shortened to "Scout" for simplicity. Several engineers at PARD were assigned to work with Stoney as required, while the engineering design was handled by DMES, and the instrumentation by IRD.The PARD Rocket Section, under J. G. Thibodaux, was given responsibility for all rocket procurement. Five contracts were required for the basic components of the vehicle.

The rocket motors were to be procured in three contracts. First, the first-stage Jupiter Senior, renamed "Algol," was to be procured from Aerojet-General, the second stage improved Sergeant, renamed "Castor," from Thiokol via Army Ordnance, and the third and fourth stages from ABL via Navy BuOrd. The guidance and control system was to be a fourth contract. The fifth contract was to cover airframe hardware, service tower, launcher, and assembly at Wallops.

The first contract negotiated under the Scout program was finalized with ABL on October 23, 1958, for the third and fourth stages. Four motors of each type were to be delivered. The most urgent part of this contract was development of the third-stage motor. This motor, designated X254, was basically an enlarged X248 motor. It had a wound fiberglass-phenolic case of the same type as the X248, a diameter of 30 inches, a length of 9.5 feet, and a weight of about 2,285 pounds. It was a long-burning motor (40 seconds) and produced a thrust of 13,400 pounds. The X254 was named "Antares" by PARD. When it was learned that ABL would be able to supply X248 motors for this project, the plans

36. Letter from Clotaire Wood to Langley, July 11, 1958, enclosing Specifications for Solid-Fuel Rocket Test Vehicle, dated July 10, 1958.

were changed to include these for the upper stage instead of the Grand Central Meteor proposed by the Air Force. The X248 motor, as used here, was named "Altair." R. L. Swain, PARD rocket engineer, was assigned to monitor the ABL contract. One change made in the early design of the X254 (Antares) was to increase the thickness of the wall from 0.072 inch to 0.100 inch for increased strength in the vehicle structure (ref. 117). With this change, the motor designation became X254A1.

The next contract to be awarded was that with Aerojet-General Corporation for the Algol motors. The contract became effective on December 1, 1958, following several months of negotiations. The contract covered several static firings and the delivery of nine motors. The contract was monitored by W. K. Hagginbothom of PARD. Because this motor was not a fully qualified version, its operation was initially limited to a temperature of 70°F. This limitation imposed a special requirement for a storage and shipping container, and a combination container and transporter named a "transtainer" was developed, which had its own temperature control system. One of these "transtainers" was used for each shipment from Aerojet in California across the country to Wallops.

The third contract, signed on December 5, 1958, was with Thiokol, through Army Ordnance, for the third-stage Castor motors. As mentioned earlier, Thiokol had begun work on the Castor for the NACA under an earlier contract. The requirements had increased because the motors were now desired for Scout and Little Joe as well as for general PARD rocket-model use. A combined contract covered all these needs. R. D. Smith of PARD was appointed monitor for the contract. By this time, Thiokol had found that adapting the new propellant to the Sergeant to create the Castor motor was not as simple as had been indicated at first. The first static firing had been quite successful, but attempts to load additional motors resulted in many rejects and difficulties. To avoid delays in the Little Joe program, some of the motors were produced with the older polysulfide propellant. Thibodaux named these motors "Pollux" as a near twin to Castor, since identical cases were used for the two motors.

Because of the difficulties encountered by Thiokol with the Castor motor, Stoney decided to procure four Jupiter Junior motors from Aerojet as a backup. The Jupiter Junior motor was developed by Aerojet along with the Jupiter Senior but was not originally considered by PARD for Scout because it was almost identical to the improved Sergeant in performance. Aerojet renamed these motors "Aerojet Junior." As supplied for Scout, the motors used the same motor case as that for Castor and, with their polyurethane propellant, provided about the same performance as the Castor. Motors for three static firings were specified in this extension of the Aerojet contract, as well as the four motors for flight use. The motors were successfully developed and delivered by Aerojet, but they were not used on the NASA Scout. In 1966, these motors were to be returned to Aerojet for examination and refurbishing. Two of them were used successfully in Project Scanner flight tests at Wallops in August and December of that year. Aerojet Junior motors were also used in some of the Air Force versions of Scout and in later Aerojet sounding rockets for NASA.

While the contracts for the rocket motors were being negotiated, specifications were being prepared for the overall vehicle and its control and guidance system. The plan for a satellite launch was to program the flight path of Scout on a ballistic trajectory up to ignition of the fourth stage, which was to be stabilized by spin in the same manner as that used for Vanguard. With respect to this flight path, the vehicle was to be stabilized by an automatic control and guidance system actuating controls on the first stage, and by hydrogen peroxide reaction jets on the second and third stages. The Algol motor was equipped with four 45-degree delta fins for partial aerodynamic stability of the vehicle at launch. Control was exercised through a combination of delta tip controls on the fins plus interconnected vanes within the jet exhaust. Proposals for the guidance system were received from eight companies on October 20, 1958, and after several months of negotiation a contract was awarded to Minneapolis-Honeywell on January 12, 1959. In the original specifications, both the first and second stages were aerodynamically stable, but this was changed in March 1959 to provide active guidance to the second stage as well as to the third stage with hydrogen-peroxide reaction jet controls.

The fifth contract was for the airframe and launcher. The specifications called for four vehicle airframes and one launcher. Although the cost estimate was only about $1 million, 22 contractors, including all the major airplane companies (ref. 118), indicated a desire to bid. Interest was high because of the potential gains from follow-on contracts for the Air Force as well as NASA. After a thorough analysis of all proposals submitted, Chance Vought Aircraft was selected and a contract was awarded on April 21, 1959, for a fixed price of $1,069,300. Initially, assembly was to be made by Langley and Wallops labor, but before the first vehicle was delivered, the Vought contract was amended to include field services for assembly, as well as construction.

The Scout was developed under the cognizance and funding of the Office of Space Flight Development, whose Director was Abe Silverstein. Silverstein obtained the transfer of Elliot Mitchell from Navy BuOrd to his office to oversee solid-rocket motor development, and Mitchell promptly took Scout under his wing. PARD had had earlier contacts with Mitchell in connection with the Deacon rocket motor procured through BuOrd. Kurt Stehling was also available to Silverstein from the NRL Vanguard group transferred to NASA. Although Langley was responsible for development of Scout, Silverstein asked Gilruth and the Space Task Group to oversee the activities of Langley for him. Gilruth was officially listed as one of the Assistant Directors of the Goddard Space Flight Center, and it was expected that Scout, as well as Mercury, would eventually be at Goddard.

At the request of Silverstein, J. A. Shortal, W. E. Stoney, Jr., and E. C. Kilgore described the Scout system to NASA Headquarters personnel on November 21, 1958. In attendance were representatives from the Vanguard project, as well as potential payload people. The Vanguard people were generally noncommittal at the meeting but were obviously not enthusiastic about this competition for Vanguard. Stoney emphasized that the Scout was a logical extension of the PARD rocket vehicles to allow research at reentry speeds. The only thing new about Scout was its reaction control system, which allowed controlled flight outside the atmosphere (ref. 119). In December 1958, a detailed plan for use of the first eight Scouts in general research at Wallops was sent to NASA Headquarters. This covered research support for such things as ICBM nose cones, Dyna-Soar, manned space capsules, inflatable and self-erecting space structures, reentry target identification, reentry physics, and space communications.

The following tests were proposed for the first eight Scouts (ref. 120):

1. Vertical shot with a 12-foot inflatable sphere.
2. Test of heat transfer to nose cone reentering at Mach 30.
3. Ablation tests of low-drag ICBM nose.
4. Orbital test of 12-foot sphere.
5. Test of heat transfer to glide-type vehicle.
6. Test of heat transfer to manned space capsule.
7. Vertical launch of erectable radar dish.
8. Orbiting of a recoverable space capsule.

The chief purpose behind the submittal of this plan was to forestall assignment of any of the payloads for the development Scouts to Space Center projects, by showing that Langley had well-justified uses planned for them.

In December 1958, Mitchell and Stehling raised the question of substituting the Polaris propulsion system for the first two stages of Scout. Their idea was to take advantage of the extensive development program underway for Polaris. The two propulsion stages for Polaris had about the same performance as the first two stages proposed for Scout. Langley had considered the Polaris motors earlier in the Scout program but had decided to stay away from this military program of higher priority. A new evaluation of the motors was made by a team composed of Stoney, Thibodaux, P. R. Hill, and E. C. Kilgore. After visits to Aerojet, Lockheed, and BuOrd, the team recommended that the Polaris motors not be used, because of their higher cost.[37] The estimated unit cost of Scout at this time is of interest, in view of later upward revisions. The cost estimate was as follows for the two versions of Scout:

Item	*Current Version*	*Polaris Version*
First stage	$110,000	$146,500
Second stage	75,000	164,133
Third stage	35,000	35,000
Fourth stage	12,000	12,000
Hardware	60,000	60,000
Guidance and Control	50,000	50,000
Total	$342,000	$467,633

37. Letter from Langley to Space Task Group, Jan. 22, 1959, regarding selection of Senior rocket motor for first stage of Scout vehicles.

The Air Force bided its time during the negotiations of contracts for Scout. Air Force interest picked up in April 1959 when the service asked NASA Headquarters to procure eight sets of propulsion components for its initial program.

The Space Task Group continued to take an interest in the Scout mainly because Silverstein insisted on it. In February 1959, R. O. Piland returned to Langley after a temporary tour of duty with the Killian Committee. Because so many experienced rocket-model men had transferred from PARD to STG, PARD Chief, J. A. Shortal was pleased when Piland returned to Langley, and tried to get him to stay at PARD with greater rocket-model responsibilities. Since Piland was not convinced that PARD would have an active part in a continuing space flight program, he elected to join STG to look after Scout. Piland's assignment was soon expanded at STG to include responsibility for Mercury, in his position as Assistant Chief of Flight Systems Division of STG (ref. 121). J. T. Markley represented STG in some of the negotiations for the Scout program.

Although the major elements of Scout were procured under contract, one rather large area remained to be handled by Langley. This was the instrumentation of the vehicle and of the first four spacecraft or payloads. The test program proposed for the first eight Scouts in December 1958 was considered too broad for the first development firings, and a new plan was developed with emphasis on vehicle certification. In each test, however, an instrumented payload was carried by the vehicle to provide scientific data in case of success.

The first two flights were scheduled to be just vertical probes because of their simplicity in comparison with orbital shots, and because the range at the firing of the fourth stage would be within 300 miles of Wallops, thereby allowing continuous radar and telemeter tracking. The two probe shots were scheduled for October and December 1959. Since the primary purpose of Scout was to place scientific payloads in orbit, however, the final proof of its performance was an orbital attempt. The third and fourth shots, therefore, were so scheduled. They were set for January and March 1960.

Since the injection point for orbital shots would be about 1,600 miles from Wallops, additional radars were required. Millstone Hill radar was one possibility, and the MIT radar installed on the mainland at Wallops was another, provided it would be ready in time. The MIT mainland radar, discussed with the Trailblazer project earlier in this chapter, required a beacon in the test vehicle for long-range tracking. A third possibility for downrange radar tracking was the radar to be installed at Bermuda as a part of the Mercury worldwide range. Unfortunately, this radar was not expected to be available for the first four shots.

The instrumentation planned for the vehicle was as follows:

First Stage	NASA FM/AM telemeter for temperature and control position.
Second Stage	Two destruct receivers in the forward end of the stage.
Third Stage	A commercial FM/FM 16-channel 10-watt telemeter in the guidance compartment at the head end of the stage, to provide data on temperatures, vibrations, and operational events. In addition, S-band and C-band radar beacons were included.
Fourth Stage	A commercial FM/FM 10-watt telemeter to transmit accelerations and roll rate, and a radio beacon to enable Doppler velocity measurements.
Payload	Additional instrumentation as required by the experiment.

Initally, it was planned to use AFSWC cosmic ray instrumentation in the first two probe shots because of their availability, at no cost, in connection with the Air Force Javelin/Journeyman project at Wallops. The orbital payloads were originally planned as micrometeoroid experiments designed and developed by Langley. The special instrumentation for this satellite was to be developed by IRD at Langley. The AFSWC payload was selected for the probe shots because it contained a long-range telemeter with provision for measuring accelerations and roll rate as well as radiation from trapped particles in the earth's magnetic field. This FM/FM telemeter could provide data needed for performance evaluation of the entire vehicle. In addition, the Air Force would be able to provide data on the trajectory by tracking the telemeter signal from the Atlantic Missile Range. The radiation measurements would complement those obtained in the Javelin/Journeyman program. The orbital experiment proposed was based on a proposal by W. J. O'Sullivan, Jr., to determine the puncture capability and frequency of micrometeorites by telemetering the pressure loss in a large number of cans of different thicknesses exposed to the environment of space (ref. 122).

The first meeting of the NASA-Air Force Scout Coordination Committee was held at NASA Headquarters on May 8, 1959. The chairman of the committee was E. Mitchell of Headquarters. Langley was represented by Stoney and Kilgore, while Piland represented STG. NASA Headquarters was represented by E. Mitchell and R. Wasel of Space Flight Development and R. May of Aeronautical and Space Research. The Air Force representatives were from ARDC Headquarters and AFBMD. The Ballistic Missile Division had been assigned overall responsibility for the Air Force program, with Lieut. Colonel D. A. Stine as Project Manager for BMD. The Air Force program was designated Project TS609A. It was agreed that the Air Force would transfer funds to NASA for procurement of all Air Force vehicles, with the transfers to be considered as amendments to the NASA contracts. The Air Force required ten vehicles to be flown between March and October 1960. There were four full Scout vehicles, one first-, second-, and third-stage vehicles (1,2,3), and five second-, third-, and fourth-stage vehicles (2,3,4). The Air Force had tentative plans for 25 additional vehicles in Fiscal Year 1961 and 40 in 1962. The Air Force payloads were to be supplied by four Air Force Centers as follows:

Cambridge Research Center	radiation probes
Air Force Special Weapons Command	radiation probes
Wright Air Development Center	Reentry shots for tests of Dyna-Soar stability and structures
Rome Air Development Center	Radar response of probes

All Air Force tests were to be launched from Cape Canaveral (ref. 123).

The fact that the Air Force planned to use Cape Canaveral as the launchsite was a blow to NASA. In earlier discussions, Wallops had been proposed as the site for at least the first eight tests, along the lines of the earlier Air Force cooperative programs such as JASON and Javelin. Langley considered such firings as extensions of its own work, benefiting from the research data without the expense of the vehicles.

In carrying out the Air Force responsibility, BMD proposed to bring an additional contractor into the program as a "payload and test contractor," whose function was to formulate a specific test program based on the needs of the ARDC test centers, and to provide the payloads and supervise the assembly, launching, and data recording. The actual assembly was to be done by an Air Force military unit with special training. The contractor was to have the same position in the Air Force program that Langley had for NASA. Prospective contractors were briefed on the program at Space Technology Laboratory on May 21, 1959 (ref. 124).

A major difference between the Air Force and NASA vehicles was that the Air Force desired the fourth stage to be stabilized by a reaction-jet system instead of by spin. In commenting on the Air Force program, Kilgore stated,

> It appears that much of the Air Force program is similar to the NASA program and certainly should be coordinated. However, this represents an opportunity for the development of a full family of economical research-type vehicles for use in NASA's future program. The Air Force program will not only greatly accelerate the development of these vehicles but will cover the development funding. For these reasons, it is recommended that Langley proceed with this program.

Unfortunately for Langley, the expected gains by NASA from the Air Force participation were not realized. Instead, the added burden of handling the contractual details for the Air Force greatly extended the manpower requirements of Langley without material benefit.

The Air Force program, as described to the prospective bidders, covered a wide range of space research projects as follows:

Dyna-Soar support
Anti-ICBM research
Nuclear weapons test
Development of space components such as guidance, life support, and photographic systems
Test of decoy, reentry, and recovery techniques
Development of deceleration devices
Geophysical measurements such as atmospheric density, concentration of micrometeoroids, and space radiation

Notably lacking was any mention of orbital flights.

In a NASA meeting at Headquarters on April 21, 1959, prior to discussions with the Air Force, it was decided that NASA would agree to fire the first eight Air Force Scouts from Wallops, but would decide on later aid to the Air Force on the basis of mutual research interest. It was also agreed that NASA would explore the possibility of the Air Force's building a Scout pad at the Pacific Missile Range. This would be useful to NASA for a polar orbit. Discussions were also held with personnel from the Office of Space Flight Development regarding payloads for the first eight NASA Scouts. The possibility was discussed of using some of the payloads remaining from the Vanguard program (ref. 125).

In June 1959, M. B. Ames requested that the RA for Scout (A74L269) be redesignated a specific RA instead of a general authorization. This was in recognition that the Scout was being developed as a service to the Office of Space Flight Development. Apparently Ames did not share the feeling of Langley that Scout should be a major new vehicle for research, but instead felt it was to be a "space flight" booster.

The Air Force BMD selected Ford Aeronutronic for its payload and test contractor. Ralph P. Morgan was project manager and was assisted by former Langley employee Keith C. Harder. Morgan had had previous experience with Lockheed on the X-17 program. In July 1959, a meeting was held at BMD with Aeronutronic, NASA, Chance Vought, and Minneapolis-Honeywell personnel, to discuss details of Project 609A and its relation to Scout. The need for study contracts on the modifications required by the Air Force was discussed (ref. 126).

By September 1959 the estimated cost for the first four Scouts and eight sets of motors had risen to nearly $6,000,000, and an additional $2,455,000 was requested for the additional four sets of hardware, controls, and instrumentation (ref. 127).

The proposal made by Stoney that an available AFSWC instrumentation package be used in the first Scout was opposed by Goddard personnel, who agreed to prepare a comparable payload. When this was proposed, the tentative arrangement with AFSWC was dropped. By the end of September 1959, when it appeared that the Goddard package would not be ready in time, negotiations were reopened with AFSWC. At a meeting at Langley on October 1, 1959, AFSWC again offered to supply the needed payload. AFSWC representatives were in favor of continuing their research flights cooperatively with Langley as before and were not enthusiastic about the new 609A project with Aeronutronic as the coordinator (ref. 128). In a letter to NASA Headquarters on October 13, 1959[38] AFSWC officially offered to provide a payload for the first Scout. AFSWC Deputy Commander, Colonel C. L. O'Bryan, Jr., reviewed the cooperation between AFSWC and Langley as follows:

> Since the Jason project of 1958 and throughout the current Javelin/Journeyman series we have enjoyed exceptionally good relationships with the Langley Research Center and with the Wallops Space Station. These relationships have proved extremely beneficial in a mutual way although it must certainly be conceded that NASA has given AFSWC much more than it has received in return. Certainly this constructive and mutually profitable relationship should be maintained, and it is our opinion that such joint Scout flights as we propose herein could be conducted to the positive interest of all concerned.

Langley strongly recommended to NASA Headquarters that the offer of AFSWC be accepted because of the needs of the Scout program and the interest in restoring a good working relationship with the Air Force. Recent contacts with BMD regarding the 609A project indicated that the Air Force had no intention of using the Wallops facility, and the long-time cooperative rocket-model program as previously carried out appeared to be coming to an end. Swanson strongly urged the continuation of the AFSWC-Langley cooperative program as a means of avoiding duplication in space research[39] (ref. 129).

The Office of Space Flight Development in NASA Headquarters was not as enthusiastic as Langley about cooperating with AFSWC on a NASA Scout, and in November 1959 informed AFSWC that Goddard was to supply the payload for the second Scout probe shot, and that the only way an AFSWC

38. Letter from AFSWC to Director, NASA, Oct. 13, 1959, regarding participation in programmed Scout flights.
39. Letter from Langley to NASA, Oct. 30, 1959, regarding AFSWC participation in Scout flights.

payload could be considered would be as a possible short-notice backup.[40] AFSWC accepted the offer to be only a "backup" participant[41] and that was the way the situation remained until February 1960. The Scout development encountered unexpected difficulties, and the first launch data slipped from November 1959 to January 1960. In addition, the calculated peak altitude of the Scout as a probe decreased from 10,000 miles to about 5,000 miles. For these reasons, Goddard withdrew its offer to provide a radiation payload for Scout 2. In view of this, Silverstein informed AFSWC that space would be available on Scout 2 for the AFSWC package.[42]

The first Scout also carried an Air Force experiment but not in the payload section. In October 1959, a representative of Air Force Cambridge Research Center visited PARD to discuss the possibility of adding "a geodetic flare package to a Scout as a part of a geodesy program to develop new and better techniques for improving the accuracies of intercontinental datum ties." Stoney was interested in such a flare as a backup to the radars for trajectory determination, and indicated a willingness to cooperate with AFCRC. The understanding with AFCRC was that the flare package would be compatible with the Scout and would be a completely self-contained unit, independent of the Scout wiring. The first Scout was selected for this use and by January 1960 the flare package was ready as approved. It consisted of twelve modified Daisy flares (200,000 candle-seconds for 10 milliseconds) mounted on the skirt section around the X248 nozzle. The complete unit, including a timer and a power supply, weighed about 5 pounds. The first flare was timed to fire about 20 minutes after launch (ref. 130).

AFCRC offered to reimburse NASA for any expense connected with this test, but Langley returned the procurement order form unsigned with the statement that NASA considered it a mutually beneficial experiment and was glad to cooperate with AFCRC on the usual basis without any transfer of funds.[43] Captain C. D. Bailey, ARDC Liaison Officer at Langley, took this opportunity to remind all ARDC offices of the proper procedure for obtaining such free assistance from Langley.

On November 4, 1959, Silverstein established a Delta-Scout Review Team to review the design, engineering, and test aspects of these two new vehicles from a reliability standpoint. B. T. Lundin of Lewis was appointed chairman, and E. Mitchell, secretary. Langley was represented on the team by R. L. Gungle of DMES, who had contributed to a successful solution of a design problem on the Thor-Able launch vehicle and was not directly involved with Scout at that time. Other members on the team were from Cornell Aero Laboratory, ABMA, and Goddard (ref. 131). Between November 13, 1959, and December 14, 1959, the team visited Langley and all of the contractors on the Delta and Scout vehicles. The team, in its final report, was critical of the rather informal project organization of Scout and made a number of recommendations. Two areas of disagreement existed, after review of all the recommendations of the team. The team felt that the level of the vibration loads used in the environmental tests of the transition sections should be higher, and that the assumed thrust misalignment of the rocket motors should be 0.25 degree instead of 0.16 degree. Except for these two items, Kilgore and Stoney felt that the review of the Scout had been valuable and had led to improved checkout and launch procedures. "Also, added confidence in several aspects of the design was gained from the discussions" (ref. 132).

One outcome of the review was establishment of a Scout Project Group reporting directly to the Langley Associate Director. At a meeting at Headquarters on February 23, 1960, R. E. Horner, NASA Associate Administrator, asked that this arrangement be made. The group was to carry the entire responsibility for the Scout development program and "would report to Ostrander's office through E. Mitchell." Horner stated that "the operational responsibility for the developed Scout would be assigned to ABMA at an appropriate future time" (ref. 133). D. R. Ostrander was now the Director of the new Office of Launch Vehicle Programs established December 29, 1959, with responsibility for all launch vehicles. The decision had been made by the President to transfer ABMA to NASA, and the associated problems were being resolved at this time.

40. Letter from A. Silverstein to Commander, AFSWC, Nov. 4, 1959, regarding use of AFSWC radiation package on a NASA Scout.
41. Letter from Lt. Col. J. L. Beavers, II, AFSWC, to A. Silverstein, Nov. 13, 1959, regarding AFSWC payload package for Scout.
42. Letter from A. Silverstein to AFSWC, Feb. 17, 1960, regarding AFSWC payload for Scout.
43. Letter from Langley to ARDC Liaison Officer at Langley, May 23, 1960, regarding transfer of funds for flare experiment.

The organization of the Scout Project Group, effective February 29, 1960, was as follows:

W. E. Stoney, Jr.	Head
R. D. English	Technical Assistant
A. Leiss	Administrative Assistant
Edith R. Horrocks	Secretary
E. J. Wolff	609A Coordinator
C. L. Robbins	609A Minneapolis-Honeywell Representative
L. C. Forrest	609A Chance Vought Representative
C. T. Brown, Jr.	Mechanical Design and Assembly
E. D. Schult	Guidance and Control
W. M. Moore	Instrumentation
J. R. Hall	Field Director

In addition, each division at Langley engaged in support of the Scout project identified a responsible employee to represent that division on matters pertaining to support work of the division. At AMPD (formerly PARD), C. A. Sandahl was so identified for Scout, and A. G. Swanson for 609A support (ref. 134).

The general layout of Scout is shown in figure 473. The overall length was 71 feet, and the launch weight, 36,842 pounds. The solid-rocket motors served as the main structural member and were connected by built-up structural sections designed and fabricated by Vought. Base A was attached to the bottom end of the first-stage Algol motor and supported the four delta stabilizing fins, tip controls, and jet vanes. It contained an FM/AM telemeter and the hydraulic system for operating the controls. Between the Algol and the Castor was Transition B, with its upper section attached to the Castor and lower section attached to the Algol. This section contained the destruct system for the Algol and the reaction jets for control of the second stage. Between the Castor and the Antares motors was Transition C, likewise divided into an upper and lower section. Transition C contained the safe-arm unit for the Castor destruct system and the command destruct receivers. Between Antares and Altair was Transition D. The lower section was attached to the front end of Antares and contained an FM/FM telemeter for system monitoring. The upper section was attached to the Altair motor. Three separate heat shields were used, one around the Antares, one around the Altair, and the third around the payload. Two telemeters were used in the payload, an FM/AM system and an FM/FM system. Each of the upper three motors was attached to the motor behind it by blowout diaphragms that collapsed upon ignition of the rocket motor and separated the upper and lower sections.

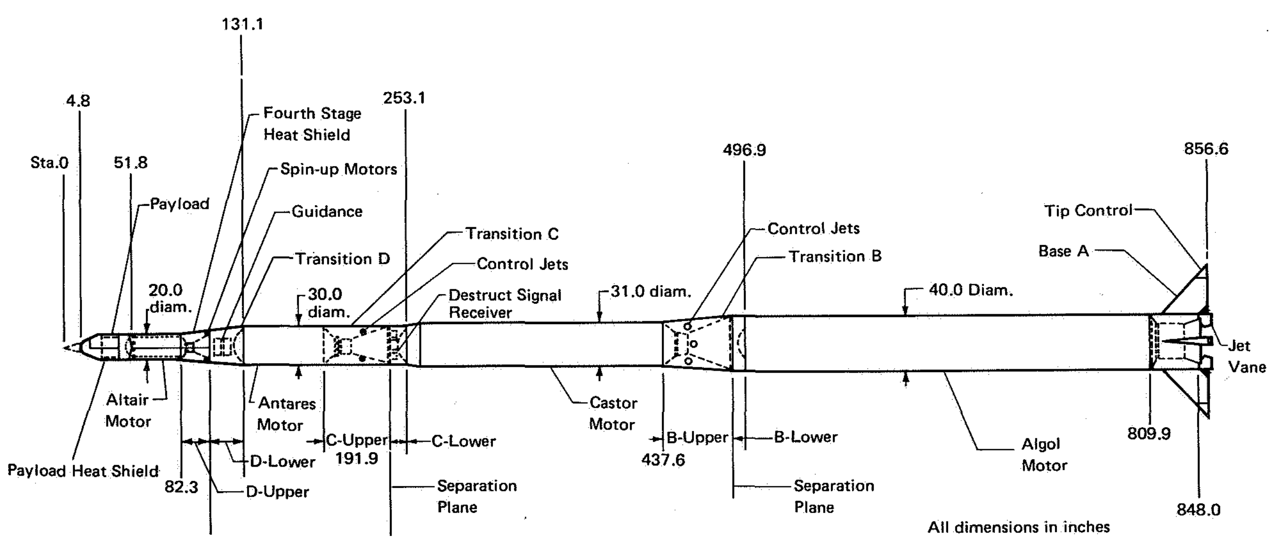


FIGURE 473. Drawing showing general arrangement of Scout test vehicle.

It had been the practice with multistage rocket vehicles developed at PARD to make the connecting sections between stages out of rather heavy cast magnesium. In designing these sections for Scout, Vought chose to follow the normal aircraft construction practice of using either built-up aluminum structures with thin skins and internal stiffeners, or fiberglass monocoque structures. Access doors were provided in each section for access to the instrumentation and control components. This type of construction presented quite a problem to the Scout group because it meant that each section had to undergo detailed structural analysis and environmental testing to ensure reliability.

The launching area for Scout was No. 3, constructed under the Project 2080 expansion of facilities authorized by NASA. The concrete launch pad and the launch tower were funded by the Scout project. In figure 474, the tower is shown with the Scout assembled in a vertical attitude and the work platforms hinged back out of the way. In figure 475, the Scout is shown lowered to its launch attitude. The tower was the first large service tower erected at Wallops and, except for size, was patterned after such towers in use at Cape Canaveral. It had an elevator and access to various work levels. Since the initial plan was to launch the Scout some 5 degrees to 15 degrees from vertical, the vehicle support arm could be lowered as desired. Assembly and checkout of the guidance system were performed with the vehicle in a verticle position. It was soon found necessary to enclose the different work areas for the protection of the vehicle as well as the workers. Although supposedly this was an advanced system as used at Cape Canaveral, it lacked the convenience and simplicity of the beam-type launchers in use at Wallops. After several years, it was replaced by a special beam-launcher and was finally dismantled.

The control room for Scout operations was Blockhouse No. 3, which was designed for use in launches of liquid-rocket vehicles as large as Thor, but was especially arranged for Scout use.

Because the Air Force 609A program included tests of Dyna-Soar configurations, the loads on the Air Force Antares and Altair motors were expected to be higher than those on Scout. For this reason, the thickness of the wall of the Air Force Antares was increased from 0.100 inch to 0.150 inch, and 48

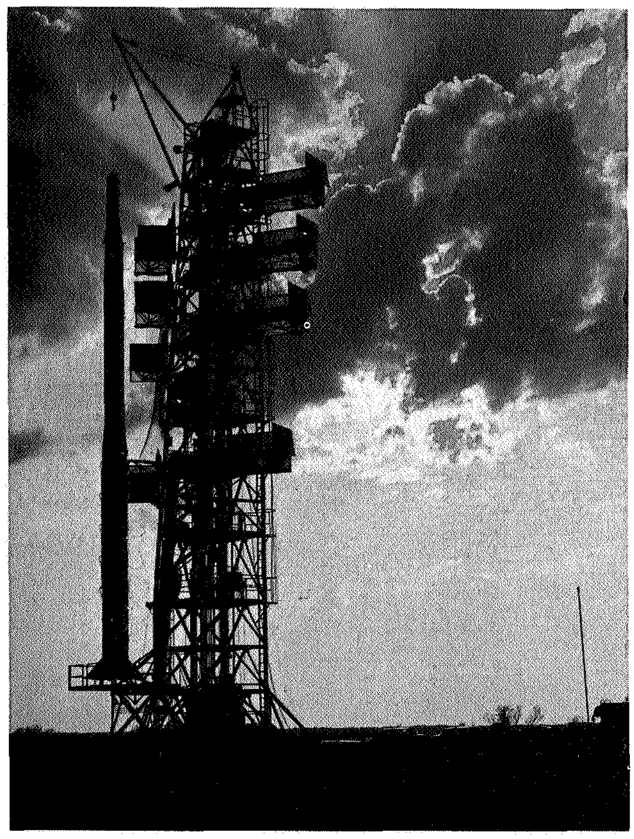


FIGURE 474. Service tower with work platforms hinged back and Scout on launcher in a vertical position, following erection.

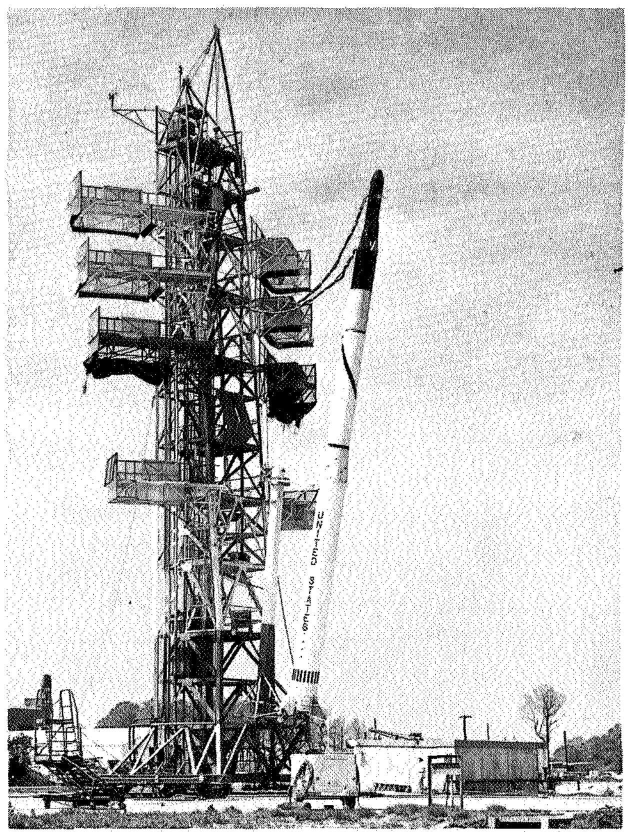


FIGURE 475. Scout ST–1 in launch attitude on service tower-launcher at Wallops, July 1, 1960.

bolts were required on both the forward and rear mounting rings. This modified Antares was designated X254A2. The Altair motor was changed from X248A5 to X248A6, and 24 bolts were required on both mounting rings.[44] By the time of the NASA-Air Force Scout Coordination Committee meeting held on April 12, 1960, the NASA contracts had been amended to include the nine systems for Project 609A, and a first firing scheduled for May 11, 1960, at Cape Canaveral appeared to be realistic. The Air Force at this time was planning a future firing rate of about 50 vehicles per year, ten times the planned rate of NASA (ref. 135).

The planned January 1960 launch date for the first Scout came and went. Problems in many areas contributed to a slippage of the schedule. By January 1960, the Algol, Castor, and Altair motors had been accepted for flight. The Antares motor, however, had experienced considerable trouble with bonding of the propellant to the motor case. After this was corrected, additional trouble was encountered when the motor was tested in the high-altitude facility at Tullahoma. The fiberglass lining of the nozzle pulled loose and caused considerable concern. This problem was not corrected until May. Another delay was in delivery of the hydrogen-peroxide reaction control motors. A simulated vehicle had been mounted on air bearings in a test area connected with the 16-foot tunnel at Langley, to check the operation of the reaction control system. These tests were successfully completed in February 1960. The fitting and testing of the airframe hardware took longer than expected. The heat shields required considerable testing under heating conditions and actual separation.

Dummy motors were sent to Vought for use in fitting the transition sections during construction. After delivery of the components to Langley, another set of dummy motors was required for assembly there to check overall alignment and general suitability including freedom from interference with components supplied by other contractors. When the assembly appeared to be satisfactory, it was taken apart and shipped to Wallops. At Wallops, the components were first placed in the large Fasron hangar at the Chincoteague main base, where they were assembled with empty rocket motor cases and compatibility with range equipment was verified. Then all components were taken to the island and were assembled with live motors. Assembly was performed in Assembly Shop No. 4 in the Scout launch area and, finally, on the launcher itself. The same men were involved in the assembly at all stages, to provide a continuity of experience and thus increase the chance of success.

A field service team from Vought was assigned to assist in the Wallops assembly. In addition, a service team from Minneapolis-Honeywell was also assigned for assistance in installation and checkout of the guidance and control package. Finally, an instrumentation team from Vought was engaged to assist IRD in assemblying, testing, and installing the many elements of the instrumentation system.

The hiring of an instrumentation team from Vought was proposed by Stoney and Kilgore as part of a plan to expedite the follow-on Scout firings as well as the first test. Although initially it was planned that NASA personnel would perform most of the assembly functions at Wallops, as time went by more and more men from the contractors' organizations were involved, and Wallops personnel were not used in the assembly operations. They were involved, however, in the launch operations and safety procedures. The main solution to the problem of how to expedite Scout was to work large amounts of overtime. This became a way of life for the last several months prior to the first launch (ref. 136). Both H. L. Dryden and R. E. Horner were anxious to expedite Scout and would approve any plan that offered a possibility.

A dummy Scout was erected on the launcher during the latter part of March 1960, as shown in figure 476. Stoney took this opportunity to study the effects of winds on the vehicle in a vertical position and the need to attach spoilers to the sides of the vehicle to alleviate oscillatory motions, as had been done with the Vanguard vehicle. The spoilers were made of foamed plastic and were designed to blow off once appreciable forward velocity was achieved. The spoilers were undesirable because of the possibility of damaging antennas as they blew off (ref. 137).

On March 7, 1960, after repeated demands from Headquarters that some type of flight test be made in the Scout program as soon as possible, F. L. Thompson suggested that an unguided Scout be fired to obtain some information on the overall configuration. In this test, only the first and third stages

44. Letter from K. C. Harder, Jr., Aeronutronics, to Lt. Col. D. A. Stine, AFBMD, Dec. 1, 1959, regarding modifications to the Scout motors.

were to be live, and the second stage was replaced by a weighted dummy motor. The controls on the first stage were given a fixed deflection to produce a stabilizing spinning motion. This expedited test was made on April 18, 1960, with the vehicle shown in figure 477. Actual Vought transition sections were installed between the motors. This test was not an official Scout test. It was identified as SX-1 and was called "Cub Scout." It was handled by a group from AMPD under the direction of R. A. Falanga. Because of an error in interpreting the rolling effectiveness data for the tip ailerons, the roll rate induced was greater than planned. In flight, the roll coupled with a natural bending mode and caused a structural failure near the time of burnout of the first stage, thus preventing the planned test of the X254 third stage. A deficiency in the design of the heat shield on the third stage was revealed when the shield broke away from the motor as the vehicle passed through the transonic region. Later wind-tunnel tests indicated very high external pressures near the front of the shield at Mach 0.90. The pressure difference acting on the heat shield was greater than that assumed in the design. In addition to this finding, the Cub Scout test provided the first flight test of an Algol motor, which performed as expected. The test also provided experience with erection of Scout components on the new launcher, and with an actual firing from it (ref. 138). Nevertheless, the failure was a blow to the prestige of the project, and efforts to complete the first actual Scout were redoubled.

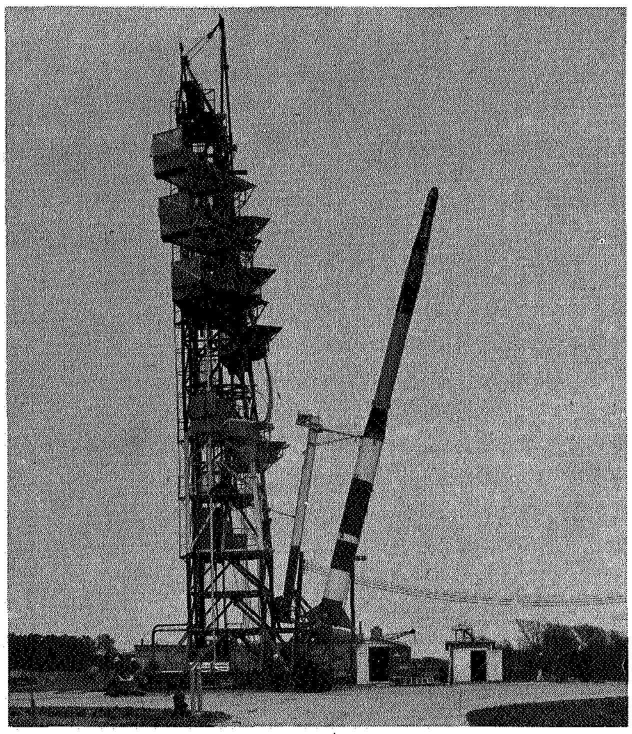


FIGURE 476. Dummy Scout vehicle on launcher in preparation for wind tests, March 1960.

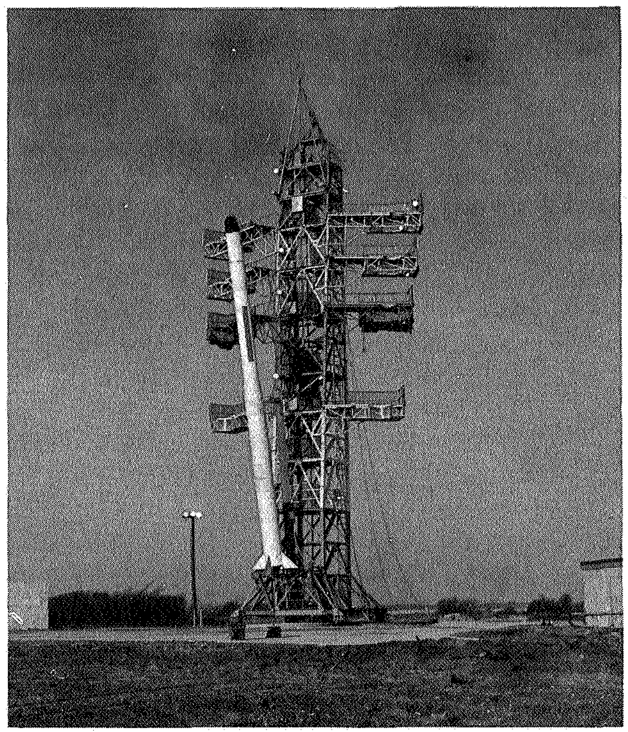


FIGURE 477. Preliminary modified Scout (SX-1) in launch position for flight test, April 18, 1960.

By June 1960, the Scout operations had expanded so much that Wallops had turned over several buildings for the sole use of Scout. The new causeway had been opened on March 21, 1960, and transportation to the island was no longer any problem. The buildings on the island now occupied by Scout were Assembly Shop No. 2, (the old Preflight Jet shop) and Assembly Shops No. 4 and 5 in the new area just north of the cafeteria and across the road from Launch Area No. 3. In addition, Scout had sole responsibility for the Scout tower and south pad terminal building in this launch area. Since Krieger had no employees working full time in these areas, nor was anyone at Wallops completely familiar with the equipment there, he asked that the Scout Group establish a safety organization within the framework of the Wallops safety regulations.[45] The only exceptions made by Krieger were that

45. Letter from R. L. Krieger, Wallops, to Langley, June 9, 1960, regarding safety on Scout Project.

Wallops would continue to have "responsibility for explosive, pyrotechnic, and pad safety." Langley assigned responsibility for safety within the Scout Group at Wallops to J. R. Hall, Field Test Director. Hall, in turn, appointed B. C. Deis as facility coordinator, and R. P. Parks and D. F. Fromal as safety operators.[46]

The first Scout was finally assembled on the launcher, shown in figure 475, and was launched on July 1, 1960, as shown in figure 478. The payload was an acceleration and radiation package prepared at Langley, and the vehicle was programmed for a probe shot. It was launched on an azimuth of 107 degrees and an elevation angle of 85 degrees. With the 193-pound payload, the apogee was predicted to be at an altitude of 2,020 nautical miles, with an impact range of 4,400 nautical miles. A maximum velocity of 22,000 feet per second was expected. The firing plan was to provide an 18-second

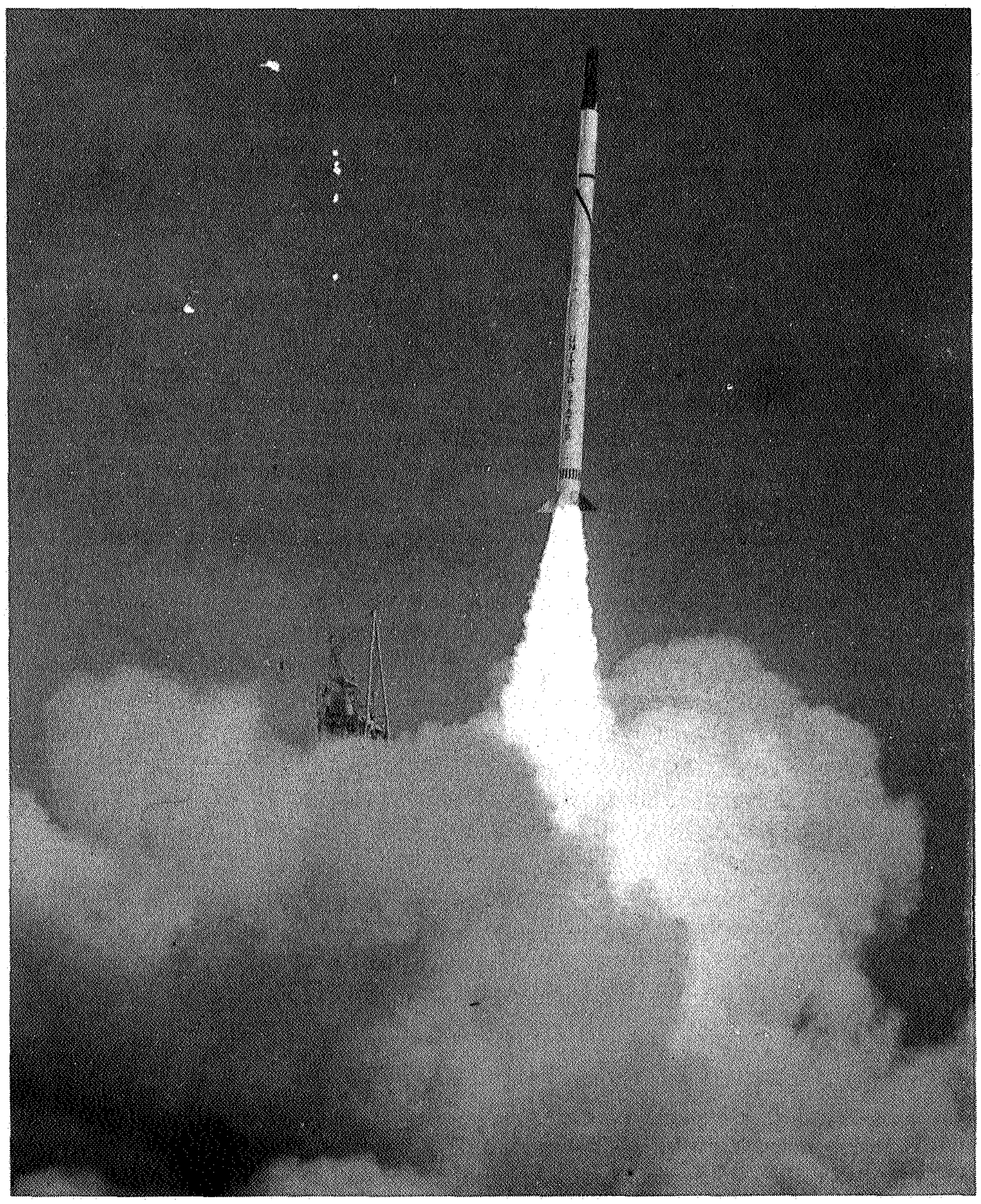


FIGURE 478. Launch of first complete Scout vehicle (ST–1) at Wallops, July 1, 1960.

46. Telegram from F. L. Thompson to R. L. Krieger, June 16, 1960, regarding Scout safety organization at Wallops.

coast period following burnout of the Algol to allow the vehicle to attain an altitude of 130,000 feet before ignition and separation of the Castor. A 5-second coast period followed burnout of the Castor motor to allow time for ejection of the three heat shields. Following ignition, separation, and burning of Antares, a coast period of 30 seconds was planned, during which time the remaining vehicle would be pitched over 15 degrees at a rate of 1 degree per second. Then would come spin-up of the fourth stage on its spin table by three small Pet rocket motors, each having 40 pound-seconds of total impulse. This spinning of the fourth stage would maintain the attitude of the stage existing at that time. The Altair motor would then be ignited, and after burnout the remaining stage would coast to splash at an estimated time of 53.7 minutes.

In the actual flight, the Scout performed as planned, with a few exceptions, up to the burnout of the third stage. These exceptions were as follows: as the vehicle passed through the transonic region, the heat shield around the third stage came off just as it had in the Cub Scout test. Although the forward end of the heat shield had been vented to equalize the pressure, additional holes drilled at other locations counteracted the intended effect and maintained the high differential pressure as before. During second stage burning, when the vehicle passed through the D layer of the atmosphere, a loss of telemeter signal occurred, which would be restored each time a hydrogen-peroxide jet control motor was fired (ref. 139). During third-stage burning, the motor was so rough that the "g" switch chattered and constantly switched the high and low controls in and out during motor burning. (The purpose of the switch was to activate the change from a high-level to a low-level thrust unit for pitch control after burnout, to conserve jet fuel during coasting.) At 136 seconds after takeoff, a rolling moment developed with the Antares motor, which the roll motors could not overcome. After a roll of 210 degrees, the roll impulse ceased and control was regained. The rolling of the vehicle caused the FPS-16 radar, which had been incorrectly tracking a side lobe of the C-band beacon, to be reoriented to the main lobe. This shift of the radar indicated on the plotboard that the vehicle had taken a violent turn in azimuth and a dip down in elevation. When this apparent violent motion appeared, the safety officer actuated the hold-fire signal for the fourth stage, preventing firing of that stage. Although the radar tracks recovered from the indicated violent maneuver and continued on a slightly different but normal track, the hold-fire command could not be countermanded, and everyone stood by helplessly as the vehicle coasted along with no way to complete the Scout test by firing the fourth stage. Although the flight had to be called a failure, the Scout Group did not feel that it was a total loss, inasmuch as the fourth stage never had a chance to perform.

The test verified many aspects of the Scout, and the majority of the objectives were achieved. Overall results showed the design concepts to be sound. The three rocket motors that were ignited had normal performance, the thrust misalignment was within the tolerances used in the design of the control system, and the guidance and control system functioned as designed except during the erratic roll event during third-stage burning and its high-level vibrations (ref. 140).

Although this first Scout vehicle did not reach the design altitude as a probe, radiation measurements were successfully made to an altitude of 875 miles (ref. 141).

A fully successful Scout launching was achieved on October 4, 1960, when Scout No. 2 was launched as a probe with the AFSWC radiation payload on board. A maximum altitude of 3,500 miles and a total range of 5,800 miles were reached. Scout was to become a member of NASA's stable of launch vehicles and was to see service in satellite launchings, in high-altitude probe research, and in high-velocity reentry studies.

EPILOGUE

The history of Wallops Island from 1945 through 1959 closes with Wallops blossoming out as a separate entity in the overall NASA organizational structure. At the same time, the change signaled the end of PARD (Pilotless Aircraft Research Division) as it once was. PARD and Wallops were synonymous in this period—the history of Wallops is at the same time a history of PARD. Wallops Island was the experimental station or "equivalent wind tunnel" for the aeronautical researchers in the parent division at Langley. The changing of the name of PARD to AMPD (Applied Materials and Physics Division) at the close of 1959 eliminated the last reminder of this direct relationship.

Wallops and PARD achieved their greatest fame in the early fifties through the timely development of techniques to provide experimental design information so necessary for our nation's supersonic aircraft. For many years, this was the sole source of such vital data. In the evolution of Wallops, the quest for higher and higher speeds took precedence over continued activity in previously explored speed ranges until finally the airplane was displaced by ballistic missiles, sounding rockets, and satellites. By pushing the rocket-model technique to space activity, PARD literally pushed itself out of business, for by dictate of NASA Administration, Langley Research Center was not to become a space center. Wallops, on the other hand, became the only NASA-owned rocket test range.

The rocket-test techniques developed at Wallops were almost as valuable as the research results themselves. The many engineers and technicians who were trained in this technique, and later migrated to other ranges or private companies, used the knowledge in many new applications. A prime example is Project Mercury, in which most of the pioneers in the project were Wallops-trained. In addition, the successful staging of from four to seven tandem rockets in multistage systems was an inspiration to all rocket technologists, as well as a source of direct benefit to the development of sounding rockets and solid-fuel ballistic missiles. Under NASA, the techniques were to be applied on an international scale.

In this era, Wallops was recognized nationally for its informality and for the friendly and helpful attitude of its workers. When the center became an independent range under NASA, this attitude did not change, for the original work force became the nucleus of the expanded station. As the NASA rocket test range, Wallops was to become the main training ground for international cooperative space programs. The history of cooperation of Wallops personnel made it possible to carry out this assignment with such success that it was to be continued over the years ahead. The attitude toward visitors expressed in "What can we do for you?" rather than "What do you want?" partially explains why Wallops was to retain its position in the NASA organization despite future curtailment of other NASA activities.

By the end of 1969, Wallops had achieved international fame as a space center for launching sounding rockets and satellites. It is hoped that this history will have shown that Wallops was once just as famous for its contribution to the successful development of supersonic aircraft through rocket-model flight testing.

References

1. Ulmer, R. E., Memorandum for NASA Administrator, December 23, 1958, regarding Naval Air Station, Chincoteague, Va.
2. Buckley, E. C., Memorandum for A. F. Siepert, Mar. 2, 1959, regarding other possible users of Chincoteague.
3. Berlin, Kurt, Memorandum for record, Mar. 4, 1959, regarding Wherry Housing, Chincoteague Naval Air Station.
4. Krieger, R. L., Memorandum for Associate Director, Mar. 24, 1959, regarding provision of space for contractors at Wallops.
5. Reeder, J. P., Memorandum for Associate Director, Aug. 13, 1959, regarding status of airport and facilities at Chincoteague, Va.
6. Messick, J. C., Memorandum for Director, June 2, 1958, regarding selection of architect-engineer for study of causeway to Wallops Island.
7. Krieger, R. L., Memorandum for Wallops Station Staff, Mar. 16, 1960, regarding use of Wallops Island causeway.
8. Miller, N. P., Chief, Plant and Facilities Construction Program, Goddard Space Flight Center, Memorandum for NASA Administrator, Apr. 30, 1959, progress report no. 6.
9. Swenson, Loyd S., Jr.; Grimwood, James M.; and Alexander, Charles C.: *This New Ocean, A History of Project Mercury*, NASA SP–4201, 1966.
10. Faget, Maxime A.; Garland, Benjamine J.; and Buglia, James J.: "Preliminary Studies of Manned Satellites, Wingless Configuration; Nonlifting." Paper presented at NACA Conference on High Speed Aerodynamics, Ames Aeronautical Laboratory, Moffet Field, Calif., Mar. 18–20, 1958. Reissued as NACA RM L58E07a and NASA TN D–1254, Mar. 1962.
11. Bird, John D.; and Reese, David E., Jr.: "Stability of Ballistic Reentry Bodies." Paper presented at NACA Conference on High-Speed Aerodynamics, Moffett Field, Calif., Mar. 18–20, 1958. Reissued as NACA RM L58E02a.
12. Blanchard, Willard S., Jr.; and Hoffman, Sherwood: *Effects of Nose Corner Radii, Afterbody Section Deflections, and a Drogue Chute on Subsonic Motions of Manned-Satellite Models in Reentry Configuration.* NASA TN D–223, Mar. 1960.
13. Carter, Howard S.; Kolenkiewicz, Roland; and English, Roland D.: *Principal Results From Wind-Tunnel Stability Tests of Several Proposed Space Capsule Models Up to an Angle of Attack of 33°.* NASA TM X–21, Sept. 1959.
14. Usry, J. W.: *Investigation of the Static Stability Characteristics of a Reentry Spacecraft Model in Free Flight For Mach Numbers From 2.62 to 1.11 Launched at an Angle of Attack of 180°.* NASA TM X–615, Dec. 1961.
15. Bland, W. M., Jr., Memorandum for Associate Director, June 6, 1958, regarding trip to NADC, Johnsville, Pa., on May 26 and 28, 1958.

16. Heberlig, J. C., Memorandum for Associate Director, Aug. 4, 1958, regarding NACA contoured couch support system tests.
17. Hammack, J. B., Memorandum for Associate Director, Apr. 28, 1958, proposing drop tests of manned ballistic satellite.
18. Hammack, J. B., Memorandum for Associate Director, Sept. 3, 1958, regarding visit to Pioneer Parachute Co.
19. Kurbjun, Max C., Memorandum for Associate Director, Dec. 22, 1958, reporting on the free-fall parachute recovery capsule drops, as of Dec. 22, 1958.
20. Swenson et al., *op. cit.*, p. 143.
21. Bond, Aleck C., Memorandum for Associate Director, Aug. 12, 1958, regarding visit to WADC on July 30, 1958, to discuss ablation test activity for Air Force man-in-space program.
22. Roberts, Leonard: "Ablation Materials For Atmospheric Entry." *Proceedings of the NASA-University Conference on the Science and Technology of Space Exploration,* Chicago, Ill., Nov. 1–3, 1962, p. 461.
23. Wallops PARD Log, Apr. 22, 1959.
24. Wallops PARD Log, Mar. 11, 1959.
25. Blanchard, Willard S., Jr.; and Hoffman, Sherwood: *Full-Scale Flight Test of a Proposed Abort-Escape System For a Manned Space Capsule From Sea Level.* NASA TM X–351, Aug. 1960.
26. Blanchard, Willard S., Jr.; and Raper, James L.: *Full-Scale Flight Test From Sea Level of an Abort-Escape System for a Project Mercury Capsule.* NASA TM X–422, Oct. 1960.
27. *A Proposed Simple Means For Manned Space-Flight Research.* Langley Pilotless Aircraft Research Division, Jan. 24, 1958.
28. Swenson et al., *op. cit.*, p. 100.
29. Purser, P. E., Memorandum for E. C. Draley, Apr. 17, 1959.
30. Sandahl, C. A., Memorandum for Associate Director, Mar. 4, 1959, regarding Little Joe recovery operations.
31. Carter, H. S., Memorandum for Associate Director, Sept. 3, 1959, regarding tests of Thermolag in Wallops Ethylene Jet.
32. Rose, James T.; and Rose, Rodney G.: *A Rapid Method of Estimating Launcher Setting to Correct for the Effects of Wind on the Trajectory of an Unguided Fin-Stabilized Rocket Vehicle.* NASA TM X–492, Mar. 1961.
33. Swenson et al., *op. cit.*, p. 638.
34. Royall, John F., Jr.; and English, Roland D.: *Investigation of Flight Performance of Little Joe Booster For Project Mercury.* NASA TM X–298, July 1960.
35. Carter, H. S., Memorandum for Associate Director, Nov. 13, 1959, regarding progress from Oct. 18 to Nov. 7, 1959, on Langley support of Project Mercury.
36. Baber, Hal T., Jr.; Carter, Howard S.; and English, Roland D.: *Flight Test of a Little Joe Boosted Full-Scale Spacecraft Model and Escape System For Project Mercury.* NASA TM X–629, May 1962.
37. *Performance Summary For the Little Joe Sounding Rocket Vehicle.* Chance Vought Corp., Report AST/E1R–13330, Apr. 1961.
38. Green, Cloid D.; Welch, B. E.; et al.: *Studies of Escape from Ballistic Space Vehicles. I. Biomedical Evaluation.* Report No. 61–29, School of Aviation Medicine, Brooks Air Force Base, April 1961.
39. Swenson et al., *op. cit.*, p. 198.
40. Mayes, William H.; Helton, David A.; and Hardesty, Charles B.: *Flight Noise Measurements for Three Project Mercury Vehicles.* NASA TN D–997, Jan. 1962.
41. Swenson et al., *op. cit.*, p. 338.
42. Rumsey, C. B., Memorandum for Associate Director, Feb. 24, 1959, regarding meeting to discuss Project Mercury problems to which PARD rocket firings might contribute information.
43. Lee, Dorothy B., Memorandum for Associate Director, Aug. 25, 1960, regarding flight test data from a rocket vehicle, to study heat transfer on the Mercury capsule.
44. Swenson et al., *op. cit.*, p. 198.
45. Carter, H. S., and Sandahl, C. A., Memorandum for Associate Director, Mar, 16, 1959; weekly progress report for Mar. 8, 1959, on Langley support of Project Mercury.
46. Rashis, Bernard: *Preliminary Indications of the Cooling Achieved By Ejecting Water Upstream From the Stagnation Point of Hemispherical, 80° Conical, and Flat-Faced Nose Shapes at a Stagnation Temperature of 4,000° F.* NACA RM L57I03.
47. Witte, William G.; and Rashis, Bernard: *An Experimental Investigation and Correlation of the Heat Reduction to Nonporous Surfaces Behind a Porous Leading Edge Through Which Coolant is Ejected.* NASA TM X–235, Mar. 1960.
48. Walton, Thomas E., Jr.; and Rashis, Bernard: *Measurement and Empirical Correlation of Transpiration-Cooling Parameters on a 25° Cone in a Turbulent Boundary Layer in Both Free Flight and a Hot-Gas Jet.* NASA TN D–967, Oct. 1961.
49. Winters, Clyde W.; and Bracalente, Emedio M.: *A Sensor For Obtaining Ablation Rates.* NASA TN D–800, Apr. 1961.
50. Winters, Clyde W.; Witte, William G.; Rashis, Bernard; and Hopko, Russell N.: *A Free-Flight Investigation of Ablation of a Blunt Body to a Mach Number of 13.1.* NASA TN D–1500, Dec. 1962.
51. Morton, Mark: *Progress in Reentry-Recovery Vehicle Development.* General Electric Co., Missile and Space Vehicle Dept., Philadelphia, Pa., Jan. 2, 1961.
52. O'Sullivan, W. J., Jr., Memorandum for Associate Director, July 6, 1956, regarding inquiry from G.E. relating to sphere drag for Project 107–A.
53. Wallops PARD Log, Apr. 7, 1959.
54. Hinson, William F.: *Investigation of the Subsonic and Supersonic Release Characteristics of an Externally Carried Fuel Tank From a 1/40-Scale Model of a Bomber Airplane.* NASA TM X–354, Jan. 1961.
55. Hinson, William F.: *Investigation of a New Technique For Releasing an Externally Carried Fuel Tank at Subsonic and Supersonic Speeds, Using a 1/40-Scale Model of a Supersonic Bomber Airplane.* NASA TM X–462, Apr. 1961.

56. Inouye, Mamoru; and Neel, Carr B.: *Free-Flight Measurements Up to a Mach Number of 11 of Pressure and Turbulent Heat Transfer on a Blunted Cone-Cylinder With Flared Afterbody.* NASA TM X–505, Mar. 1961.
57. DuMond, Jesse W. M.; Cohen, Richard E.; Panofsky, W. K. H.; and Deeds, Edward: "A Determination of the Wave Form and Laws of Propagation and Dissipation of Ballistic Shock Waves." *Jour. Acous. Soc. of America,* vol. 18, no. 1, July 1946, pp. 97–118.
58. Witham, G. B.: "The Behavior of Supersonic Flow Past a Body of Revolution, Far From the Axis." *Proc. Roy. Soc.* (London), vol. 201, no. 1064, sec. A, Mar. 7, 1950, pp. 89–109.
59. Randall, D. G.: *Methods For Estimating Distributions and Intensities For Sonic Bangs.* Tech. Note No. Aero. 2524, British R. A. E., Aug. 1957.
60. Maglieri, Dominic J.; and Carlson, Harry W.: *The Shock-Wave Noise Problem of Supersonic Aircraft in Steady Flight.* NASA Memo 3–4–59L.
61. Maglieri, Dominic J.; Hubbard, Harvey H.; and Lansing, Donald L.: *Ground Measurements of the Shock-Wave Noise From Airplanes in Level Flight at Mach Numbers to 1.4 and at Altitudes to 45,000 Feet.* NASA TN D–48, Sept. 1959.
62. Dembling, Paul G., Memorandum for Fiscal Officer, June 11, 1959, approving payment of $154.18 for replacement of plate glass window.
63. Lina, Lindsay J.; and Maglieri, Dominic J.: *Ground Measurements of Airplane Shock-Wave Noise at Mach Numbers at 2.0 and at Altitudes to 60,000 Feet.* NASA TN D–235, Mar. 1960.
64. Gardner, W. N., Memorandum for Associate Director, Apr. 7, 1958, regarding visit of Lincoln Laboratory personnel to PARD on Apr. 1, 1958.
65. Gardner, W. N., and Stone, D. G., Memorandum for Associate Director, Sept. 25, 1958, requesting ARPA support on the antimissile phase of the reentry physics program.
66. Henning, Allen B.: *Some Experimental Results for a Doppler Tracking Method Using a Simple CW Beacon.* NASA TN D–2188, Mar. 1964.
67. Gardner, William N.; Brown, Clarence A., Jr.; Henning, Allen B.; Hook, W. Ray; Lundstrom, Reginald R.; and Ramsey, Ira W., Jr.: *Description of Vehicle System and Flight Tests of Nine Trailblazer I Reentry Physics Research Vehicles.* NASA TN D–2189, Apr. 1964.
68. *Reentry Physics Program Semiannual Technical Summary Report to the Advanced Research Projects Agency, October 1, 1958, to June 30, 1959.* Contract AF 19(604)–4599, Lincoln Laboratory, MIT, Oct. 8, 1959.
69. *Reentry Physics Program Semiannual Technical Summary Report to the Advanced Research Projects Agency, July 1, 1959, to December 31, 1959.* Lincoln Laboratory, MIT, Mar. 23, 1960.
70. Stone, David G.: *Report on D58 Reentry Physics Research Program,* June 8, 1959.
71. Dickerson, R. M., Memorandum to All Concerned, June 12, 1959, giving summary of pilot observations and operational problems in connection with D58–3001 firing.
72. Brown, C. A., Jr., Memorandum for Associate Director, Oct. 7, 1959, regarding visit to Picatinny Arsenal on Sept. 29, 1959, to discuss photoflash devices.
73. Gardner, W. N., Brown, C. A., Jr., and Lundstrom, R. R., Memorandum for Associate Director, Sept. 3, 1959, regarding visit to Lincoln Laboratory on Aug. 6–7, 1959.
74. Brown, Clarence A., Jr.; and Keating, Jean C.: *Flight Test Description of a Rocket Vehicle For Producing Low-Speed Artificial Meteors.* NASA TN D–2270, Apr. 1964.
75. *The Truax Steam Rocket, Model TR–1, A High Performance Rocket Designed Specifically for the Serious Amateur and Student Scientist.* Experiment Incorporated, Richmond, Va.
76. Wallops PARD Log, Feb. 25, 1959.
77. Pierce, J. R.: "Jet Propulsion." Jour. of Am. Rocket Soc., Apr. 1955, pp. 153–157.
78. Mitchell, Jesse L., Memorandum for Associate Director, Aug. 18, 1958, outlining organization of NACA 100-foot-diameter communications satellite experiment.
79. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Feb. 19, 1959, regarding establishment of a task group to carry workload on 30-inch, 12-foot, and 100-foot satellites.
80. Jaffee, Leonard, Memorandum for Information, June 16, 1959, regarding results of Project Echo Planning Meeting on June 10, 1959.
81. Jaffee, Leonard, Project Echo Report on results of Second Planning Meeting, Oct. 13, 1959.
82. Thompson, F. L., Memorandum for Abe Silverstein, Mar. 25, 1960, regarding Project Echo.
83. Bressette, W. E., and Coffee, C. W., Jr., Memorandum for Space Vehicle Files, May 22, 1959, regarding gas leakage from the 100-foot sphere, caused by meteoroid puncture.
84. James, Robert L., Jr.; and Harris, Ronald J.: *Calculation of Wind Compensation for Launching of Unguided Rockets.* NASA TN D–645, Apr. 1961.
85. James, Robert L., Jr.: *A Three-Dimensional Trajectory Simulation Using Six Degrees of Freedom With Arbitrary Wind.* NASA TN D–641, Mar. 1961.
86. Crabill, N. L.: *Ascent Problems of Sounding Rockets.* AGARD Report 391, July 1961.
87. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Nov. 16, 1959, regarding results of Shotput test no. 1.
88. O'Sullivan, W. J., Jr., Memorandum for Associate Director, Jan. 19, 1960, regarding Echo satellite collapsing and inflation pressures.
89. Bailey, C. D., Memorandum for Files, Feb. 29, 1960, regarding Shotput 3.

90. Parks, J. H., Memorandum for Echo Files, July 28, 1960, regarding development ground tests for Echo project.
91. O'Sullivan, W. J., Jr., Memorandum for Associate Director, June 6, 1960, regarding results of Shotput 5.
92. Rosenthal, Alfred: *Ventures Into Space,* NASA SP–4301, 1968, p. 89.
93. Jaffee, Leonard: "Project Echo Results." *Astronautics,* vol. VI, no. 5, May 1961.
94. Bryant, Robert W.: *The Effect of Solar Radiation Pressure on the Motion of an Artificial Satellite.* NASA TN D–1063, Sept. 1961.
95. Emme, Eugene M.: *Aeronautics and Astronautics, An American Chronology of Space and Technology in the Exploration of Space, 1915–1960.* NASA, 1961, p. 33.
96. *Ibid.,* p. 52.
97. Swanson, A. G., Memorandum for Associate Director, June 19, 1959, regarding material for meteorological requirements conference.
98. Gungle, R. L., Memorandum for Associate Director, Aug. 17, 1959, regarding divergence of Unversity of Iowa Nike-Cajun sounding rocket.
99. Corliss, William: *NASA Sounding Rockets, 1958–1968,* NASA SP 4401, 1971.
100. Swanson, A. G., Memorandum for Associate Director, Dec. 29, 1958, regarding visit of University of Michigan and BRL personnel to PARD on Dec. 19, 1958.
101. Swanson, A. G., Memorandum for Associate Director, July 16, 1959, regarding University of Michigan sounding rocket for BRL.
102. May, R. W., Jr., Memorandum for Homer Newell, Jr., Aug. 27, 1959, regarding Langley assistance in University of Michigan sounding rocket program.
103. Hansen, W. H.; and Fischbach, F. F.: *The Strongarm Sounding Rocket.* University of Michigan Report 2816:004–1–F, May 1960.
104. Fischbach, F. F.: *An Investigation of Four Strongarm Failures.* University of Michigan Memo. Tech. Rept. 04003–1, Oct. 1960.
105. *Performance Summary for the Strongarm Sounding Rocket Vehicle.* Chance Vought Corp., Rept. AST/E1R–13335, Apr. 18, 1961.
106. Swanson, A. G., and Markley, J. T., Memorandum for Associate Director, Oct. 6, 1958, regarding visit of AFSWC personnel on Sept. 16, 1958.
107. Swanson, A. G., Memorandum for Associate Director, Nov. 28, 1958, regarding availability of rocket systems for high-altitude probes.
108. *AFSWC Operation Plan Serial No. 15–59, Project Javelin/Journeyman.* Kirtland Air Force Base, N.M.
109. Walt, M.; Chase, L. F., Jr.; Cladis, J. B.; Imhof, W. L.; and Knecht, D. J.: *Energy Spectra and Altitude Dependence of Electrons Trapped in the Earth's Magnetic Field.* Lockheed Missiles and Space Division.
110. Swanson, A. G., Memorandum for Associate Director, Sept. 15, 1959, regarding transmittal of Javelin data to Goddard.
111. *Performance Summary For the Javelin Sounding Rocket Vehicle.* Chance Vought Corp., Report No. AST/E1R–13326, Apr. 18, 1961.
112. *Performance Summary for the Journeyman Sounding Rocket Vehicle.* Chance Vought Corp., Report AST/E1R–13327, Apr. 18, 1961.
113. *NASA Space Flight Program,* Preliminary Langley Staff Study, May 15, 1958, pp. 1 and 28.
114. Wood, Clotaire, Memorandum for the Director, June 5, 1958, regarding Air Force–NACA cooperation in obtaining solid-propellant rocket test vehicle.
115. Wood, Clotaire, Memorandum for Director, June 26, 1958, regarding discussions with Air Force concerning specifications for rocket test vehicle.
116. Memorandum of Understanding, Oct. 14, 1958, regarding cooperation between NASA and Air Force in development of a solid-rocket test vehicle.
117. Swain, R. L., Memorandum for Associate Director, Nov. 20, 1958, regarding visit to BuOrd to discuss four-stage solid-fuel test vehicle.
118. North, W. J., Memorandum for Administrator, Mar. 3, 1959, Status Report No. 1, Scout.
119. Stoney, W. E., Jr., Memorandum for Associate Director, Nov. 26, 1958, regarding Headquarters briefing on Nov. 21, 1958, by Langley personnel, on the Scout research vehicle.
120. Stoney, W. E., Jr., and Shortal, J. A., Memorandum for Associate Director, Dec. 10, 1958, regarding advance hypersonic rocket model research program.
121. Gilruth, R. R., Assistant Director, Beltsville Space Center, Memorandum for All Concerned, Feb. 16, 1959, regarding organization of Space Task Group.
122. Stoney, W. E., Jr., Memorandum for Associate Director, Apr. 14, 1959, regarding instrumentation for first four Scout vehicles.
123. Stoney, W. E., Jr., and Kilgore, E. C., Memorandum for Associate Director, May 11, 1959, regarding meeting of NASA–Air Force Scout Coordination Committee on May 8, 1959.
124. Kilgore, E. C., Memorandum for Associate Director, May 25, 1959, regarding contractors' briefing by AFBMD on Project 609–A (Scout) Payload and Test contract.
125. Stoney, W. E., Jr., Memorandum for Associate Director, Apr. 27, 1959, regarding meeting at Headquarters on Apr. 21, 1959, to discuss Scout.
126. Stoney, W. E., Jr., Memorandum for Associate Director, July 15, 1959, regarding first NASA–Air Force–Contractor meeting on July 13, 1959, regarding Project 609A.

127. Stoney W. E., Jr., and Kilgore, E. C., Memorandum for Associate Director, Sept. 17, 1959, regarding Scout funding for FY 1960.
128. Swanson, A. G., Memorandum for Associate Director, Oct. 14, 1959, regarding meeting with AFSWC on Project 609A and AFSWC package for Scout.
129. Swanson, A. G., Memorandum for Associate Director, Oct. 27, 1959, regarding AFSWC participation in Scout flights.
130. Swanson, A. G., Memorandum for Associate Director, Jan. 13, 1960, regarding AFCRC geodesic experiment on first Scout flight.
131. Silverstein, A., Memorandum for Chairman of Delta-Scout Review Team, Nov. 4, 1959, regarding responsibilities of the team.
132. Kilgore, E. C., and Stoney, W. E., Jr., Memorandum for Associate Director, Feb. 19, 1960, regarding meeting in NASA Headquarters to discuss recommendations of Delta-Scout Review Team.
133. Draley, E. C., Memorandum for Files, Mar. 4, 1960, regarding Scout organization.
134. Reid, H. J. E., Memorandum for All Concerned, Feb. 29, 1960, regarding establishment of Scout Project Group.
135. Kilgore, E. C., Memorandum for Associate Director, Apr. 14, 1960, regarding NASA–Air Force Scout Coordination Committee meeting on Apr. 12, 1960.
136. Stoney, W. E., Jr., and Kilgore, E. C., Memorandum for Associate Director., Jan. 28, 1960, regarding steps required to expedite the firing of Scout.
137. Jones, George W., Jr.; and Gilman, Jean, Jr.: *Measured Response to Wind-Induced Dynamic Loads of Full-Scale Mock-Up of Scout Vehicle Mounted Vertically on Launching Tower,* NASA TN D–757, Apr. 1961.
138. Falanga, R. A.; Hinson, W. F.; Lovelace, U. M.; and Keynton, R. J.: *Report on the Results Obtained From Free-Flight Testing of a Modified Scout Test Vehicle.* Scout Working Paper, Sept. 15, 1960.
139. Sims, Theo E.; and Jones, Robert F.: *Rocket Exhaust Effects on Radio Frequency Propagation From a Scout Vehicle and Signal Recovery During the Injection of Decomposed Hydrogen Peroxide.* NASA TM X–529, Feb. 1961.
140. Mayhue, Robert J.: *NASA Scout ST–1 Flight-Test Results and Analyses, Launch Operations, and Test Vehicle Description.* NASA TN D–1240, June 1962.
141. Gurtler, C. A.: "Radiation Measurements in the Slot Between the Van Allen Belts to an Altitude of 1415 Kilometers." *Jour. Geophys. Res.* vol. 66, no. 9, Sept. 1961, pp. 3050–3054.

APPENDIX A

ROCKET MOTORS USED AT WALLOPS 1945–1959

The following table gives characteristics of the rocket motors available at Wallops during the center's first 15 years of operation. The motors are listed in the order of their first use there. All of the motors shown had solid propellants except the Typhoon, a British experimental self-contained liquid rocket. Its only test at Wallops was on a static-thrust stand. The Cherokee and the two large spherical motors, of 25-inch and 40-inch diameter, respectively, were developed for use at Wallops but were never tested there.

It is of interest that the size of the motors increased dramatically in this 15-year period, from the first 3.25-inch motor, weighing only 29 pounds, to the 40-inch Algol, weighing over 22,000 pounds. Of greater significance, however, as an indicator of progress in rocket technology, was the increase in propellant-mass fraction from 0.31 for the 3.25-inch motor to 0.93 for the 10-inch spherical motor.

From the beginning, the Wallops rocket-model program depended heavily upon motors developed for military projects, although some were developed specifically for Wallops by NACA/NASA either at Langley or under contract. Notable among these were the Deacon, the Cajun, the spherical motors, the Castor and the Antares X254.

Motor	*Diameter (inches)*	*Length (inches)*	*Thrust (pounds)*	*Time (seconds)*	*Weight (pounds)*		*Propellant-Mass Fraction*
					Total	*Propellant*	
3.25-inch MK 7	3.2	46.0	2,200	0.9	29	9	0.31
British Cordite	5.0	45.0	1,200	4.0	67	27	0.40
Monsanto WF-1	10.6	39.1	250	45.0	230	85	0.37
Monsanto ACL-1	10.4	53.2	10,800	1.8	320	120	0.38
Standard HVAR	5.0	52.0	5,570	0.9	79	24	0.30
Lightweight HVAR	5.0	52.0	5,570	0.9	63	25	0.40
Deacon	6.2	107.0	5,700	3.3	150	100	0.67
12AS1000	9.6	35.0	1,000	12.0	202	104	0.52
7KS6000	12.8	57.0	5,730	7.6	528	210	0.40
14AS1000	10.2	35.4	1,000	14.0	194	79	0.41

Motor	Diameter (inches)	Length (inches)	Thrust (pounds)	Time (seconds)	Weight (pounds)		Propellant-Mass Fraction
					Total	Propellant	
Typhoon	4.0	75.0	1,920	2.0	52	24	0.46
65-Inch HVAR	5.0	67.0	7,300	1.0	90	37	0.41
T40	8.0	48.0	3,160	5.8	132	103	0.79
T42	5.8	32.9	3,780	1.3	38	27	0.71
T44	4.0	55.0	657	7.0	40	26	0.65
T55	5.8	37.0	4,800	1.3	46	34	0.74
T58	5.8	36.8	4,110	1.6	45	31	0.69
HPAG	5.0	70.0	2,830	2.7	66	40	0.60
Nike	17.6	134.4	45,000	3.1	1,180	740	0.63
Honest John M6	23.4	196.8	83,300	4.4	3,874	2,050	0.53
Cajun	6.8	103.2	8,300	2.8	161	117	0.73
Recruit	9.0	99.6	34,640	1.5	334	268	0.80
Loki I	3.0	66.0	3,340	0.8	18	13	0.72
Gosling	10.9	132.0	22,000	2.8	446	313	0.70
Lance	15.0	163.2	51,000	5.3	1,651	1,190	0.72
Sergeant	31.0	230.4	50,000	27.5	8,185	7,033	0.86
10-inch Sphere	10.0	14.0	2,300	3.2	33	31	0.93
5-inch Sphere	5.0		444	2.5	4.2	3.8	0.90
20-inch Sphere	20.0	25.5	6,750	8.5	260	239	0.92
25-inch Sphere	25.0	42.0	7,500	16.5	527	484	0.92
40-inch Sphere	40.0	60.0	18,750	26.0	2,145	1,981	0.92
Arcon	6.1	102.6	1,430	24.0	208	156	0.75
Castor	31.0	245.0	62,580	27.2	8,845	7,320	0.83
Pollux	31.0	245.0	50,000	27.0	8,252	7,033	0.85
Altair X248	18.0	59.0	2,820	41.4	515	456	0.89
Antares X254	30.0	114.0	13,450	39.7	2,285	2,084	0.91
Algol	40.0	358.0	102,980	36.0	22,048	18,998	0.84
Yardbird	9.0	100.0	16,977	3.4	334	269	0.81
Arcas	4.4	60.0	336	28.0	65	35	0.54
Cherokee	5.0	68.0	10,000	1.2	73	53	0.73
Baby Sergeant	6.4	33.0	1,975	5.4	59	48	0.83
Asp	6.5	106.9	5,982	5.9	192	150	0.78

APPENDIX B

PROGRAM IDENTIFICATION

During the early years of Wallops, the general research rocket-model programs were identified by a uniform system starting with RM−1 (research missile-1) and proceeding to RM−13, with each number relating to a different test technique. Later, individual engineers deviated from this system and identified their projects in a random manner. For example, FR was used to identify flutter research; RJ, ramjet; and TWN, transonic wing nacelle. Each specific military project was identified by either its name or an MX project number (e.g., Lark, MX−570, MX−800). In addition, each model within a given program was assigned a number in a series starting with 1, and repeat models were given a letter identification such as 1a, 1b, etc. This practice led to confusion in the shops, since several models at a given time could have the same serial number. The identifying number was used on the model drawings and on parts, after construction.

Early in 1949, the entire program was renumbered. This time, only one model was assigned a particular serial number, and the serial numbers were assigned without regard to program identification. In a "Model Book" established at PARD, all models were entered serially along with important milestones such as flight dates. The book also included a brief description of each model. Each program was identified by a new series of numbers starting over with "1," plus a prefix that identified the branch of PARD responsible for the work. The branch designations were D, for Stability and Control; E, for General Aerodynamics; F, for Performance Aerodynamics; and T, for Instrument Research Division. Later, SV was added for Space Vehicle; G, for Blast Facility; H, for High Temperature; and B, for Research Techniques and Operations. Specific military projects were identified by the same prefix letter and a number, either the MX project number or a number in a new series starting with 100.

Both the old and new identification codes are given in the following table.

Code		Technique or Program
New	*Old*	
		Basic Research
D1	RM−1	Supersonic missile
E2	RM−2	Simple drag
D3	RM−3	Missile dynamic stability
D4	RM−4	Missile automatic stabilization
E5	RM−5	Fixed control rolling effectiveness

Code		Technique or Program
New	*Old*	
		Basic Research
F5	RM-5	Fixed control rolling effectiveness
F6	RM-6	Preliminary body drag
E7	RM-7	Longitudinal trim and drag of airplanes
D8	RM-8	Control hinge movements
D9	RM-9	Control damping
E10	RM-10	Aerodynamic heating and skin friction
F10	RM-10	Aerodynamic heating and skin friction
D11	RM-11	Pilot escape capsule
E12	RM-12	Base pressure and jet effects
D13	RM-13	Damping-in-roll by torque nozzle technique
E14	RM-5D	Sting-mounted models
E15	RM-3A	Airplane dynamic longitudinal stability
E16	RM-5P	Control effectiveness by pulsed ailerons
E17		Drag of large wing-body combinations
D18	FR	Flutter
D19	RM-5M	Simple control effectiveness
B20		
D20		
E20	Misc.	Development models associated with instrumentation, structure,
F20	Names	propulsion, or mechanical operation
H20		
T20		
D21		Jet-vane stabilization
D22	RJ-6	Ramjet interceptor missile
F23	RJ-3	Ramjet flight research
F24	RJ-4	Ramjet internal flow
E25 F25	TWN	Transonic wing-body drag
F26		Transonic inlet
D27		Control-surface buzz
D28		Transonic buffeting
F29		Solid-fuel ramjet
D30		
E30		Helium-Gun models
F30		
E31		Aeroelasticity
D32		Damping-in-pitch
F33		Flat-plate skin friction

Code New	Code Old	Technique or Program
		Basic Research
E34		Minimum-body wing drag
D35		Aeropulse technique for drag due to lift
F36		Long-range ramjet
D37		Simplified high-speed flutter
D38		Simple infrared homing missile
E39		Gust loads
F40 H40		Hypersonic heat transfer
E41 H41		Hypersonic stability
E42		Lateral stability
D43		Roll-to-turn missile
D44		Nonlinear missile control
G45		Blast-facility models
D46 E46		Short-span missiles
D47		High-speed flutter
E48		Reentry body stability
H49		Structural dynamics
H50		Cooling of structures
H51		Insulation
H52		Materials
F53		Hypersonic glider stability
D54		Reaction controls
D55		Spin stabilization
SV56		Inflatable radar target
E57 F57		Manned capsule
D58		Trailblazer reentry research
H59		Lewis high-energy rocket engine
E60		Shotput
D61		Horizon detection
F62		Scout
		Specific Research
E100		Sperry Sparrow missile
F101		Hermes diffuser missile
E102		Douglas XF4D-1 Skyray or F5D-1 Skylancer airplane

Code		Technique or Program
New	*Old*	
		Specific Research
D103		Grumman XF10F-1 airplane
E104		Hermes A-3 missiles
E105		McDonnell XF3H-1 airplane
CF105		Canadian AVRO CF-105 Arrow airplane
E106		Convair XF2Y-1 Sea Dart airplane
D107		Eastman Kodak Dove missile
E108		Convair XFY-1 Pogo airplane
D109		Navy acoustic seeker missile
D110		Navy Sidewinder missile
E111 F111		McDonnell XF-101 Voodoo airplane
E112		Lockheed XF-104 Starfighter airplane
E113		Grumman XF9F-9 (F11F-1) Tiger airplane
E114		Chance Vought XF8U-1 Crusader airplane
D115		Chance Vought Regulus II missile
D116		Martin Bullpup missile
D117		Nike missile control
E118		McDonnell XF4H-1 Phantom airplane
E119		Martin tactical bomber WS-302A
B120		Hurricane photography (Hugo) sounding rocket
H121		Terrapin sounding rocket
F122		Martin Titan missile
F123		GE Atlas nose cone
B124		NOL instrumented rocket
E125 F125		Lockheed Polaris missile
D126		Thiokol Tart missile
F127		AFSWC JASON project
E128		NRL Arcon sounding rocket
E129		Oriole sounding rocket
E130		Temco Corvus missile
F131		Ames heat-transfer program
H132		Pentomic missile
F133		AFSWC Javelin/Journeyman project
F134		Strongarm sounding rocket
	MX-570	Hughes Tiamat missile
	MX-800	Kellogg MX-800 missile
	Lark	Navy Lark missile

Code		Technique or Program
New	*Old*	
		Specific Research
E558	D-558-II	Douglas D-558-II research airplane
E656	MX-656	Douglas X-3 research airplane
D743	XS-2	Bell X-2 research airplane
F770		North American Navaho missile
D775A		Northrop Snark missile
D775B		Northrop Boojum missile
E776		Bell Rascal missile
E809		Republic XF-91 airplane
E813		Convair XF-92 airplane
D904		Hughes Falcon missile
E1554		Convair F-102 Delta Dagger airplane
E1626		Convair B-58 Hustler airplane
E1712	MX-1712	Boeing supersonic bomber
E1894		North American YF-100 Supersabre airplane

The system used by Goddard for identifying sounding rockets has been described briefly in Chapter 15. It consists of a number identifying the sounding rocket, with each such rocket used being given a decimal number in sequence. This designation is followed by two letters, the first identifying the instrumenting agency and the second, the type of experiment, in accordance with the list below.

For example, the designation 3.01 GS identifies the first Nike-Asp sounding rocket as being instrumented by Goddard for a Solar Physics experiment.

Sounding Rockets			
1.	Aerobee-100	10.	Nike-Cajun
2.	Arcon	11.	Argo D-8
3.	Nike-Asp	12.	Special Projects
4.	Aerobee-150, 150A	14.	Nike-Apache
5.	Iris	15.	Arcas
6.	Aerobee-300	16.	Astrobee-1500
7.	Argo E-5	17.	Aerobee-350
8.	Argo D-4	18.	Nike-Tomahawk
9.	Skylark		
Instrumenting Agency			
C	Industrial	D	DOD
G	Goddard	A	Other Government Agency
N	Other NASA Centers	I	International
U	College or University		
Type of Experiment			
A	Aeronomy	G	Galactic Astronomy
M	Meteorology	R	Radio Astronomy
E	Energetic Particles and Fields	B	Biological Research
I	Ionospheric Physics	P	Special Projects
S	Solar Physics	T	Test and Support

Effective May 1, 1959, Wallops instituted a numbering system for all tests conducted there. This system identified the organization for which the test was made, the type of operation, and the number of stages, if applicable. The designation was completed by a serial number running consecutively for all Wallops Station facilities.

For example, L5–26 identified a test that was made for Langley, was ground launched, contained five stages, and represented the twenty-sixth ground launch since May 1, 1959. Similarly, KP–28 identified a test that was made for a college or university, was conducted in the Preflight Jet, and represented the twenty-eighth test of any kind in the Preflight Jet since May 1, 1959.

The identifying letters used in the code are as follows:

First Letter		Second Letter	
A	Ames	A	Air Test
B	Navy	B	Blast Facility
C	Lewis	D	Air Drop
D	Air Force	L	Air Launch
E	Army	P	Preflight Jet
F	Foreign Nations		Absence of a second letter indicated that the test was ground launched.
G	Goddard		
H	High-Speed Flight Station		
I	Industry		
J	Jet Propulsion Laboratory		
K	Colleges and Universities		
L	Langley		
N	NASA, Atlantic Missile Range		
O	Other		
S	Scientific Community Other than Colleges and Universities		
W	Weather Bureau		

APPENDIX C

SUMMARY OF WALLOPS FLIGHT OPERATIONS

Program	Code	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Specific Missiles																	
Hughes Tiamat	MX-570	4	3	2	1												10
Navy Lark	Lark		5														5
Kellogg MX-800	MX-800			6													6
Bell Rascal	E776				8	4	3	2		2	1						20
Sperry Sparrow	E100				7	6	4	2	1								20
Northrop Boojum	D775B						5	1	2	1							9
Northrop Snark	D775A						1	2	2	1	2						8
Hermes Diffuser	F101						2	1	2								5
General Electric Hermes A2	F20								9								9
General Electric Hermes A3	E104							2	1	2	4						9
Eastman Kodak Dove	D107							1	2								3
North American Navaho	F770							1	4	2	2	1					10
Hughes Falcon	D904							1		3	2	1					7
Grumman Rigel	D37								3								3
Navy Acoustic Seeker	D109								4								4
Army 40-mm Shells									30								30
T231 Rocket Projectile											10	5					15
Navy Sidewinder	D110									1	2		1				4
Chance Vought Regulus II	D115										4	1					5
Martin Bullpup	D116											9	1				10
Martin Titan	F122													3			3
Nike Control	D117														1		1
General Electric Atlas	F123													1	1		2
Lockheed Polaris	E125														5	1	6
	F125														6	3	9
Temco Corvus	E130														2	3	5
Thiokol Tart	D126														2		2
Total		4	8	8	16	10	15	13	60	12	27	17	2	4	17	7	220

Specific Airplanes																	
Douglas D-558-II	E558			4	7	4	3	2	1								21
Republic XF-91	E809			4	4	3											11
Douglas X-3	E656			5	1	1	3	1	2	2							15
Convair XF-92	E813			2	4		3										9
Bell X-2	D743			4			1	1	1	1							8
Grumman XF10F-1	D103						1	2	1								4
Douglas XF4D-1	E102							4	1								5
McDonnell XF3H-1	E105								1	1		2					4
Convair XF2Y-1	E106								1	2	1						4
Convair XFY-1	E108								1	2	1						4
Convair XB-58	E1626								4	2	3	1	1				11
North American YF-100	E1894								2	3							5
Chance Vought XF8U-1	E114									3	1	2					6
Convair F-102	E1554									1	1						2
Lockheed XF-104	E112										1						1
Boeing MX-1712	E1712										2						2
Grumman XF9F-9 (F11F-1)	E113									1	2						3
McDonnell XF-101	E111										4	3					7
	F111											1					1
Republic F-105	D37										2						2
AVRO CR-105	CF105												2				2
Douglas F5D-1	E102											1	1				2
McDonnell XF4H-1	E118												2	1	1		4
Martin Bomber WS-302A	E119												1				1
Total				19	16	8	11	10	15	18	18	10	7	1	1		134
Sounding Rockets																	
University of Michigan Nike-Deacon	F20											2					2
University of Michigan Nike-Cajun	F20												1			2	3

Program	Code	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
University of Maryland Terrapin	H121												2				2
Hurricane Photography (Hugo)	B120												1	1	4		6
Arcon	E128														3	6	9
NOL Smoke Rocket	B124													13			13
NOL Instrumented Rocket	B124														10		10
University of Maryland Oriole	E129														9		9
AFSWC JASON	F127														10		10
University of Michigan Exos	E20														2		2
Hi-Ball Radar Target	SV56														4		4
AFSWC Javelin	F133															2	2
Goddard Javelin	8.00															1	1
Shotput	E60															1	1
University of Iowa Nike-Cajun	10.00															3	3
University of Michigan Strongarm	F134															2	2
Goddard Nike-Asp	3.00															5	5
Trailblazer I	D58															3	3
Arcas	Arcas															3	3
Total												2	4	14	42	28	90
Air Launches and Drops																	
Langley Bomb Drop		3	7(a)	7(a)	5		4	4	2								32
Lewis Ramjet				2	12	8	8	3	3	1	3		1				41
Lewis Heat Transfer										2	2	5(b)	3(c)	7	5	2	26
Mercury Capsule Model	F57														3		3
Mercury Boilerplate															4	11	15

Capsule																	
Camera Capsule															1		1
General Electric Atlas Data Capsule																3	3
Martin Domar																13	13
Total		3	7	9	17	8	12	7	5	3	5	5	4	7	13	29	134
Basic Research: Ground Launch																	
Automatic Control	RM-1	2	7	1													10
	D4					5	1	1	1	1	1	2					12
	D38								7	4	3	4					18
	D44												1				1
Drag	E2	7	148	71	94	118	41	47	17	11	18	7	3	5	2	3	592
	F6		2	3	2												7
	E12				1	2											3
	E17					6	7	6	5	4	3						31
	F25					13	13	23	17	29	13	20	23	3			154
	E25							1	10	9	7	6	2				35
	E30						19	33	39	124	81	47			11		354
	D30									10	2	4					16
	F30									4	15	5	15	9		30	78
	E34							16	10	2	7						35
	D35								1	1	2	5					9
Aerodynamic Heating and Boundary Layer	F10				1	6	7	3	5	1	4	3	1			1	32
	E10			3	2	4	8	2	1	5		1					26
	F33							3				2					5
	F40									1	4	4	8	11	4	6	38
	H40														1		1
	E41										3	3	6	2	3		17
	H41														1		1
	F131															1	1

Program	Code	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Basic Research: Ground Launch (continued)																	
Control	E5		34	117	131	134	88	35	27	18	39	22	7				652
	F5						4										4
	D8			1		2	2	1	1		2	1					10
	D9			1	1												2
	E16					1			2	3		3					9
	D21					1	1		1	3	1						7
Stability	D3				1	5	4	3			2	1	3	6	1		26
	E7			3	5	5	2	1	2	5	1	3	2				29
	D13				4	49	55	5	7								120
	E14				4	8	11	4	4	3	2						36
	E15				5	3	2	5	1	3	5	5	3		1		33
	D32							4	4	6	1						15
	E42										2	2	6	2			12
	D46													1			1
	E48													2	4	3	9
	D55														2		2
	F53														2	3	5
Flutter	FR-1			3	1	1											5
	FR-2			7	4	9											20
	FR-3				2												2
	D18						1	2	4	4	4	3	1	2			21
	D27						2	1	1			2		2			8
	D37									3		1					4
Ramjet	F23					1	7	5	1	2	1	1	1				19
	F24			3		1											4
	D22						1	1		1		1					4
	F29								3	3	2	3	1		3		15
	F36								2	1							3

Inlets	F26						5	9	19	14	4	3	5				59
Pilot Escape	D11				2												2
Jet Effects	F12								1		4	12		3	6	1	27
Buffeting	D28						2	3	6	6	7	1	1				26
Aeroelasticity	E31							2	3	2							7
Gust Loads	E39								2	2	2	1	1	2			10
Blast Loads	G45										4	11	6	4	1		26
Cooling	H50														2		2
Manned Satellite	E57														2	5	7
	F57															12	12
	STG															5	5
Lewis Hydrogen-Fluorine Rocket	H59														2	1	3
Solid-Rocket Motor				18	1												19
Technique Development	B20													1		3	4
	D20					1	4	6	3	10	4			6	2		36
	E20			5	5	17	11	3	10	6	9	13	9	3	6	3	100
	F20						1	2	1	4	12	17	3	2	2	3	47
	H20												5	2	1		8
	T20		4	5	16	14	2	4	5		4		1	1	1	1	58
Ground Launch Total		9	195	241	282	406	301	231	223	305	275	219	114	69	60	81	3011
Total Test		16	210	277	331	432	339	261	303	338 (a)	325(d)	253	131	95	133	145	3589
Tracking Rockets(e)		24	100	227	316	338	233	145	166	252	265	173	97	90	124	108	2658
Helium-Gun Dummy								26	37	46	32	20	2	2	10	3	178
Air Total		40	310	504	647	770	572	432	506	636	622	446	230	187	267	256	6425

Notes: (a) An unknown number of these drops were made at Langley.
(b) Number includes 2 practice drops.
(c) Number includes 1 dummy drop.
(d) Number includes 150 2.25-inch test rockets in stability study.
(e) Normally 3.25-inch rockets were used to verify readiness of radars or to train crew.

APPENDIX D

SUMMARY OF WALLOPS PREFLIGHT JET OPERATIONS

Project	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
A Jet												
General Research												
Ethylene Ramjet Engines		x	x	x	x	x	x	x				
Liquid or Slurry Ramjet							x					
Solid-Fuel Ramjet				x								
Inlets and Diffusers			x	x		x		x	x			
Jet Effects				x	x	x	x	x	x	x	x	
Heat Transfer and Pressures				x				x	x	x	x	
External Flow Shadowgraph				x					x	x		
Structural Components				x	x	x			x	x	x	
Structural Wing Panels					x	x	x	x	x			
Store Ejection Research									x			
Upstream Missile Launch									x			
Hypersonic Gliders										x	x	
Model-Booster Trim										x		
Fiberglass Liner for Wind Tunnel								x				
Noise Survey for Tunnel Design									x	x		

Project	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
A Jet												
Specific Research												
Republic F-105 Bomb Drop						x	x	x	x			
Republic F-103 Pilot Escape							x					
Lockheed F-104 Tank Drop										x	x	
Convair F-106 Release of MB-1									x	x	x	
Convair B-58 Pod Drop												x
Avco Vehicle Drop									x			
Martin Titan Heat Transfer									x			
Martin Bomber Flutter Test									x			
Hughes Falcon Stabilizer							x					
Aeroproducts Power Source									x			
WADC Pressure Suit Component											x	
Thiokol Ducted Ramjet											x	
Thiokol Tart Fin											x	
Total Tests [a]		← 382 →		139	82	181	125	236	351	229	345	80
B Jet (1948–1955) / *Ethylene Jet* (1956–1959)												
General Research												
Ethylene Ramjet Engines	x	x	x	x	x	x	x	x				
Liquid or Slurry Ramjet			x	x	x	x	x					
Solid-Fuel Ramjets			x	x	x	x	x	x				
Inlets and Diffusers			x	x	x	x	x	x				
Jet Effects							x					
Heat Transfer and Pressures				x	x				x	x	x	
Structural Components				x		x	x	x	x	x	x	
Insulated Structural Panels							x		x		x	x
Missile Nose				x	x							
Missile Controls					x	x					x	
Metal Ignition								x				
Materials									x	x	x	
Cooling Research						x	x	x	x	x	x	x
Ablation Research											x	x
Hypersonic Glider											x	

Project	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
	B Jet								*Ethylene Jet*			
Specific Research												
Eastman Kodak Heat Seeker				x								
Convair Transpiration Cooling											x	x
Bell Aircraft Multiskin Panels										x		x
Polaris Ablation Materials												x
Emerson Electric Thermolag												x
Total Tests[a]	←— 554 —→			320	155	160	205	180	105	138	203	130
	C Jet											
Inlets and Diffusers									x			
Heat Transfer and Pressures										x		
Center-of-Pressure Test										x		
Acoustic Survey										x		
Continental Rotating Ramjet										x		
Total Tests[a]									22	49		
	Other											
Jet Board				x	x	x	x					
Whirligig						x	x					

Note: (a) Includes calibration tests.

APPENDIX E

TECHNICAL REPORTS FROM WALLOPS OPERATIONS

Program	Code	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Specific Missiles																	
Hughes Tiamat	MX-570	1	4	1		1											7
Navy Lark	Lark		3	2													5
Kellogg MX-800	MX-800			1													1
Bell Rascal	E776					1	1	1			2	1					6
Sperry Sparrow	E100						1	3									4
Northrop Boojum	D775B						1			1							2
Northrop Snark	D775A							1	1		1	1	1				5
Hermes Diffuser	F101										1						1
General Electric Hermes A2	F20									1							1
General Electric Hermes A3	E104										1	1					2
Eastman Kodak Dove	D107									1							1
North American Navaho	F770									1							1
Hughes Falcon	D904										2	1					3
Grumman Rigel	D37									1							1
Navy Sidewinder	D110										1	2					3
Chance Vought Regulus II	D115										1		1		1		3
Martin Titan	F122													2	2		4
Nike Control	D117															1	1
Lockheed Polaris	E125															3	3
	F125															2	2
Temco Corvus	E130															1	1
Army 40-mm Shells										1							1
T231 Rocket Projectile													1				1
Total		1	7	4		2	3	5	1	6	9	6	3	2	3	7	59

Specific Airplanes																	
Douglas D-558-II	E558										1						1
Republic XF-91	E809			1	2		1										4
Douglas X-3	E656				1		2	1		1	1						6
Convair XF-92	E813					2		2									4
Bell X-2	D743						1					1					2
Grumman XF10F-1	D103							1	1	1	1						4
Douglas XF4D-1	E102							1	2	1	1						5
McDonnell XF3H-1	E105									1	3		2				6
Convair XF2Y-1	E106									1	2	1					4
Convair XFY-1	E108										2	1					3
Convair XB-58	E1626									2		1	1		1		5
North American YF-100	E1894									1	4						5
Chance Vought XF8U-1	E114										2	1	2				5
Convair F-102	E1554										3	1					4
Lockheed XF-104	E112										1						1
Grumman F11F-1	E113											1					1
McDonnell XF-101	E111											2	2				4
	F111												1				1
Boeing MX-1712	E1712											1					1
McDonnell XF4H-1	E118													1		1	2
Douglas F5D-1	E102												1	1			2
Republic F-105 Flutter	D37												1				1
Republic F-105 Bomb Drop	PFJ												3	1			4
Convair F-106 Bomb Drop	PFJ													2		1	3
Avco Test Vehicle	PFJ												1				1
Lockheed F-104 Store Drop	PFJ															1	1
Total				1	3	2	4	5	3	8	21	10	14	5	1	3	80

Program	Code	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Sounding Rockets																	
University of Michigan Nike-Deacon	F20											1					1
University of Michigan Nike-Cajun	F20													1			1
University of Maryland Terrapin	H121													1			1
AFSWC JASON	F127															1	1
University of Michigan Exos	E20															1	1
Hi-Ball Radar Target	SV56															2	2
Total												1		2		4	7
Air Launch and Drops																	
Langley Bomb Drop		3	4	5	4	2	2	2		2	1						25
Lewis Ramjet					1	1	3		3	1	4	1		1			15
Lewis Heat Transfer										1		2	2	2		2	9
Total		3	4	5	5	3	5	2	3	4	5	3	2	3		2	49
Basic Research																	
Automatic Control	RM-1		2	1	2	1											6
	D4					1	2	3		2	1	2					11
	D38									2		2	1				5
Drag	E2		6	6	3	3	10	6	7	3	3		1	1			49
	F6				1												1
	E17						3	1	1	1							6
	E25									2	2	2		1			7
	F25						2	6	3	4	3	2	2	4	2		28
	E30									4	2		3			1	10
	D35								1		2	2	2	3			10
Aerodynamic Heating	F10						1	2	1		5	2	1	1			13
and Boundary Layer	F40									1	1	4	5	21	14	4	50
	E41												2	1			3

	PFJ								1	1							2
Control	E5			3	9	3	5	8	2	6	6	3	3	3			51
	D8					1		1	1	1	1		1	1			7
	E16								1					2			3
	D21						2		1				1				4
Stability	D3						1		6	1					1	1	10
	E7					1			1	1	2						5
	D13					1	2	3	1	1							8
	E14						1	1	1		1						4
	E15					1	2	2	6	2	3	3	1		1		21
	D32								1		2						3
	E42												3	1		1	5
	E48												1	1	3	2	7
	F53															2	2
Flutter	FR-1			1	3		1										5
	FR-2			1		1	1										3
	FR-3					1											1
	D18								2			2					4
	D27									1		1		1			3
	D37											1					1
	Other							1		1	1						3
Ramjet	F23						3		4	3		1					11
	F24				1												1
	D22													1			1
	F29								2		1	1	3			1	8
	F36										1						1
	PFJ							1									1
Inlets	F26						1	2		4	2	3		1	1		14
	PFJ								1								1
Pilot Escape	D11					1											1

Program	Code	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	Total
Basic Research (continued)																	
Jet Effects	F12										4	3	3	7		1	18
	PFJ										1	2	2		2	2	9
Buffeting	D28								2	2	3	1					8
Aeroelasticity	E31									1	1						2
Gust Loads	E39									1	1	1	2				5
Wing Dropping							1	1									2
Solid Rocket Motor					2	1			1				1	1	1	2	9
Jet Board and Whirligig	PFJ								1		1						2
Structures	PFJ									3		1		7	3	3	17
Blast Loads	G4S											2		2		1	5
Store Ejection	PFJ											1	2	1			4
Materials												1					1
Cooling	HSO											1		1	1	1	4
Launch Technique													1			2	3
Simplified Missiles												2	1				3
Manned Capsule	F57														1	4	5
Telemeter Blackout	T20														1		1
Total			8	12	21	16	38	38	48	48	50	46	42	62	31	28	488
Grand Total		4	19	22	29	23	50	50	55	66	85	66	61	74	35	44	683

APPENDIX F

ROCKET PROPULSION SYSTEMS DEVELOPED AT WALLOPS

Success of the rocket-model program at Wallops was largely dependent on the ability of the Langley engineers to convert solid-rocket motors into efficient and reliable multistage launch vehicles or boosters. When the program began in 1945, aircraft rockets—each consisting of a rocket motor, a nose cone with a warhead, and stabilizing fins—were available. Converting these devices to the propulsion system of a rocket model meant discarding the warhead and fins and designing new fins and attachments as required for particular test models.

Adapting a motor as an internal propulsion unit called not only for the designing of physical attachments but also for consideration of such items as the transfer of thrust to the model and the expansion of the hot motor case during burning of the rocket. Adapting a motor as a booster required consideration of the size of the fins needed for the stability of the configuration, the structural loads and bending-under loads involved, and the problems connected with attaching the motor to the model with enough strength and stiffness to prevent failure under direct load or divergence, and yet with enough flexibility to provide a system capable of separating safely from the model after burnout. Reliable ignition systems for the motors were also required.

The listing below gives the major propulsion systems or launch vehicles used at Wallops from the beginning in 1945 through 1959. The total shown includes 95 ground-launched and 9 air-launched systems. Some of the smaller rockets are not listed, nor are rocket motors of reduced length for special applications. All of the ground-launched systems were designed by Langley's Dynamic Model Engineering Section (DMES). For the most part, all construction was performed in the Langley shops, although in later years many of the standard booster-fin assemblies and adapters were constructed by industry, under contract. The air-launched systems were developed by Lewis Research Center with the aid of Langley.

In this listing, the rocket motors are given in the order in which they were fired, without regard to whether they were carried internally as "sustainers" or externally as "boosters."

Ground-Launched Rocket Systems			
No.	*Rocket System*	*First Project*	*Date of First Launch*
1	Six Cordites – (WF-1)	Tiamat	July 1945
2	(ACL-1) – (WF-1)	Tiamat	Aug. 1945
3	Cordite	RM-1	Oct. 1945
4	Cordite – Cordite	RM-1	Oct. 1945
5	3.25-inch	RM-2	Oct. 1945
6	HVAR	FR-2	Feb. 1947
7	12AS1000	FR-1	Mar. 1947
8	3.25-inch – 3.25-inch	RM-5	Apr. 1947
9	HVAR – 3.25-inch	65-inch RM-10	Apr. 1947
10	Deacon	Motor Test	Apr. 1947
11	HVAR – HVAR	XS-3	Aug. 1947
12	(ACL-1) – HVAR	XF-92	Nov. 1947
13	7KS6000	Motor Test	Nov. 1948
14	HVAR – Cordite	D13	Dec. 1948
15	Double Deacon	D4	July 1949
16	3.25-inch – Cordite	D13	July 1949
17	65-inch HVAR – 3.25-inch	E16	July 1949
18	Deacon – 65-inch HVAR	Sparrow	Sept. 1949
19	Deacon – 3.25-inch	E10	Nov. 1949
20	65-inch HVAR – Deacon	Sparrow	Feb. 1950
21	Deacon – Deacon	RM-10	Feb. 1950
22	65-inch HVAR	E14	Feb. 1950
23	3.25-inch – HVAR	XF-92A	Mar. 1950
24	65-inch HVAR – 65-inch HVAR	E2	May 1950
25	65-inch HVAR – Cordite	D18	Nov. 1950
26	Double Deacon – Deacon	RM-10	Nov. 1950
27	HPAG	Motor Test	Dec. 1950
28	Deacon – Cordite	XF10F-1	Dec. 1950
29	Double Deacon – 65-inch HVAR	Sparrow	Jan. 1951
30	T44	Motor Test	Mar. 1951
31	Two underslung 3.25-inch Motors	E20	Aug. 1951
32	T40	Hermes	Feb. 1952
33	Deacon plus two strap-on 3.25-inch Motors	D109	Apr. 1952
34	HPAG – 3.25-inch	F25	May 1952
35	Triple Deacon	F23	July 1952
36	Two underslung Deacons	B-58	July 1952
37	Deacon plus two strap-on HPAG's	D109	Sept. 1952

Ground-Launched Rocket Systems (continued)			
No.	*Rocket System*	*First Project*	*Date of First Launch*
38	Quadruple Deacon	D20	Jan. 1953
39	Double Deacon — 14AS1000	RM-10	Feb. 1953
40	Quadruple Deacon — HPAG	E2	Feb. 1953
41	14AS1000	D38 Target	Apr. 1953
42	HPAG — Deacon	YF-102	July 1953
43	Triple Deacon — HPAG	E10	Aug. 1953
44	Nike	Navaho	Oct. 1953
45	Nike — Deacon	F40	Nov. 1953
46	HPAG — Cordite	D18	Dec. 1953
47	Deacon — HPAG	D35	Jan. 1954
48	Double HPAG — Deacon	F-102A	Jan. 1954
49	Nike — Nike — Deacon	F40	Apr. 1954
50	Three peel-away Deacons — Deacon — HPAG	F40	Apr. 1954
51	Double Deacon — HPAG	E2	Apr. 1954
52	Double Deacon — T40	Hermes	Apr. 1954
53	Double Deacon — two underslung HPAG's	E15	Sept. 1954
54	Nike — Nike — T40	F40	Oct. 1954
55	Nike — Nike — HPAG	E41	Oct. 1954
56	Nike — Nike — T40 — T55	E41	Oct. 1954
57	Two underslung Deacons — Deacon	E15	Nov. 1954
58	Nike — HPAG	E2	Jan. 1955
59	Triple Deacon — Deacon	E10	Feb. 1955
60	Underslung Deacon — Cordite	F25	Mar. 1955
61	Nike — Nike — Triple Deacon — T40	F40	Apr. 1955
62	Double HVAR — 3.25-inch	F12	Apr. 1955
63	Honest John — Nike	F40	Sept. 1955
64	Honest John — Nike — T40 — T55	E41	Mar. 1956
65	Double Deacon — HVAR	D3	Mar. 1956
66	Honest John — Nike — Triple Deacon — T40	F40	June 1956
67	Cajun	Motor Test	June 1956
68	Nike — Nike	E41	June 1956
69	Double Deacon — T40	E20	June 1956
70	Nike — Cajun	F20	July 1956
71	Honest John — Nike — T40	F40	July 1956
72	Honest John — Nike — Nike — Recruit — T55	F40	Aug. 1956
73	Cajun — Loki	H20	Aug. 1956
74	Nike — T40 — T55	F40	Sept. 1956

Ground-Launched Rocket Systems (continued)

No.	*Rocket System*	*First Project*	*Date of First Launch*
75	Nike – Recruit	F40	Oct. 1956
76	Cajun – Double Loki	E41	May 1957
77	Honest John – Nike – Nike	F123	Oct. 1957
78	Double Cajun – T40	E20	Nov. 1957
79	T55	F29	Mar. 1958
80	Sergeant plus two Recruits – Lance – Lance – Recruit – T55	F40	June 1958
81	Nike – Double Loki	E15	Sept. 1958
82	Honest John	Corvus	Nov. 1958
83	Recruit	E48	Jan. 1959
84	Gosling	E48	Jan. 1959
85	Honest John – Nike – Nike – 20-inch Sphere	F20	Mar. 1959
86	Honest John – Nike – Lance – T40 – T55 – 5-inch Sphere	D58	Mar. 1959
87	Nike – Nike – Cajun	F40	Apr. 1959
88	Honest John – Nike – Nike – X248	Javelin	July 1959
89	Nike – Asp	GSFC	Aug. 1959
90	Sergeant plus two Recruits – X248	Shotput	Oct. 1959
91	Quadruple Pollux plus four Recruits	Little Joe	Oct. 1959
92	Honest John – Nike – Nike – Yardbird – Baby Sergeant	Strongarm	Nov. 1959
93	Quadruple Castor plus four Recruits	Little Joe	Dec. 1959
94	Honest John – Nike – Gosling	F40	Apr. 1960
95	Algol – Castor – Antares – Altair	Scout	July 1960

Lewis Air-Launched Rocket Systems

No.	*Rocket System*	*First Project*	*Date of First Launch*
1	14AS1000	Ramjet	June 1950
2	T40	Ramjet	Jan. 1952
3	T55	Ramjet	Feb. 1956
4	T40	Heat Transfer	Mar. 1953
5	T40 – T55	Heat Transfer	Nov. 1955
6	Triple Loki – Loki	Heat Transfer	Dec. 1955
7	Recruit	Heat Transfer	Nov. 1956
8	Recruit – T55	Heat Transfer	July 1957
9	Triple Recruit – Recruit – T55	Heat Transfer	Jan. 1959

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16. Abstract

This document is a record of the first fifteen years (1945 - 1959) of research and development tests that were performed at Wallops Island. It begins with the events that led to the establishment of the National Advisory Committee for Aeronautics flight test range on Wallops Island to the first year as a part of the National Aeronautics and Space Administration.

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