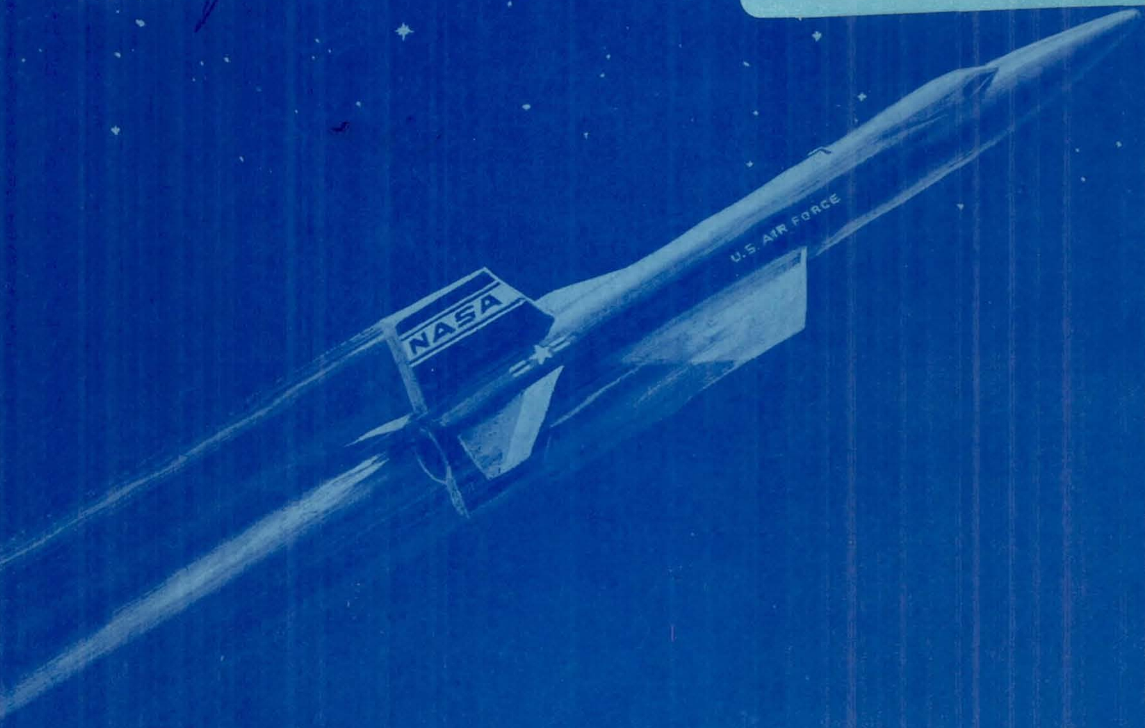

# X-15

## RESEARCH AT THE EDGE OF SPACE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# CONTENTS

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# MISSION AND ACCOMPLISHMENTS

# I

In the fall of 1963, the X–15 completed a series of flights at speeds and altitudes never before attained by any vehicle fully controlled by a pilot from launch to landing on the ground. In the process of making almost 100 successful flights, it had essentially completed its original program of flight research and had begun to carry out additional aerospace experiments.

From conception through the phases of design, construction, test, and operation, it had rounded out some 11 years of exploring a variety of technological and scientific problems. The X–15 program had produced 3 major conferences and more than 60 technical reports completed or in process.

Probing ever higher and faster in the course of a progressive series of research flights, the X–15 in August 1963 reached a peak altitude of 354,200 feet (67 miles)—more than three times as high as any other winged aircraft. It had set two official (FAI) world altitude records of 246,750 feet and 314,750 feet. On another flight it had reached 4,104 miles per hour and it had repeatedly flown faster than 3,600 m.p.h., a mile a second. In 1962, four of its pilots had received the Robert J. Collier Trophy at the hands of President John F. Kennedy for "the greatest achievement in aeronautics or astronautics in America, with respect to improving the performance, safety, or efficiency of air and space vehicles."

The "greatest achievement" for which it won this trophy—widely acknowledged as the highest in aerospace affairs—consisted of that long series of flights in the small, black-painted, stub-winged, rocket-powered research craft known simply as "X–15"—in probing the unknown, investigating the suspected, documenting the vaguely familiar.

Records have kept the X–15 in the public view through newspaper headlines, but records are incidental to the goals of the program. The real mission of the X–15 is a quest for knowledge. In carrying out this mission, the X–15 has made a number of substantial contributions to the advancement of aerospace science.

Although primarily an aeronautical vehicle with wings and aerodynamic controls, the aircraft travels well beyond the effective atmosphere on most of its flights. At extreme altitudes, the pilot controls the X–15 by reaction jets, like a spacecraft; he is weightless for brief periods, and the research plane reenters the atmosphere like a spacecraft.

Thus, the research contributions of the X–15 embrace both aeronautics and space flight. Its flight program has provided important knowledge applicable to the design and development of future spacecraft and to tomorrow's man-carrying aircraft, such as the commercial supersonic transport.

It is impossible to detail all the knowledge gleaned by the X–15, but a mention of some of the findings, and their actual or potential applications, will point up the research airplane's value.

One important contribution of the X–15 program resulted from the investigation of aerodynamic heating in a new regime of flight. Aerodynamic heating is a phenomenon of high-speed flight in which the high-velocity movement of air molecules over and around an airplane brings about an increase in temperature on the plane's surfaces due to friction and compression. These temperatures must be taken into consideration in the design of supersonic or hypersonic aircraft, because excessive aerodynamic heating could cause deterioration of the aircraft's structural integrity.

Before construction of the X–15, aircraft designers believed it was possible to predict surface temperatures to be encountered at given speeds and altitudes by means of existing heat transfer theories. Later, an extensive series of wind-tunnel tests investigated aerodynamic heating at very high speeds. However, the wind tunnel tests produced values different from the theoretical calculations. In the design of the X–15, a compromise was made by taking both sets of data into account. The X–15 was designed to withstand a maximum temperature of 1,200° F.

In a number of flights, the X–15 exceeded this maximum temperature under certain controlled conditions, occasionally reaching a temperature of 2,000° on the leading edges of the wing and tail. Flight research also revealed that temperatures on the fuselage, wing, and tail surfaces were generally lower by 100° or more than the predicted compromise figures. Although the cause of the difference is not fully known, it is now apparent that use of simple, unmodified wind-tunnel data may give inaccurate results for aerodynamic heating. Further investigation of the differing values will be important to the design of all future hypersonic aircraft. Thus the X–15 made a contribution in focusing attention on an unexpected problem area.

The aerodynamic heating investigations of the X–15 are proving helpful in a number of other areas. The data acquired will be useful in the design of any reentry vehicle and certain new aircraft, such as the supersonic passenger transport, which will encounter high temperatures for long periods and go through repeated cycles of extreme heating and cooling.

The X–15 also has produced important knowledge on the glass needed for windshields and passenger windows in high-speed aircraft, and factors of its installation and environment. Initially, a soda-lime glass was considered adequate for any temperatures the X–15 might encounter, but on one flight in 1961 a soda-lime windshield panel failed. As a result, a new windshield of alumino-silicate glass was substituted. On a later flight in 1961, the alumino-silicate panel failed. The failures were not serious, incidentally, because the X–15 has double windshield panels and only one of the outer panels failed in each instance. Analysis later indicated that retainer design, not the glass, was the source of the trouble, and the design was changed.

From the X–15 program, data have been gathered on the effect of high noise levels on aircraft materials. Failures of the horizontal and vertical tail surfaces, consisting of separation of the skin from the internal corrugated web used for stiffening, were encountered, and the cause was discovered. Before launch, the X–15 is carried to altitude by a B–52 plane, the research plane hanging suspended from a pylon under the B–52 wing. Close to and just outboard of this pylon are a pair of the B–52's powerful jet engines. It was learned that extreme noise from these jets was causing metal fatigue in the X–15. Modifications to the structure corrected the problem. The noise data may be applicable to the design of future aircraft; for example, the data could influence location of engines to minimize the possibility of noise-induced metal fatigue.

The landing gear of the X–15 consists of a pair of retractable skids, rather than conventional wheels, and a double-wheeled free-castoring nose gear. Experience with this unique gear has proved valuable. Provisions must be made for safe landings for glide-type spacecraft. Its landing gear must meet all the usual requirements, and also be very light and built of material that can withstand reentry temperatures. The X–15 provided a good opportunity to study the skid-type main landing gear, for the craft was instrumented to measure gear loads, gear travel, and accelerations, data which will be very valuable in designing future spacecraft landing-gear systems.

Even after six decades of aeronautical research, the behavior of the boundary layer, the layer of air close to the surfaces of an airplane, is not completely understood. The X–15 program included measurements of skin-friction drag which will be applicable to the design of any new high speed aircraft. In addition, the research craft provided the first detailed full-scale drag data at Mach numbers from 2 to 6 (two to six times the speed of sound).

Many of the complicated systems in the X–15, some being used for the first time, have applications in tomorrow's supersonic and hypersonic aircraft, and in spacecraft. For instance, a new adaptive flight control system can provide an extra degree of safety and reliability in the supersonic transport of the future. The X–15's spherical nose sensor, which indicates to the pilot angles of attack, sideslip and dynamic pressure, is being adapted for use on NASA's Saturn 1 rocket vehicle for high-altitude wind investigations.

The X–15 also provides an unequaled opportunity for development of piloting techniques at high speeds and during atmospheric exit and reentry, when the pilot, at times, is subjected to high accel-

*erations and decelerations and at other times is* weightless. In addition, the program has pioneered new types of instrument displays for supersonic and hypersonic aircraft. For instance, during the flight program a safety aid known as an "energy management system" was developed by engineers of NASA's Flight Research Center. This system consists of a radar plot of the X–15 flight path and a map of the terrain over which it is flying. In case of premature engine shutdown, a computer estimates the energy available in the aircraft and computes how far it can go in any direction without power. The pilot can then be directed to a landing area within his glide radius. It appears possible to develop an advanced version of this system for other vehicles. The information obtained by the computer could be telemetered to any aircraft, military or commercial, in an emergency situation. Instead of voice directions, a cockpit display would show the pilot the location and direction of the nearest landing field. This would be a vital instrument to the pilot of any supersonic or hypersonic aircraft. A further development being investigated is a completely airborne unit to perform the same function.

These are but a few of the ways in which the X–15 contributed to the advancement of the aerospace art. There are, and will be, a great many more.

Started in 1952, the X–15 program is a joint endeavor of the U.S. Air Force, the National Aeronautics and Space Administration, and the U.S. Navy. The pilot recipients of the Collier Trophy included a member of each of these three organizations—NASA's Chief Research Pilot Joseph A. Walker, Maj. Robert M. White of the Air Force, and Comdr. Forrest S. Petersen of the Navy—and A. Scott Crossfield, who made the first demonstration flights for North American Aviation, Inc., the company that built the plane. Other pilots who have participated in the program include Maj. Robert A. Rushworth and Capt. Joe H. Engle, both USAF, and Neil A. Armstrong, John B. McKay, and Milton O. Thompson of NASA.

In carrying out its primary mission—the acquisition of new information concerning the broad range of flight conditions in hitherto unexplored flight regimes—the X–15 has been eminently successful. Dr. Hugh L. Dryden, Deputy Administrator of NASA, called it "the most successful research airplane ever built." The X–15 program is far from finished; as the basic objectives are attained, the research vehicles will be assigned new and equally important tasks in aeronautics and space.

# EARLIER RESEARCH AIRCRAFT

# II

In the broad sense, every new airplane is a research airplane, since each new increase in performance is obtained through accumulated flight experience at lower levels. In this manner, aircraft evolved over the first four decades of powered flight from the 25-mile-per-hour Wright Flyer of 1903 to the bombers and fighters of World War II, flying in the 200-to-400-mile-per-hour speed range.

In the latter years of that war, the first operational turbojet-powered aircraft came into being, and the aircraft performance curve climbed beyond the 500-mile-per-hour mark. It was obvious that the next major step in speed increase would be a flight beyond the speed of sound, which is approximately 760 miles per hour at sea level and drops off to about 660 miles per hour at high altitude. This was an unexplored area of flight. Even the research tools of that day, such as wind tunnels and free-flying models, could not provide adequate data upon which to base the design of supersonic aircraft. More visionary minds in the National Advisory Committee for Aeronautics (forerunner of NASA) and the military services believed that while the so-called "sound barrier" presented design problems, supersonic flight was not only possible but inevitable. However, if aircraft were to fly faster than sound, a comprehensive research program was needed to acquire scientific data at speeds above Mach 1, the technical term for the speed of sound.

As a result, there came into being the research airplane, a vehicle which has no purpose but the acquisition of flight data, a craft designed to carry only a pilot and instruments, rather than passengers or cargo or mail, and not intended for production or any use except research. Its assignment was exploration, probing unknown areas of flight and gathering data on the behavior of aircraft in these flight regimes.

The research airplane program got underway in 1944, when the Congress appropriated funds for NACA and the military services to contract for two types of research aircraft. The purpose of these planes was to explore the transonic speed range, the area from just below to just above Mach 1.

The first vehicle of the new program was a rocket-powered aircraft called the XS–1, later redesignated the X–1. In 1944, Bell Aircraft Corp. was awarded a contract for the design and construction of the X–1, which was to be capable of flying faster than sound. Rocket power was important because of the speed and altitude requirements of the X–1, but it limited flight duration because of the extremely high rate of fuel consumption coupled with the small size of the vehicle. The second of the two research airplanes, the Douglas D–558–I, was jet powered, and although it did not have the speed potential of the X–1, it was capable of sustained flight in the Mach 0.9 region.

The X–1 was a small airplane, smaller than fighter aircraft of the day. It was 31 feet long and 10 feet 10 inches high, and its sturdy straight wing spanned only 28 feet. Power was supplied by a Reaction Motors, Inc., rocket engine having four separate chambers, each producing 1,500 pounds thrust. Because of its brief power duration, the X–1 was hauled to altitude in the bomb bay of a converted B–29 bomber, then released to proceed on its own power. Three of them were built. Starting in January 1946 at Pinecastle Army Air Base, Fla., the X–1 was put through a series of glide flights to check out stability, control, and landing characteristics. Then, in 1947, after installation of the rocket engine, high-performance flights were initiated at Rogers Dry Lake at Muroc Air Force Base, Calif., later called Edwards AFB, Calif.

The X–1 made history on October 14, 1947. On that date, at Muroc, Capt. Charles E. ("Chuck") Yeager, USAF, made the first supersonic flight, piloting the little rocket plane to a speed of Mach 1.06, or 700 miles per hour at 43,000 feet. Later flights reached Mach 1.45 and 71,902 feet.

Flights of the D–558–I began in April 1947. Powered by a General Electric TG–180 turbojet, the "Skystreak," as it was called, was 35 feet long, 12 feet high, and spanned 25 feet. Unlike the X–1, it took off under its own power. In the course of a series of flights designed to investigate the aerodynamic aspects of the straight-wing configuration at high subsonic speeds, the D–558–I attained a top speed of 650.8 miles per hour in August 1947, for an official world record.

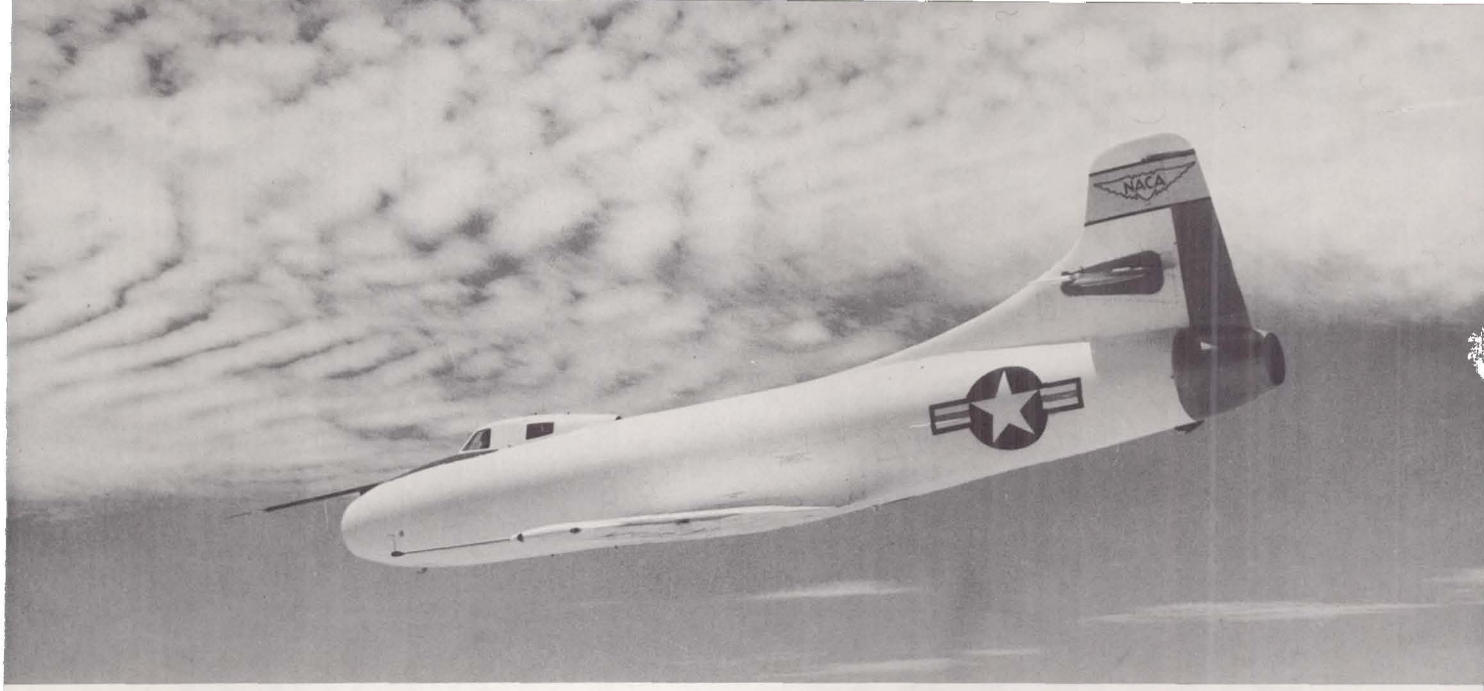
The next step in the research airplane program was the Douglas D–558–II "Skyrocket," designed to study the flight characteristics of swept-wing aircraft at transonic and supersonic speeds. There were three configurations of the D–558–II, one powered by a single turbojet engine, a second by a combination of jet and rocket power, and a third by rocket powerplant alone. Although the D–558–II was designed like its predecessor (D–558–I) to take off and land under its own power, the later phases of the program utilized a B–29 for air launch. The D–558–II had wings swept at an angle of 35°. First flight was made in February 1948, and over a long period the research craft was pushed to higher and higher speeds and altitudes. In August 1951, Douglas Aircraft Co. test pilot Bill Bridgeman flew it to 1,243 m.p.h. and, 8 days later, to 79,494 feet. In August 1953, Lt. Col. Marion Carl, USMC, set a new unofficial altitude record of 83,235 feet. Finally, in November 1953, the "Skyrocket" became the first airplane to fly at more than *twice* the speed of sound or Mach 2.005, when Scott Crossfield, flying as a research pilot for the National Advisory Committee for Aeronautics, attained a speed of 1,291 m.p.h.

There was a series of follow-on aircraft to the X–1, modified versions of the basic X–1, designed either for higher performance or for specialized missions. The most successful plane of this series was the X–1A, which flew its first powered flight in February 1953. The X–1A was similar in general design to the original X–1 series, but its fuselage was lengthened by 5 feet. This increase in length permitted installation of additional fuel which, with a turbodriven propellant pump, provided a considerable increase in performance. Designed to explore flight characteristics at altitudes up to 90,000 feet and at speeds in the vicinity of Mach 2, the X–1A exceeded both goals in the course of its program, attaining a top speed of 1,612 miles per hour (Mach 2.435) and an altitude of 90,440 feet.

Other models of the X–1 series included the X–1B, X–1D, and X–1E, the latter a thin-wing version of the X–1, with an ejection-seat system and a low-pressure fuel system. A scheduled X–1C was never completed, and the X–1D was destroyed by fire during its first captive flight. Later, 500 thermocouples (temperature-measuring devices) were installed in the X–1B for a project involving the measurement of the magnitude and distribution of aerodynamic heating throughout the aircraft structure. In another assignment, the X–1B was employed in an investigation of a prototype reaction control system designed for use in aircraft flying above the effective atmosphere, where aerodynamic controls are ineffective.

The X–2, a major step in the research airplane program, made its first powered flight in November 1955. Also built by Bell, the X–2 was designed to explore a new regime of flight at altitudes above 100,000 feet and at Mach 3 speeds. The new rocketplane had a long, sleek fuselage constructed of a metal called K-monel; its wings, swept back at a 40° angle, were of stainless steel, as were the tail surfaces. Designed for airdrop from a modified B–50 bomber, it had a conventional nose wheel but no main wheels. Instead, it landed on a retractable

***Among the earliest research airplanes to fly were these three: (opposite above) the transonic, jet-propelled D–558–I "Skystreak," (center) the rocket-powered X–1 No. 1, which made the world's first supersonic flight on October 14, 1947, and (bottom) the rocket-engined D–558–II "Skyrocket," which made the first flights at twice the speed of sound, or 1,291 m.p.h.***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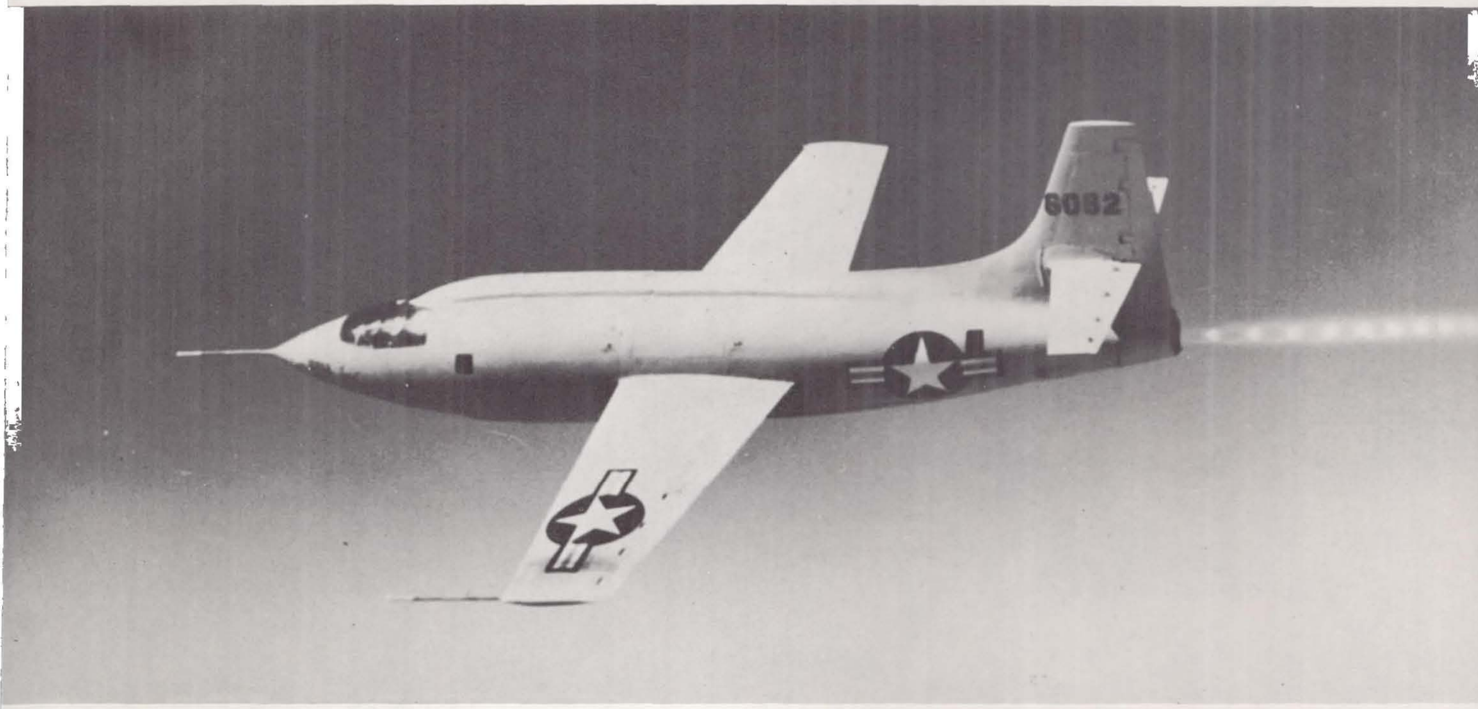
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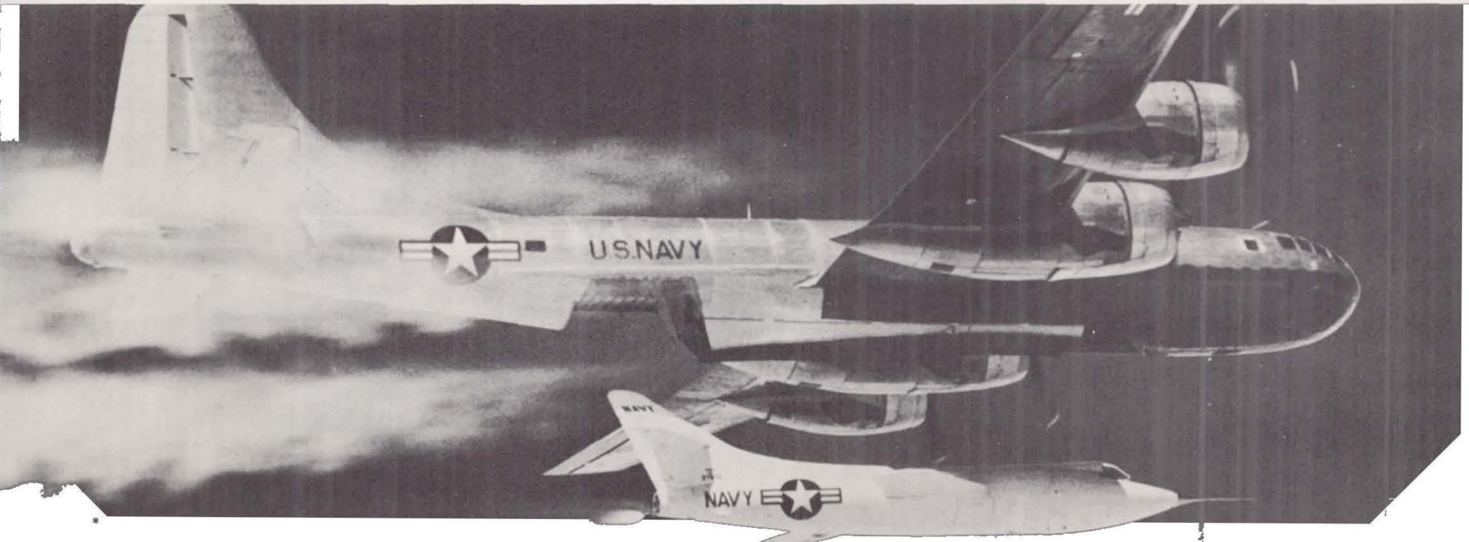
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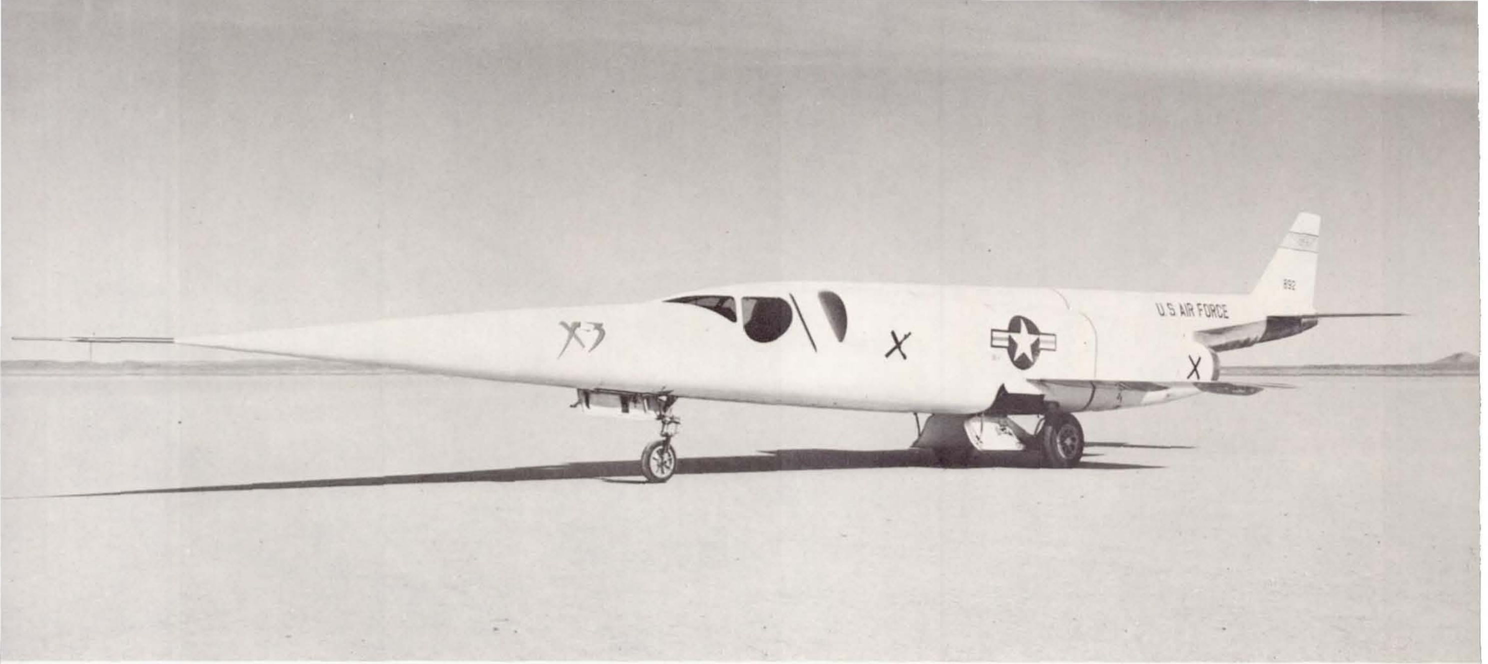
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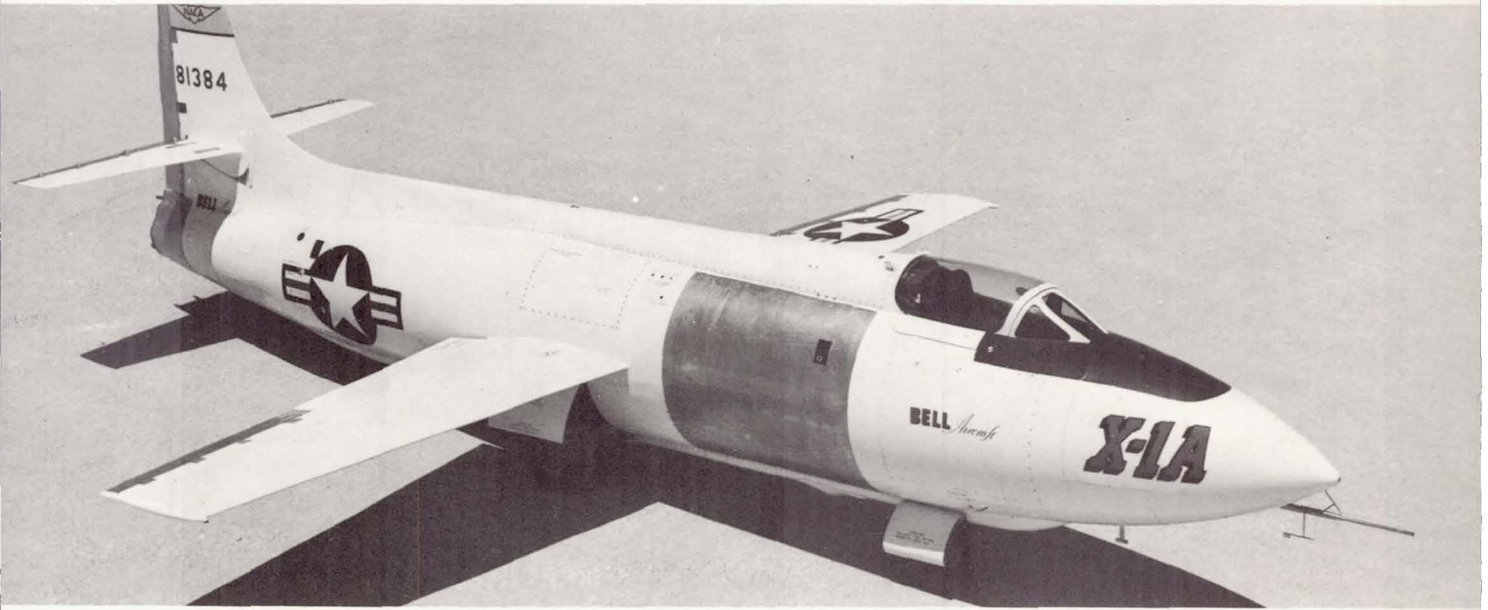
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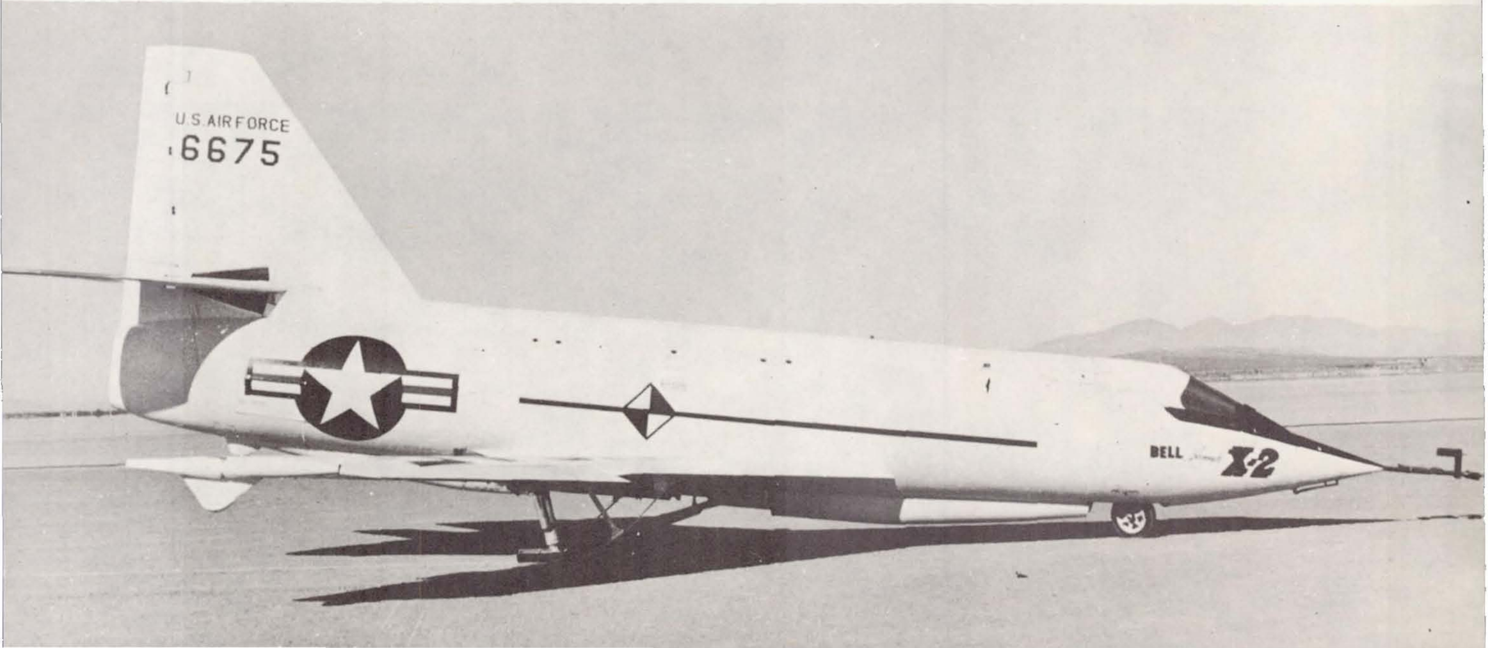
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skid. The cockpit could be blown away from the rest of the fuselage in case of emergency, permitting the cockpit and pilot to descend by parachute, similar to the system provided for pilot emergency escape from the D–558–I and D–558–II.

An important innovation in the X–2 was its rocket powerplant, designated XLR–25 and built by the Curtiss-Wright Corp. This was the first throttleable rocket engine used in American aircraft. In earlier rocketplanes such as the X–1, the amount of power applied was determined by the number of rocket chambers fired—one, two, three, or all four. The X–2 had a throttle system similar to that of a jet airplane, permitting any degree of power application between 5,000 pounds minimum and 15,000 pounds maximum of thrust.

Two X–2's were built and both were lost in accidents. In May 1953, while the research airplane was still attached to its B–50 carrier on a flight near Buffalo, N.Y., an explosion in the X–2 necessitated dropping it to crash in Lake Ontario. The second X–2 was lost in September 1956, when loss of control at very high speed led Capt. Milburn Apt, USAF, to activate the detachable cockpit mechanism. He was killed in the accident. In the course of its brief flight program, the X–2 reached a maximum altitude of 126,200 feet and a top speed of Mach 3.20, or 2,094 m.p.h.

There were four other vehicles in the research airplane program: the Douglas-built X–3 (1952–56), the Northrop X–4 (1948–53), the Bell X–5 (1951–55), and the Convair XF–92A (1951–53).

The X–3, known as the Flying Stiletto, was a needle-nosed aircraft with thin, straight wings. Its primary mission was to explore sustained controlled flight at speeds beyond Mach 1 and, as a corollary assignment, to test the use of new aircraft metals such as titanium. Because of the requirement for sustained flight, it was powered by a pair of turbojets rather than a rocket engine.

The X–4 marked another departure in aircraft design. Powered by two turbojets, it was designed without a horizontal stabilizer in order to investigate transonic stability characteristics of a semitailless airplane.

The X–5 explored another area of great interest to aerodynamicists, the performance of an aircraft with a variable-sweep wing; that is, a wing whose angle of sweep could be changed in flight. With a cockpit control which permitted the sweep angle to be changed from 20° to 60°, X–5 pilots were able to select the angle most efficient for a given flight condition, such as a high degree of sweep for maximum speed, or wings swept back only 20° for landing and takeoff.

The Convair XF–92A, originally designed as a fighter plane, was the world's first delta-wing airplane capable of supersonic flight, although it normally operated just below the speed of sound. This valuable design was put to use as a research airplane. By this means it became the progenitor of the highly successful F–102A, F–106, and B–58 programs of years later. The design first flew as the XF–92 on September 18, 1948, and as XF–92A on July 20, 1951. Its last flight was in 1953.

From the start of the high-speed research airplane program in 1944 until the end of the X–2 program 12 years later, these vehicles advanced the frontiers of manned aircraft flight from the subsonic regime of the early jets to a speed above Mach 3, and from altitudes on the order of 40,000 to more than 100,000 feet. In exploring new areas of flight, they uncovered new problems and brought about solutions. They checked out and validated data obtained from wind tunnels, and obtained data not available from the tunnels.

In addition to acquiring general flight information, the research airplane program made a number of specific contributions to aircraft design. For instance, the X–3 test program uncovered a phenomenon of high-speed flight known as "inertial coupling." At that time, the first supersonic operational jet fighter was also encountering this difficulty. Flights of the X–3, followed by an intensive study of the problem, led to a solution. The variable-sweep investigations of the X–5 produced results now being incorporated in the modern military fighter, the TFX, or F–111, and which might be included in the design of the commercial supersonic passenger transport.

In the aggregate, these "X" airplanes of the 1940's and 1950's produced a large volume of information needed for design and construction of such modern aircraft as jet transports and modern Mach 2-plus military aircraft. Yet as early as 1952 it was apparent that an even more advanced research aircraft was needed, one which could fly beyond the effective atmosphere and at hypersonic rather than supersonic speeds. This was the X–15.

***The twin-jet X–3 (opposite, above) provided much data on thin wing configurations at transonic speeds; X–1A (center), an improved version of the X–1, attained a world speed record of 1,612 m.p.h. and altitude of 90,440 feet, and (bottom) X–2, powered by throttleable two-barrel rocket engine, was the first manned aircraft to fly above 100,000 feet, and faster than Mach 3.***

# CONCEPT, HISTORY, AND TECHNICAL CONSIDERATIONS

# III

The X–15 project had its birth in the summer of 1952, when NACA directed its laboratories to study concepts for very high altitude supersonic manned flight, the problems associated with it, and methods of fully exploring the problem areas. Initially, consideration was given to wind tunnels and other laboratory techniques or the use of rocket-boosted models as research tools, but after some 2 years of study it was decided that the most effective tool was the manned airplane.

On the basis of its studies, NACA recommended to the Air Force and the Navy the development of a research aircraft capable of flying at 6,600 feet per second (more than 4,000 miles per hour) and at 250,000 feet altitude. The new research vehicle would be air launched. A major obstacle to the construction of so advanced an airplane was lack of a suitable rocket engine; none was available with the necessary thrust, reliability, and controllability.

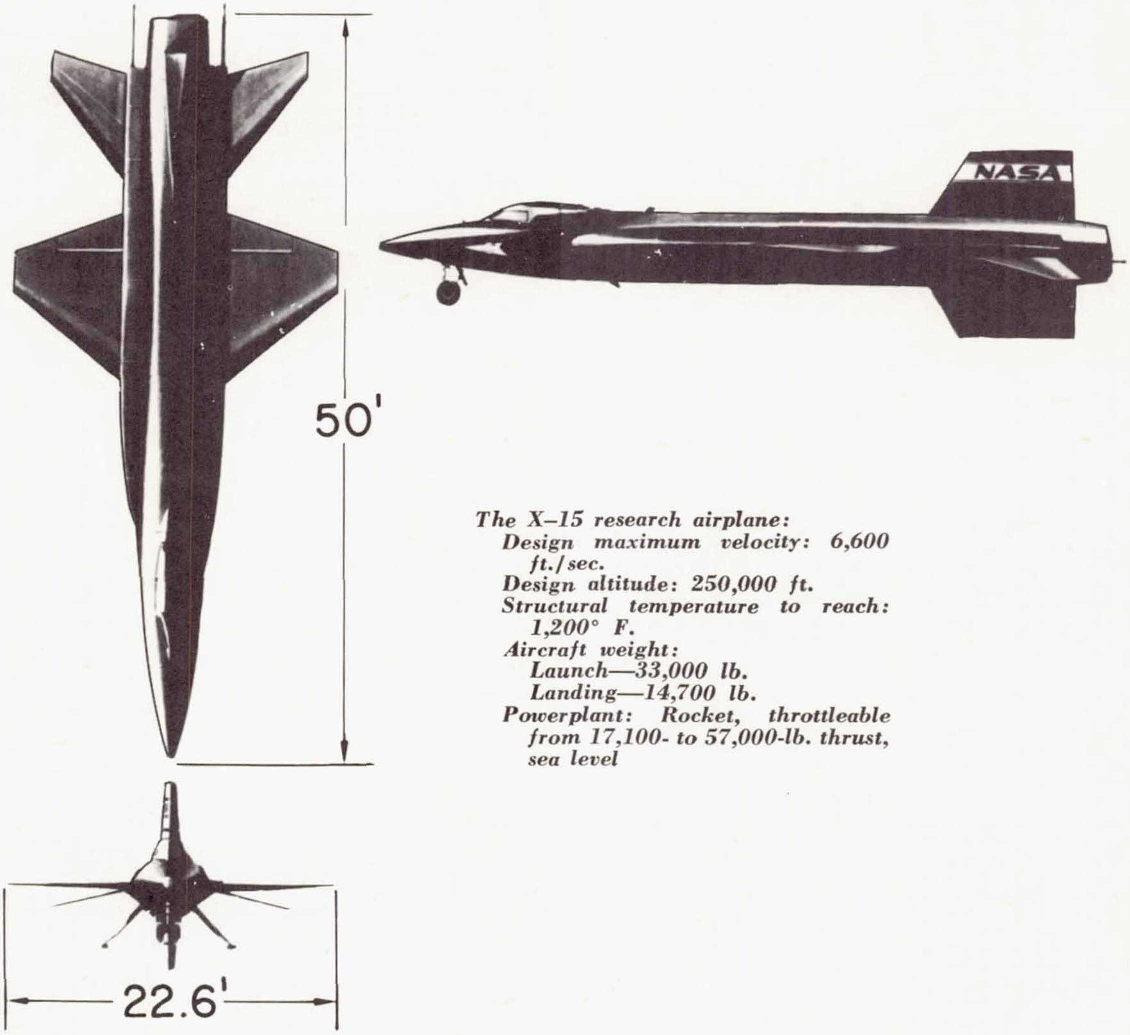
In July 1954, a committee met in Washington to consider proposals advanced for a hypersonic (faster than Mach 5) research aircraft, and a proposal advanced by NACA, based on 2 years of intensive research, was accepted. Under direction of the National Research Airplane Committee, composed of representatives of NACA, the Air Force, and the Navy, NACA was assigned technical responsibility for the project which would be financed by the Air Force and the Navy. The Air Force was assigned responsibility for administering the design and construction phases.

A dozen prospective contractors, invited to bid on construction of the airplane, were given a briefing on the project requirements in January 1955, and some time later four engine manufacturers were asked to submit engine proposals.

Proposals came in from four airframe companies. They were extensively evaluated through the summer and fall of 1955, and the bid of North American Aviation was selected. The initial contract, calling for construction of three airplanes, was awarded in December 1955.

After a similar evaluation of the engine bids, the Research Airplane Committee decided in favor of Reaction Motors, Inc., which later became a division of Thiokol Chemical Corp. The engine proposed by Reaction Motors would be capable of producing 57,000 pounds thrust in a single chamber, with in-flight thrust variation from 50 to 100 percent and an operating duration of 90 seconds at full thrust. The engine contract was awarded in September 1956.

About the same time, it was decided to construct a special instrumented range for X–15 flight operations, consisting of ground tracking stations to assist the pilot with information and guidance, and to locate the aircraft in case of emergency. Known as the "High Range," this network stretches from Wendover, Utah, to Rogers Dry Lake at Edwards, Calif., where X–15 flights originate and terminate. The range is comprised of a master station at Edwards,



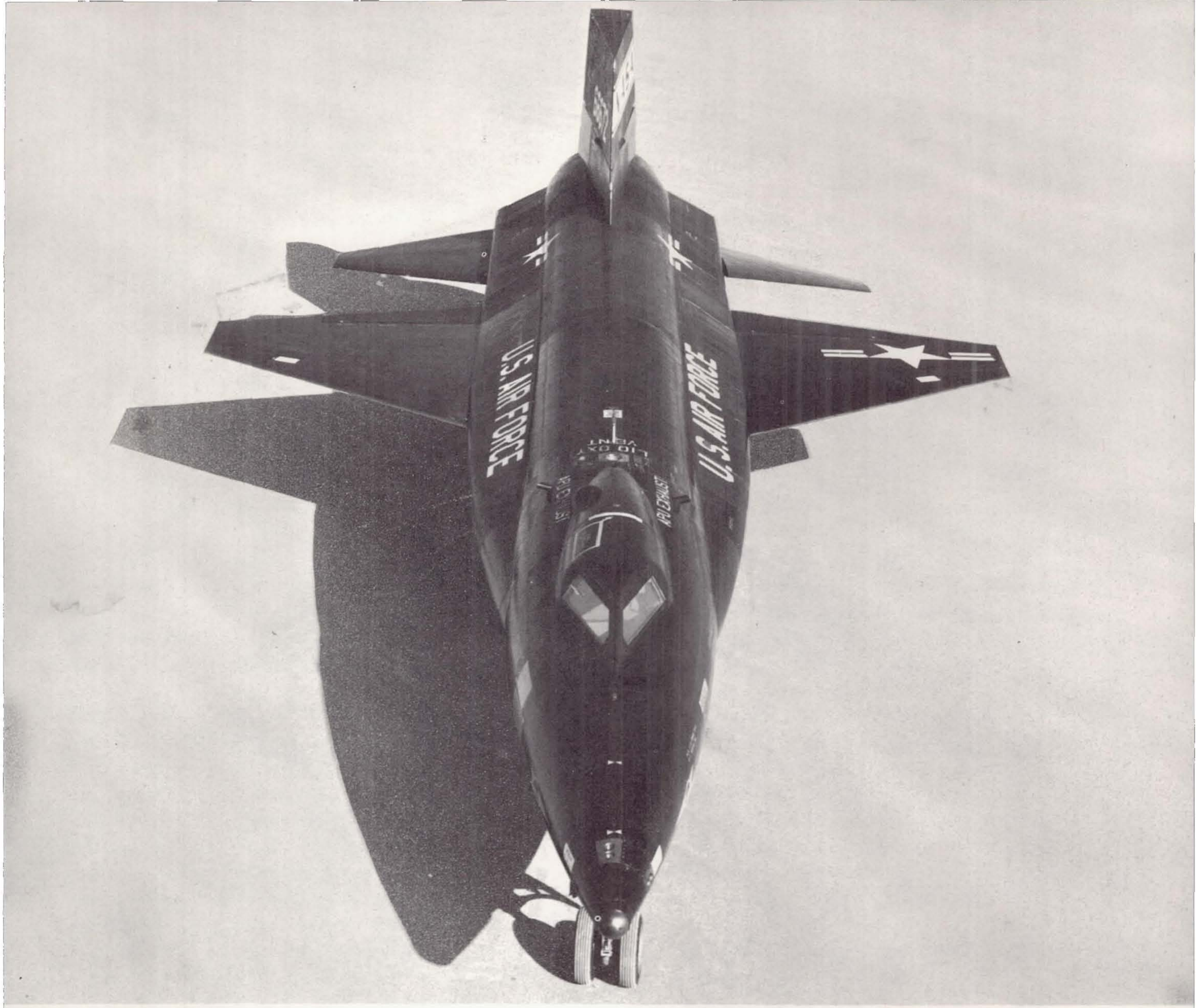
*The X–15 research airplane:*
*Design maximum velocity: 6,600 ft./sec.*
*Design altitude: 250,000 ft.*
*Structural temperature to reach: 1,200° F.*
*Aircraft weight:*
  *Launch—33,000 lb.*
  *Landing—14,700 lb.*
*Powerplant: Rocket, throttleable from 17,100- to 57,000-lb. thrust, sea level*

and radar stations at Ely and Beatty, both in Nevada. Along this range and on each side of the flight corridor are numerous level dry lake beds, which can be used as emergency landing areas.

Following extensive wind tunnel and structural component tests, North American started actual fabrication of the X–15 in September 1957. Meanwhile, work began on modification of two eight-jet B–52 airplanes to serve as carriers for the air-launched X–15.

It became apparent, however, that the great amount of development work required for the advanced rocket engine would require much more time than had been anticipated. In January 1958, the Research Airplane Committee decided to use an alternate power system for initial X–15 tests. The Committee selected the XLR–11 engine which had demonstrated its reliability in the X–1 and D–558–II. Two such engines, each developing 8,000 pounds of thrust in four chambers, were to serve as interim power for the X–15 until the larger engine was ready for flight.

The first of the three X–15's was completed and moved to Edwards AFB in October 1958, and lengthy preparations for the initial flight tests got underway.



The X–15 is relatively small as modern aircraft go, its thin fuselage stretching 50 feet from nose to tail. Fairings extending along each side of the fuselage house control and propellant and hydraulic lines. The wings are thin and stubby; they span only 22.36 feet, have 200 square feet of area, and are swept back at an angle of about 25° at the 25-percent chord line.

The vertical tail is wedge-shaped in cross section, broadening toward the rear, and it extends both above and below the fuselage. Speed brakes, located in the tail, are activated by cockpit control to slow the plane in reentry maneuvers. The cockpit itself, located far forward of the wings and just behind the tapered nose, is about as large as that in a modern jet fighter. A narrow windshield, with double glass panels on each side, provides pilot visibility.

*The stub wings have no conventional ailerons;* control in both pitch and roll is supplied by simultaneous or differential deflection of the horizontal stabilizer for flight within the atmosphere. The X–15 has conventional landing flaps, located inboard on the trailing edges of the wings.

The landing gear represents a departure from the conventional. The X–15 has normal twin nose wheels but no wheeled main gear. Instead, it lands on two steel skids which pop out from the aft fuselage below the horizontal stabilizer. On the landing approach, the skids are lowered by a mechanical system, aided by gravity and the force of the airstream. Before extending the skids, the pilot jettisons the movable lower or "ventral" portion of the vertical tail to prevent its scraping the ground as the plane touches down. For landing, the pilot brings the research craft in for touchdown in a nose-high attitude so that the skids touch first; then the airplane settles onto its nose wheel.

Aerodynamic heating at the extreme speeds encountered by the X–15 can produce temperatures higher than 1,200° Fahrenheit. For this reason the X–15 is sheathed in temperature-resisting, heat-treated Inconel X nickel-steel alloy. All three of the X–15 airplanes are painted black, to radiate as much heat as possible on reentry to the atmosphere.

Inconel X is used in all areas exposed to high temperatures, such as the skin of fuselage, wing, and tail. Titanium is used extensively as inner wing structure because of its high strength-to-weight ratio. The primary structure of titanium and stainless steel was designed to withstand heat which might penetrate the Inconel. For internal use, where neither high temperatures nor high loads are encountered, aluminum is used.

As the X–15 flies outside the sensible atmosphere on its ballistic trajectory, conventional aerodynamic controls are ineffective. For this reason, the airplane is fitted with reaction control jets for maintaining the desired attitude of the airplane. This system consists of eight small jet nozzles in the nose and four near the wingtips. These jets, fueled by hydrogen peroxide, produce from 40 to 110 pounds of thrust, sufficient for all required maneuvers. The nose jets control pitch (up and down) and yaw (side to side) movements; roll is accomplished by the wingtip jets. The pilot actuates these jets by means of a three-axis control stick on the left side of the cockpit.

The pilot's ejection seat is the emergency escape system for the X–15. Used in combination with the full-pressure suit, the ejection system can fire the pilot free of the airplane in an emergency and protect him from aerodynamic heating, windblast, and excessive accelerations which would be caused by tumbling. Designed to operate over a range of conditions from the ground at a speed of 100 m.p.h., to an altitude of 120,000 feet at Mach 4, the seat is powered by a rocket producing several thousand pounds of thrust. The system is set in motion by a twist on a handgrip at the side of the seat. An automatic system blows the canopy free of the cockpit and actuates the rocket, which boosts pilot and seat up and to the rear. A pair of folding fins and 9-foot booms pop out to provide stability and prevent tumbling. The pilot, protected by his pressure suit, remains in the seat in free fall down to an altitude of 15,000 feet. An automatic altitude-sensing device then separates pilot and seat and deploys a 24-foot-canopy parachute. Although X–15 pilots have not had to use this system, it has been fully tested by anthropomorphic dummies ejected from high-speed rocket sleds in ground tests.

Aft of the pilot's compartment is a section which houses two identical auxiliary power units that supply electrical and hydraulic power. Electrical power is used for the X–15's communication, telemetering, and recording equipment, for heating elements, for the inertial guidance system and its computers, and for the plane's instrumentation. The speed brakes in the tail, landing flaps, and aerodynamic control surfaces are operated by hydraulic pressure supplied by the APU's.

Adjacent to the APU's are a tank of liquid nitrogen and two small spherical tanks of helium. The liquid nitrogen is used in the pressurization and air-conditioning system, necessitated by the extreme altitudes and speeds at which the X–15 operates. The helium is used for pressurizing the propellant tanks.

A large section of the fuselage is taken up by the propellant system for the rocket powerplant, consisting primarily of tanks of liquid oxygen, anhydrous ammonia, and helium, together with feedlines. Finally, in the tail section, is the YLR–99 rocket engine. Combustion is brought about by mixing and igniting the ammonia (fuel) and the liquid oxygen (oxidizer), which are forced into the engine by a turbine-driven pump. The engine can be throttled to supply from 30 to 100 percent of its total thrust (57,000 pounds). It also can be shut down and restarted in flight; it has an idle mode which permits completion of about 85 percent of the engine starting cycle before launch; and it is designed so that no single component failure will create a hazardous condition. The propellants are pressure forced into the engine at the rate of 12,000 pounds per minute, a flow more than 10 times that required for a modern turbojet engine.

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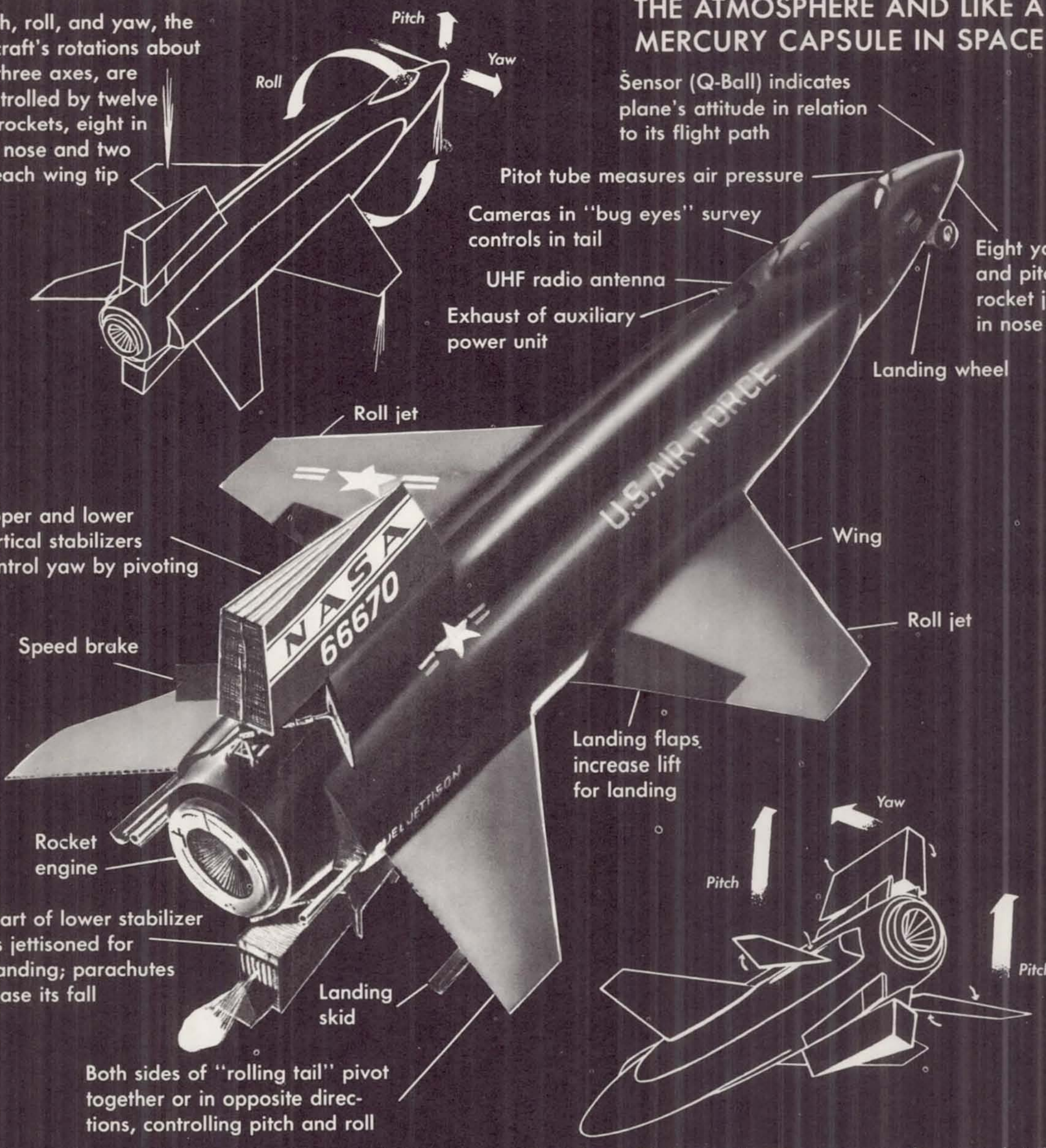
## SPACE FLIGHT

Pitch, roll, and yaw, the aircraft's rotations about its three axes, are controlled by twelve jet rockets, eight in the nose and two in each wing tip

## X-15 FLIES LIKE A PLANE IN THE ATMOSPHERE AND LIKE A MERCURY CAPSULE IN SPACE



Sensor (Q-Ball) indicates plane's attitude in relation to its flight path

Pitot tube measures air pressure

Cameras in "bug eyes" survey controls in tail

UHF radio antenna

Exhaust of auxiliary power unit

Eight yaw and pitch rocket jets in nose

Landing wheel

Roll jet

Upper and lower vertical stabilizers control yaw by pivoting

Wing

Roll jet

Speed brake

Landing flaps increase lift for landing

Rocket engine

Part of lower stabilizer is jettisoned for landing; parachutes ease its fall

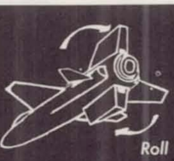
Landing skid

Both sides of "rolling tail" pivot together or in opposite directions, controlling pitch and roll

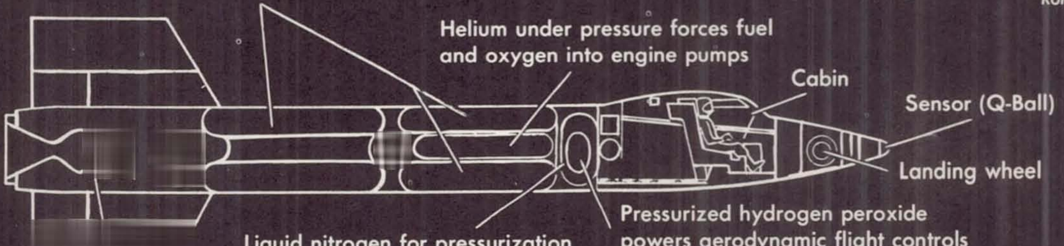
Pitch controlled by raising or depressing horizontal stabilizers. Yaw controlled by turning vertical stabilizers

## ATMOSPHERIC FLIGHT

Roll controlled by depressing one horizontal stabilizer and raising the other



5.2 tons of liquid oxygen and 4.2 tons of liquid ammonia develop up to 600,000 horsepower at burnout



Helium under pressure forces fuel and oxygen into engine pumps

Cabin

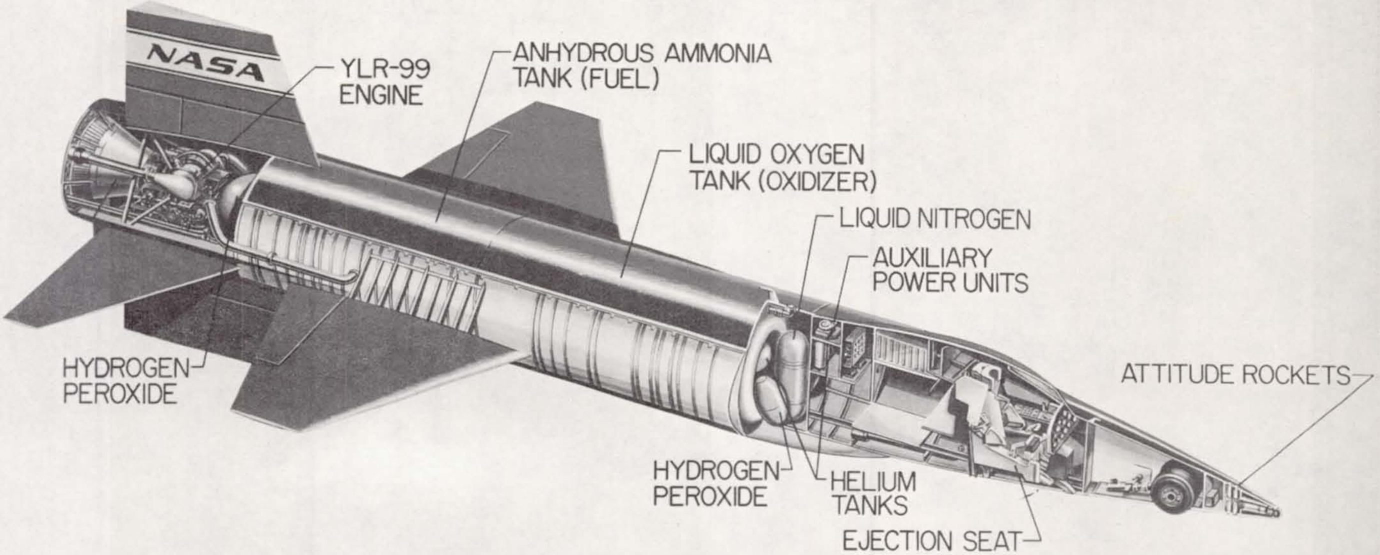
Sensor (Q-Ball)

Landing wheel

Pressurized hydrogen peroxide powers aerodynamic flight controls and ballistic control jets

Liquid nitrogen for pressurization of cockpit and pilot's suit

Rocket engine



*Cutaway drawing of the X–15 fuselage.*

X–15 missions require very precise control, and the pilot gets important control information from an inertial guidance system which senses attitude, velocity, altitude, and distance. Data from the sensors are fed through a computer to the pilot's cockpit instrument display.

Another important system is the "Q-Ball," so called because "q" is the engineering symbol for dynamic pressure, a function of speed and air density. The Q-Ball is a spherical sensor located in the nose of the X–15. A servomechanism causes the sphere to point into the relative wind at all times, and, through ports in the sphere, the Q-Ball senses relative dynamic pressures. Its information is sent to the cockpit, where instruments indicate to the pilot the angles of attack and sideslip. These angles must be maintained within certain limits on reentry maneuvers to avoid excessive aerodynamic heating.

An adaptive control system, or "thinking autopilot," is installed only on X–15 No. 3. A conventional autopilot requires a flow of information from sensors, and it must also "know" in advance the flight characteristics of the vehicle it is controlling. The adaptive autopilot needs no advance "instruction." It permits the pilot to move the control stick exactly the same at any time during the flight, whether in or out of the atmosphere. The adaptive control system determines the degree of aerodynamic or reaction control needed to perform the maneuver indicated by the movement of the control stick. This is the first system capable of blending aerodynamic and reaction controls at the critical point of atmospheric exit, where aerodynamic controls become ineffective and reaction controls must take over.

A very important component of the X–15 operational complex is the carrier airplane, which hauls the research craft to altitude. The air-launch technique, used with the X–1 and several other research airplanes, permits the research airplane to begin its mission in the relatively thin air at 40,000–45,000 feet, far above the dense lower atmosphere, where drag forces are large. Air launching permits maximum utilization of the rocket engine's brief power duration.

Two Boeing B–52's were assigned to the X–15 program as carriers. They lift the X–15 on a supporting pylon, located underneath the right wing of the B–52 between the fuselage and the right inboard pair of jet engines. To accommodate the upper or "dorsal" vertical tail of the X–15, it was necessary to cut away a portion of the B–52's flap and fix the flaps in an "up" or retracted position. The carrier was also fitted with high-speed wheels, tires, and brakes as a safety margin for no-flap takeoffs.

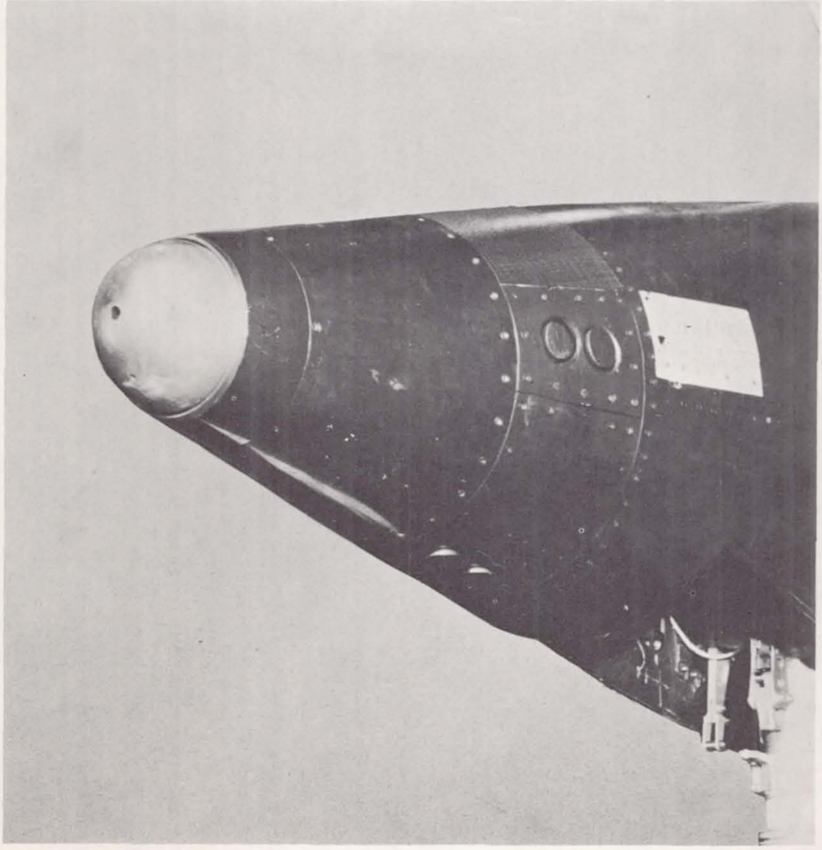
Since liquid oxygen used in the X–15's propulsion system boils off during the B–52 climb and cruise phase of a mission, it is necessary to "top off" the X–15's lox tank in flight, just before launch. For this purpose, a 1,500-gallon liquid oxygen tank was installed in the B–52 bomb bay, together with lines connecting the bomb-bay tank with the research airplane's lox tank. Other plumbing in the B–52 includes lines carrying nitrogen for the X–15 pilot's suit ventilation and breathing oxygen during the prelaunch phase, plus pneumatic pressure for opening the X–15 attachment hooks on the pylon (the hooks are normally actuated by hydraulic pressure).

In the forward pressurized compartment of the B–52 was installed a console at which the launch operator, an important member of the X–15 team, can monitor the checkout of aircraft systems before launch and can control the liquid oxygen top-off. The launch operator observes the fore and aft areas of the X–15 through a closed-circuit television system.

The pilot of the X–15 launches himself by throwing a switch in his cockpit.

The flight-monitoring staff at the "High Range" stations performs a vital role in support of X–15 flight operations. The three "High Range" stations are equipped with displays of the radar data, and selected channels of telemetered data. Duties of the staff include monitoring subsystems operations during the flight, and notifying the pilot of any discrepancies; and furnishing information for positioning the B–52 over the desired launch area at the correct time by advising the B–52 pilot of course and countdown time corrections before launch. The High Range group also provides the X–15 pilot with energy-management assistance in the event of a premature engine shutdown.

By early March 1959, the X–15 and its B–52 carrier had been thoroughly checked out and pronounced fit for flight test. The most rewarding test program in the history of winged flight was about to get underway.



***The X–15's "Q-Ball," with a rounded profile similar to a ballistic missile's reentry nose cone, senses angles of attack and sideslip during exit and reentry in the upper atmosphere. It indicates attitude angles that must be corrected to avoid intense frictional heat limits as the aircraft darts through the atmosphere.***

# THE X-15 FLIGHT PROGRAM

# IV

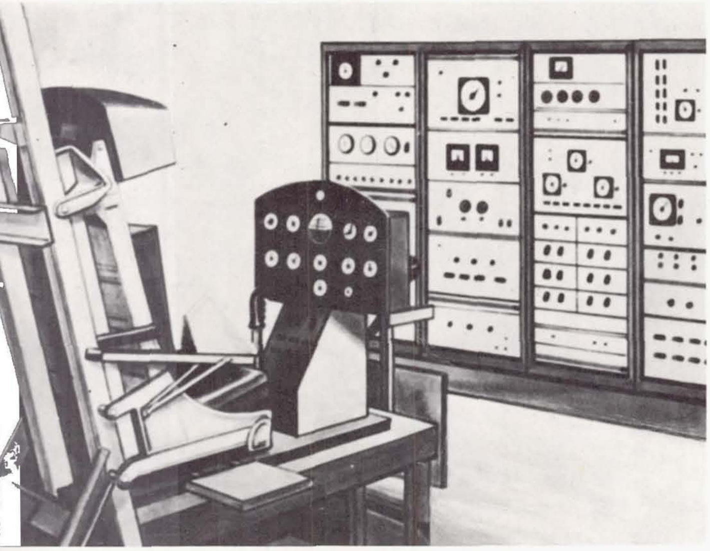
The X–15 flight research program had a simple basis: A series of progressive steps to higher speeds and higher altitudes, each step providing new data or confirming theoretical or wind tunnel data on the characteristics of an airplane performing in a very advanced flight regime. For data acquisition, instruments were installed in the X–15 which recorded the research data for later examination by scientists and engineers. The research craft was also fitted with telemetry equipment, so that certain critical portions of the data could be radioed to ground stations.

The real start of the X–15 flight program came months before the first airplane was delivered. It started on the ground with "flights" in a highly realistic X–15 simulator. This "six degree of freedom" analog simulator, constructed by North American Aviation and later transferred to NASA's Flight Research Center at Edwards, consists of an exact replica of the X–15 cockpit, with actual hydraulic and control system hardware, tied in to an analog computer. With this computer-simulator link, pilots can "fly" any mission. Both pilot and ground controller become familiar with the plane's handling characteristics and the timing required for a given mission.

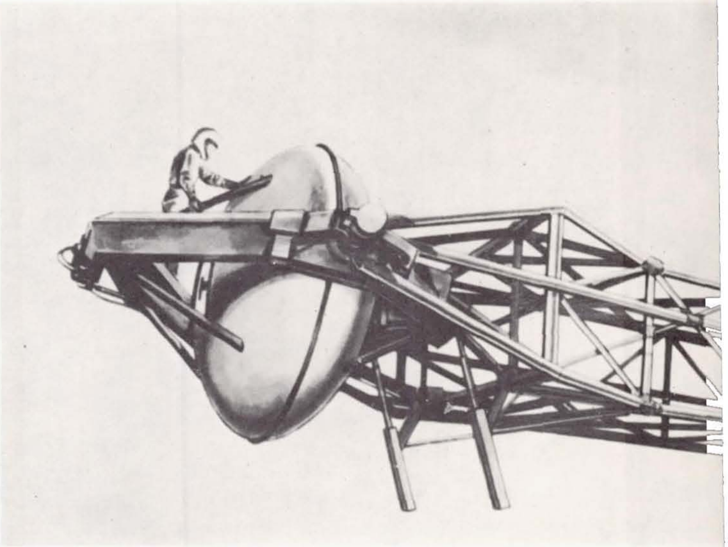
The usual practice is to "fly" a given mission several times using normal procedures. Next, variations from the planned mission are simulated, to acquaint the pilot with the overall effect of such variations. For instance, the pilot is given a simulator problem involving changes in stability, the amount of engine thrust, or the duration of thrust. Finally, the pilot goes through "trouble school," in which the simulator induces failure of one or more of the major systems, such as the powerplant, the Q-Ball, the stability augmentation system, the inertial guidance system, or the radio or radar. Through this series of "flights" on the ground the pilot becomes thoroughly familiar with anything that might happen on an actual flight.

A number of other training aids are used. A particularly useful tool is an F–104 jet airplane. This airplane has predetermined settings of lift and drag devices and engine thrust designed to simulate the low lift-drag ratio of the X–15 on landing. Before each X–15 mission, the assigned pilot flies the F–104 to landings at the primary and alternate landing sites, establishing geographic checkpoints and key altitudes in the landing pattern and familiarizing himself with the timing and positioning necessary for an X–15 landing. Other variable-stability aircraft have been employed in the X–15 training program to simulate handling characteristics under a variety of flight conditions.

Another training device employed in 1958, before delivery of the first airplane, was the human centrifuge at the U.S. Naval Air Development Center, Johnsville, Pa. The centrifuge consists of a gondola, or cockpit simulator, at the end of a long arm.



*Flights are simulated through control setup and analog computer . . .*



*. . . human centrifuge experience . . .*

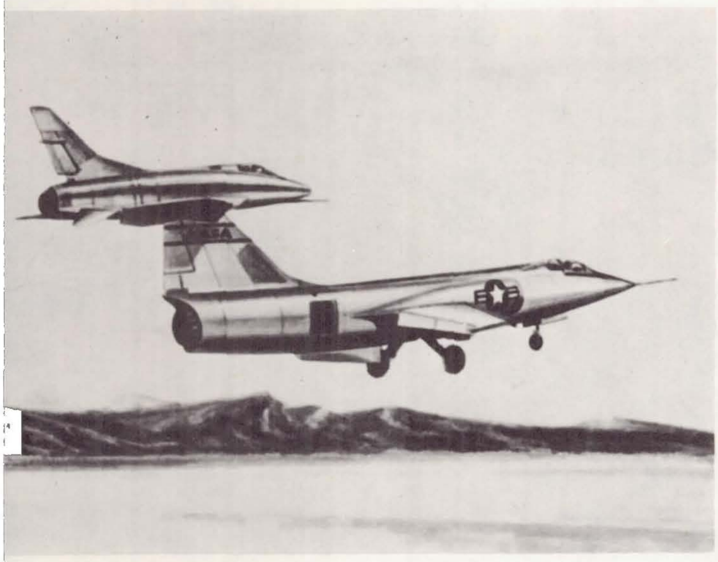
The gondola is rotated rapidly, like a high-speed merry-go-round, to produce "G" forces equivalent to those anticipated during engine operation, shutdown, and subsequent reentry. The centrifuge tests demonstrated that the pilot could successfully control the X–15 under the predicted accelerations. Other simulators, heat and pressure chambers, were used to prepare pilots and equipment for the test program.

All X–15 flights are conducted on the "High Range," which was completed before the flight program began. The "High Range" is an air corridor 50 miles wide and 485 miles long, stretching from Wendover, near Utah's Bonneville Salt Flats, to Edwards. About a third of the distance from Wendover to Edwards is the first of three ground stations, atop a 9,000-foot mountain at Ely, Nev. The second station, about another third of the way, is in the Bullfrog Hills near Beatty, Nev. The third station is at the NASA Flight Research Center at Edwards. The three stations are in a line, in a corridor remote from major cities. Along the corridor are a number of dry lakebeds whose surfaces present ideal emergency landing fields, and the lakes are so located that it is possible to fly always within gliding distance of at least one of them.

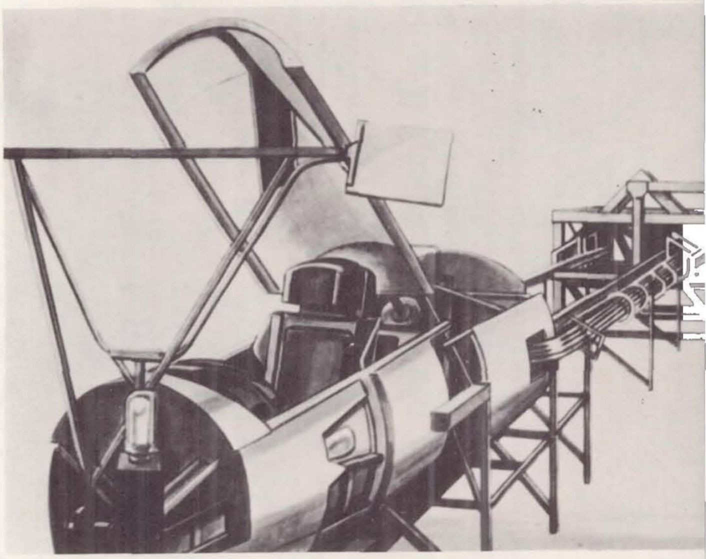
The value of the "High Range" and its natural emergency fields was attested to in January 1962, when Comdr. Forrest Petersen, USN, encountered trouble. After a normal launch near Mud Lake, Nev., Petersen experienced an engine failure due to a faulty pressure switch. After two unsuccessful attempts to restart the engine, he headed for his emergency landing site according to plan. He jettisoned his propellants and landed the X–15 safely.

At each of the three "High Range" stations are tracking radars similar to those in use on the Atlantic Missile Range: plotting boards, velocity computer, telemetry receiver, data monitor, data transmission and receiving equipment, and communications equipment.

At the ground stations, engineers monitor critical temperatures and pressures. They are in voice contact with the X–15 and can signal the pilot instantly



*. . . variable stability F–100C, and F–104 flights . . .*



*. . . and the X–15 aircraft flight simulator.*

in case of trouble. The pilot's physiological responses, such as pulse, heart action, and body temperatures, are also telemetered to the ground stations, where flight surgeons stand by to interpret them. All the telemetered information is recorded on magnetic tapes for later reduction and analysis. Not all of the information acquired by the X–15 is telemetered, however; most of it is collected by recorders in the airplane.

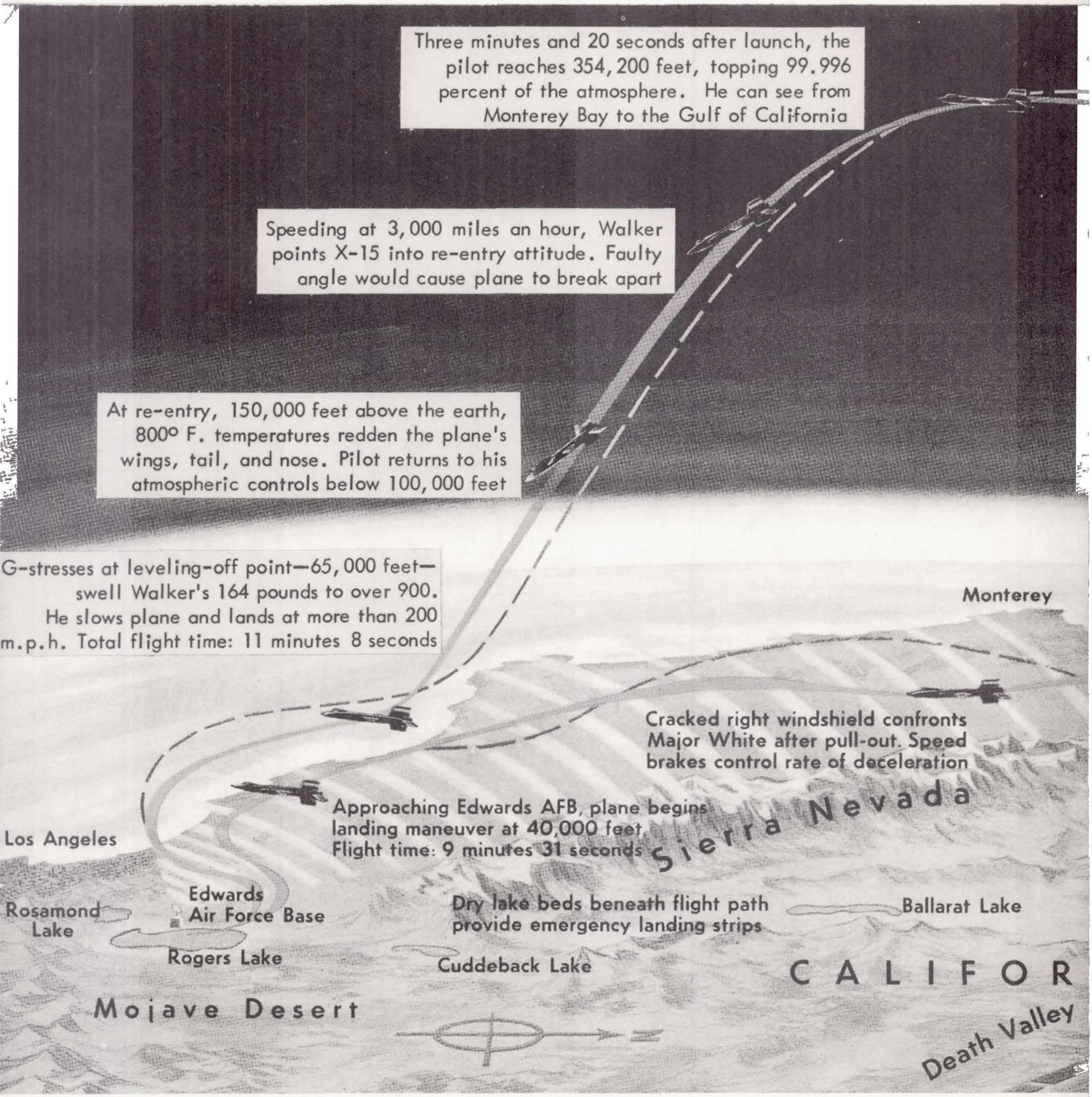
Terminus of an X–15 mission is Rogers Dry Lake, a natural landing field at Edwards in the Antelope Valley of the Mojave Desert. Twelve miles long, the lake provides plenty of landing room for the X–15, and its level surface of fine clay and silt is almost as hard as concrete.

For a detailed view of an X–15 operation, let us follow a typical flight. The first step in any flight is mission planning, in which pilots and engineers map out every detail of the flight, second by second and maneuver by maneuver. The objective, in this case, is to be an investigation of structural and aerodynamic heating and reentry techniques from an extreme altitude with the lower rudder removed. About the same time, engineers and technicians begin their elaborate task of preparing the airplane for the flight.

A profile view of the planned flight looks like an inverted "V." The engine is to fire for 84 seconds, during which time the X–15 will climb slightly more than halfway up one side of the "V." From that point it will coast on momentum to peak altitude, then start its descent. After the plunge through the upper atmosphere, the X–15 will level off in its glide and go on to Edwards. Total flight time will be approximately 11 minutes.

Just before flight day, a mission briefing is held for everyone concerned. Then there is a final crew briefing for the X–15 pilot and the B–52 crew, and for the pilots of the jet "chase planes," who will observe the flight and assist in any way possible, such as helping check the X–15 control movements on the prelaunch control sequence.

A final "premating" inspection, including a check of all systems in the X–15 and the B–52, is conducted and last-minute adjustments are made.



Three minutes and 20 seconds after launch, the pilot reaches 354,200 feet, topping 99.996 percent of the atmosphere. He can see from Monterey Bay to the Gulf of California

Speeding at 3,000 miles an hour, Walker points X-15 into re-entry attitude. Faulty angle would cause plane to break apart

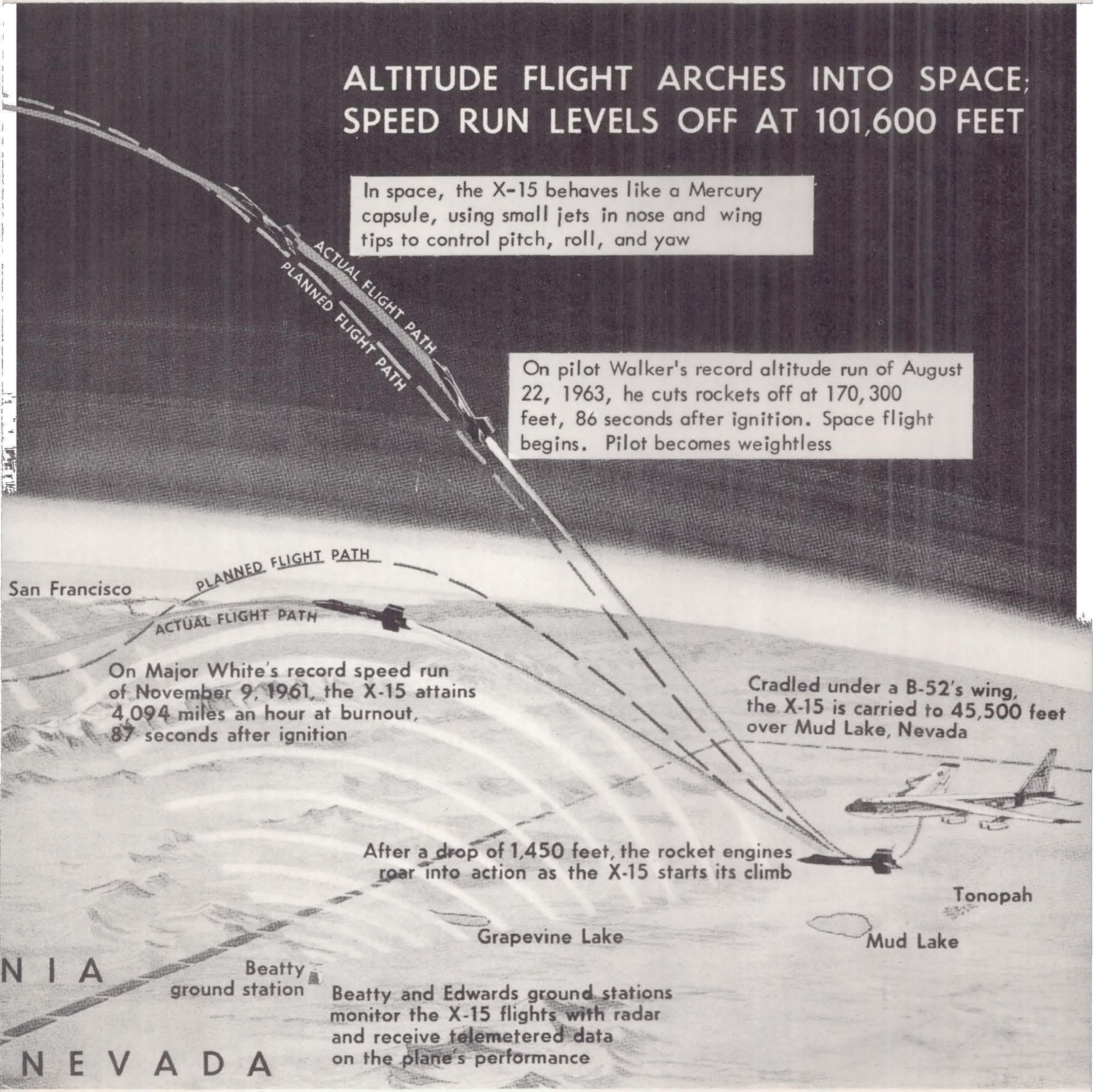
At re-entry, 150,000 feet above the earth, 800° F. temperatures redden the plane's wings, tail, and nose. Pilot returns to his atmospheric controls below 100,000 feet

G-stresses at leveling-off point—65,000 feet—swell Walker's 164 pounds to over 900. He slows plane and lands at more than 200 m.p.h. Total flight time: 11 minutes 8 seconds

Cracked right windshield confronts Major White after pull-out. Speed brakes control rate of deceleration

Approaching Edwards AFB, plane begins landing maneuver at 40,000 feet. Flight time: 9 minutes 31 seconds

Dry lake beds beneath flight path provide emergency landing strips



## ALTITUDE FLIGHT ARCHES INTO SPACE; SPEED RUN LEVELS OFF AT 101,600 FEET

In space, the X-15 behaves like a Mercury capsule, using small jets in nose and wing tips to control pitch, roll, and yaw

On pilot Walker's record altitude run of August 22, 1963, he cuts rockets off at 170,300 feet, 86 seconds after ignition. Space flight begins. Pilot becomes weightless

On Major White's record speed run of November 9, 1961, the X-15 attains 4,094 miles an hour at burnout, 87 seconds after ignition

Cradled under a B-52's wing, the X-15 is carried to 45,500 feet over Mud Lake, Nevada

After a drop of 1,450 feet, the rocket engines roar into action as the X-15 starts its climb

Beatty and Edwards ground stations monitor the X-15 flights with radar and receive telemetered data on the plane's performance

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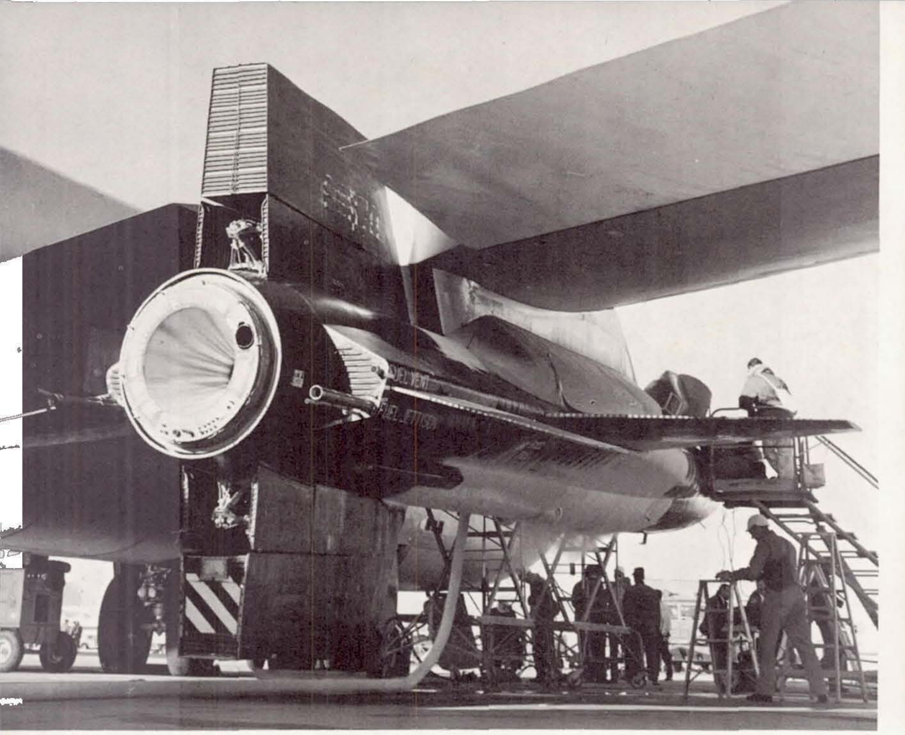
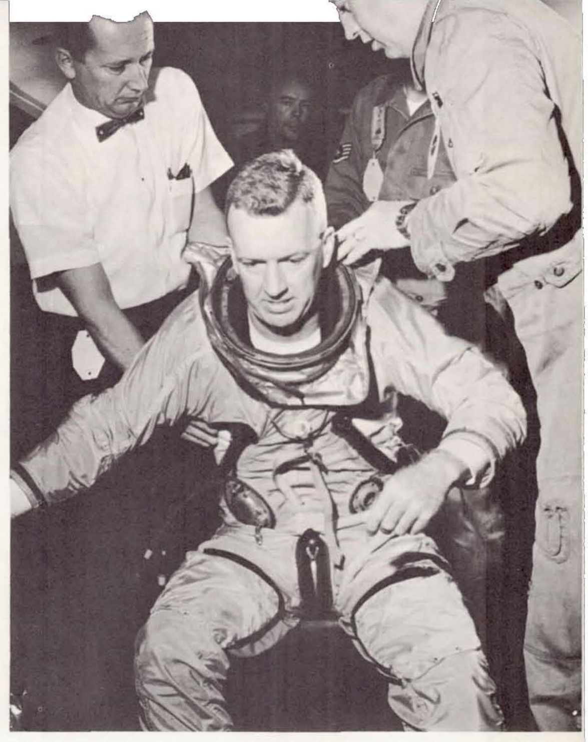




***(Above, left:) The X–15 attached under the right wing of its B–52 carrier before a flight. (Above, right:) NASA research pilot Joseph A. Walker being zipped into his inner flight suit. (Opposite, upper left:) Pilot Walker (right) approaches the B–52 and X–15 to go aboard for a flight. (Opposite, upper right:) View from the B–52 carrier plane just before an X–15 launch. (Opposite, below:) The X–15 has dropped free and is on its way.***

Next, the X–15 is rolled out on a dolly, hoisted up to the pylon below the B–52 wing, and all the connections are made. The airplanes thus "mated" and ready for flight, the 24-hour countdown begins.

Hours before flight time, technicians have started servicing both craft, filling the tanks with liquid oxygen, nitrogen, hydrogen peroxide, and helium—for pressurization, for cooling, for breathing oxygen, for the B–52's pneumatic system, and for the X–15's auxiliary power units and its reaction controls. Among the last items on the servicing checklist are the X–15's propellants, liquid oxygen and ammonia, and the helium used for tank pressurization and liquid expulsion.

The X–15 pilot and the B–52 crew board their airplanes. The X–15 canopy is closed and locked.

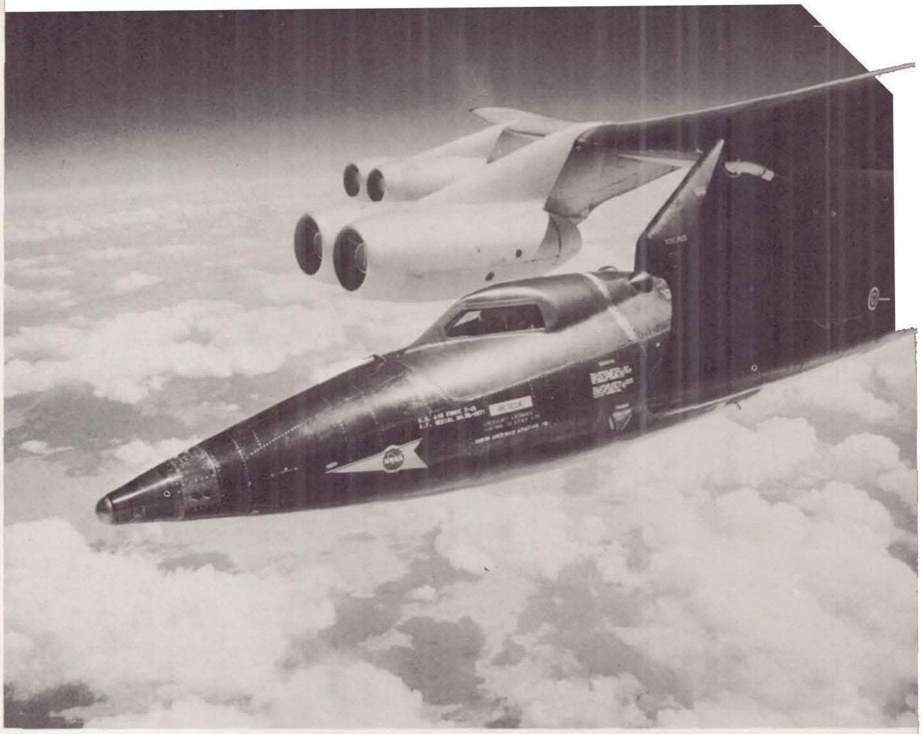
The B–52 pilots run through the lengthy B–52 cockpit check; then they start their eight jet engines. The X–15 pilot and launch operator conduct a similar check of the research airplane. As the chase planes take off, the B–52 rolls to the end of the runway; then, engines roaring, it takes off and climbs northward.

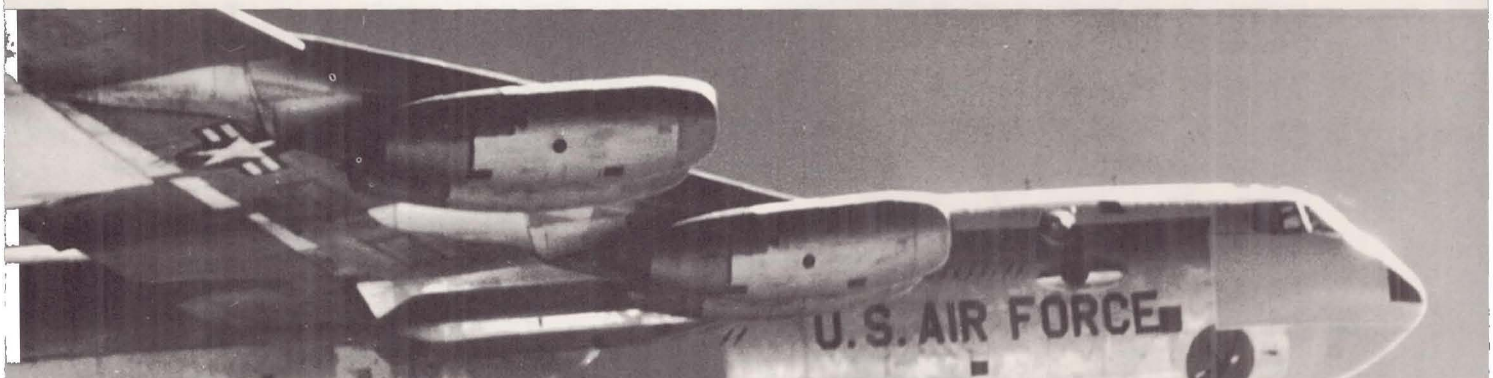
As the B–52 climbs toward the drop area, the X–15 pilot and the launch operator run through the long "litany" of the checklist, making sure all systems are in proper working order. Seven minutes before launch, the pilot switches on his auxiliary power units and makes final checks of the hydraulic and electrical power systems. At the 4-minute mark he checks the propellant jettisoning systems and with 3 minutes to go he tests the control motions under close observation of the chase pilots and the launch operator.

Now approaching Smith Ranch Lake, the planned launch point, the B–52 turns southward in the general direction of Edwards, 315 miles away, at a speed of nearly 600 miles per hour and 45,000 feet altitude. The B–52 pilot now signals the 1-minute warning. In the X–15, the pilot switches on the engine master switch and gives a final "OK." The B–52 pilot turns on the master arming switch. Over the radio comes the countdown—"Five, four, three, two, one . . . DROP!"

As the launch switch is turned on in the X–15, the pylon hooks spring open and the X–15 drops rapidly. Its pilot starts the mighty rocket engine and advances the throttle to 100 percent power. The


U.S. AIR




U.S. AIR FORCE

*The X–15 on November 9, 1961, when Air Force pilot Maj. Robert M. White attained a speed of 4,094 m.p.h.*

X–15 accelerates rapidly, and within a matter of seconds is flying faster than sound, climbing at a 48° angle. In 30 seconds it is flying at twice the speed of sound.

The engine is functioning perfectly, its 59,000 pounds of thrust pushing the research plane ever faster during the climb. Then, 88 seconds after launch, comes the preplanned "burnout," the engine quitting with a dying rumble. The X–15 is now at 170,000 feet in a steep climb, flying more than five times the speed of sound. At this altitude, above 99.99 percent of the earth's atmosphere, the pilot controls the plane with the reaction jets, using the automatic adaptive control system.

Despite the lack of power, the X–15 continues to climb on momentum, with only a slight loss of speed, following a ballistic trajectory like a missile.

Three and one-half minutes after launch, the X–15 reaches a peak altitude of 354,200 feet, at a speed of more than Mach 4, well over 2,000 miles per hour. Now, as the pilot extends the speed brakes in the tail, the X–15 noses over and starts down the other side of the inverted "V," toward the critical reentry. For more than 2 minutes at the top of the trajectory the pilot has been weightless.

The X–15 picks up speed as it plunges downward. At 200,000 feet, 5 minutes after launch, it is hurtling earthward at 1 mile a second, approximately Mach 5.

Now the X–15 heads into the atmosphere, aerodynamic controls once more taking over, the nose and wings glowing red from friction as air molecules whip over the plane's surfaces. The altimeter needle drops sharply, but speed remains high, down to about 100,000 feet. The pilot gradually flattens his angle of descent and heads for the landing at Edwards. The airplane skids along a straight path more than 5,000 feet long on the dry lakebed before it comes to a stop.

The X–15 first took to the air on March 10, 1959. This was a "captive" flight, one in which it was carried aloft under the B–52 wing for an airborne check of all systems and a validation of wind tunnel studies regarding the aerodynamic characteristics of the B–52/X–15 mating, but was not dropped. Three more captive flights were made on April 1, April 10, and May 21 of that year, attempting to make the first flight. Each time, a system malfunction prevented launching of the X–15.

On June 8, 1959, the X–15 was air-launched for the first time, but on a powerless glide flight which lasted 5 minutes. Pilot Scott Crossfield of North American Aviation made a successful landing on the lakebed at Edwards. Then, on September 17, 1959, Crossfield completed the first powered flight with the interim XLR–11 engines. He flew to an altitude of 52,341 feet and reached a speed of Mach 2.1, or 1,393 miles per hour.

The first major trouble in the X–15 program was encountered on the third powered flight, made on November 5, 1959, with Crossfield again at the controls. After a normal launch at 44,000 feet, there was an explosion in the engine during the starting sequence. The explosion blew off several inches of one of the eight rocket chambers. Crossfield immediately shut down the powerplant, jettisoned the fuel, and headed for the nearest alternate landing field, Rosamond Dry Lake, part of the Edwards complex. After a normal approach, Crossfield encountered a second malfunction, when the nose landing gear failed as the X–15 touched down on the lakebed. The X–15 virtually broke in two just aft of the instrument bay, skidding some 1,500 feet. Crossfield escaped injury. The X–15 No. 2 was returned to North American Aviation for reconstruction. Ninety days later it was in the air again.

In the early months of 1960, X–15 Nos. 1 and 2 made four more powered flights. After completion of this phase of the contractor's demonstration program, the No. 1 airplane was officially accepted by the Air Force and turned over to NASA. NASA's Chief Research Pilot Joseph A. Walker made the first Government flight on March 25, 1960, reaching an altitude of 48,630 feet and a speed of Mach 2.

Meanwhile X–15 No. 3, equipped with the large XLR–99 engine, had been delivered to Edwards and was being put through a series of systems checks. On June 8, 1960, the X–15 program suffered another setback during the first engine ground run in the No. 3. A fuel tank pressure regulator failed, overpressurizing the fuel tank and causing an explosion which blew the plane apart. The airplane was sent back to the North American plant for rebuilding. While it was dismantled the adaptive flight control

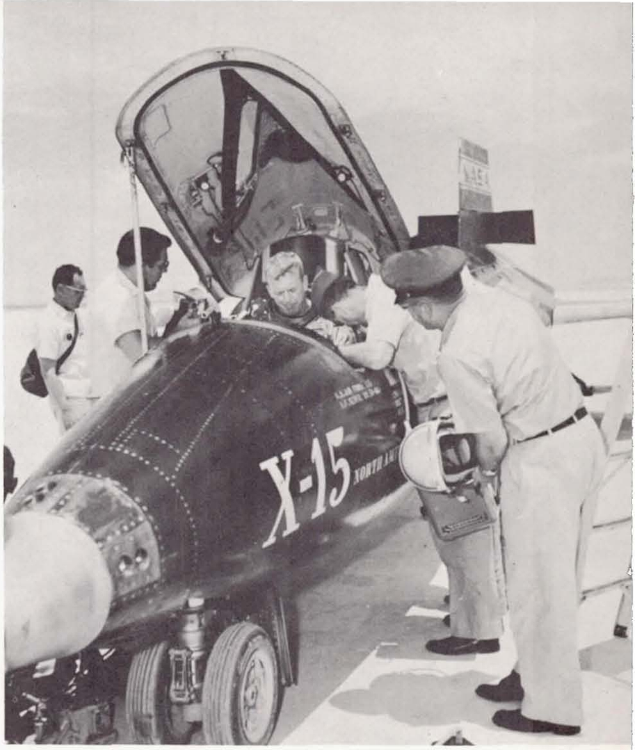
***Gear down, nose up, the X–15 glides in at more than 200 m.p.h. to a landing on the dry lakebed.***

system was installed. X–15 No. 3 was redelivered to Edwards in the fall of 1961.

During the latter part of 1960, while the Government pilots were making a series of flights with the No. 1 airplane, X–15 No. 2 was being fitted with the XLR–99 engine. After successful ground tests and two airborne captive flights, Crossfield made the first flight with this engine on November 15, 1960, attaining a speed of Mach 2.97.

A series of flights followed in which the flight "envelope" was expanded gradually, speeds and altitudes being increased in steps. On November 9, 1961, Major White reached the design speed goal with a flight at 4,094 miles per hour. This flight completed extension of the speed portion of the envelope, although a slightly higher speed was attained on a later flight. On April 30, 1962, NASA's Walker flew to 246,700 feet, essentially achieving the design altitude goal. By this time, however, it was apparent that the X–15 was capable of considerably higher altitudes, possibly up to 400,000 feet.

Some milestones in the X–15 flight log are shown in the accompanying tabulation:



*Pilot Joseph A. Walker completes postflight checks after a successful flight.*

## FLIGHT LOG

| DATE | FLIGHT NO.* | PILOT | SPEED MACH NO. | SPEED M.P.H. | MAX. ALT. (FT.) | REMARKS |
|---|---|---|---|---|---|---|
| 6–8–59 | 1–1–5 | Crossfield........ | 0. 79 | 522 | 37, 550 | Planned glide flight. |
| 9–17–59 | 2–1–3 | Crossfield........ | 2. 11 | 1, 393 | 52, 341 | First powered flight. |
| 3–25–60 | 1–3–8 | Walker.......... | 2. 00 | 1, 320 | 48, 630 | First Government flight. |
| 8–12–60 | 1–10–19 | White........... | 2. 52 | 1, 772 | 136, 500 | Maximum altitude with LR–11 engines. |
| 11–15–60 | 2–10–21 | Crossfield........ | 2. 97 | 1, 960 | 81, 200 | First flight with XLR–99 engine. |
| 12–9–60 | 1–19–32 | Armstrong....... | 1. 80 | 1, 188 | 50, 095 | First "Q-Ball" flight. |
| 2–7–61 | 1–21–36 | White........... | 3. 50 | 2, 275 | 78, 150 | Last LR–11 flight; Maximum speed with LR–11 engines. |
| 3–7–61 | 2–13–26 | White........... | 4. 43 | 2, 905 | 77, 450 | First Government XLR–99 flight; first Mach No. 4 airplane flight. |
| 6–23–61 | 2–17–33 | White........... | 5. 27 | 3, 603 | 107, 700 | First Mach No. 5 airplane flight. |
| 10–4–61 | 1–23–39 | Rushworth...... | 4. 30 | 2, 830 | 78, 000 | First flight made with lower ventral off. |
| 10–11–61 | 2–20–36 | White........... | 5. 21 | 3, 647 | 217, 000 | First airplane flight above 200,000 feet; outer panel of left windshield cracked. |
| 11–9–61 | 2–21–37 | White........... | 6. 04 | 4, 094 | 101, 600 | Highest Mach number achieved; outer panel of right windshield cracked; first Mach No. 6 airplane flight. |
| 12–20–61 | 3–1–2 | Armstrong....... | 3. 76 | 2, 502 | 81, 000 | First flight for X–15 No. 3, equipped with adaptive flight control system. |
| 1–10–62 | 1–25–44 | Petersen......... | .97 | 645 | 44, 750 | Emergency landing on Mud Lake after engine failed to light; performed without incident. |
| 4–30–62 | 1–27–48 | Walker.......... | 4. 94 | 3, 489 | 246, 700 | Design altitude flight and official FAI world altitude record. |
| 6–27–62 | 1–30–51 | Walker.......... | 5. 92 | 4, 104 | 123, 700 | Highest speed achieved. |
| 7–17–62 | 3–7–14 | White........... | 5. 45 | 3, 832 | 314, 750 | FAI world altitude record; first airplane flight above 300,000 feet. |
| 11–9–62 | 2–31–52 | McKay......... | 1. 49 | 1, 019 | 53, 950 | Engine malfunction; extensive damage to airplane in emergency landing, Mud Lake, Nev. |
| 5–29–63 | 3–18–29 | Walker.......... | 5. 52 | 3, 858 | 92, 000 | Inner panel of left windshield cracked. |
| 6–27–63 | 3–20–31 | Rushworth...... | 4. 89 | 3, 425 | 285, 000 | Fiftieth flight over Mach 4.0. |
| 7–19–63 | 3–21–32 | Walker.......... | 5. 29 | 3, 710 | 347, 800 |  |
| 8–22–63 | 3–22–36 | Walker.......... | 5. 58 | 3, 794 | 354, 200 | Fortieth flight over Mach 5.0. |

*Flight activity code:
1st number—X–15 airplane number.
2d number—flight number for specified airplane.
3d number—X–15/B–52 airborne mission number.

*X–15 research pilots: (from left) Maj. Robert A. Rushworth, USAF; John B. McKay, NASA; Comdr. Forrest S. Petersen, USN; Joseph A. Walker, NASA Chief Research Pilot; Neil A. Armstrong, NASA; and Maj. Robert M. White, USAF Project Pilot.*

*(Left:) Maj. Robert M. White, USAF. (Right:) Joseph A. Walker, NASA.*

# FUTURE

# V

By the summer of 1963, all of the major research objectives of the X–15 program had been accomplished, but there remained a lot of work for the research craft.

Part of the continuing assignment for the X–15 consists of further, detailed research on subjects already partially investigated, such as the studies of aerodynamic heating, operational and control problems, bioastronautics, hypersonic aerodynamics, structures, and problems of exit from and reentry to the earth's atmosphere. While considerable data have been accumulated in these areas, a single exploratory mission in the X–15 is necessarily of limited duration and several flights covering the same subject matter may be needed to cover the speed, altitude, and angle of attack regions of interest. As an example, further valuable information was acquired by varying flight conditions; for example, by conducting reentry maneuvers over a wide range of angles of attack.

The X–15 has also been assigned a new role to carry out a number of new experiments in aeronautical and space sciences. Early in 1962, the National Research Airplane Committee approved this new program, which involved some modifications to the airplanes and the installation of certain new types of equipment.

The X–15 offers considerable utility as a space research vehicle. While it cannot attain the altitudes of earth satellites, it can fly a great deal higher than research balloons. It has advantages over sounding rockets in that it can bring its information and equipment back to earth for detailed study, whereas in most cases sounding rocket data must be telemetered to the ground, usually only for a brief period during flight. The presence of the pilot, who can observe, make judgments, and report unforeseen findings, is of course invaluable. As a space research vehicle, the X–15 does not compete with other types of spacecraft; rather, it supplements them.

One primary project assigned the X–15 is an experiment involving photography of the ultraviolet rays of the stars. On earth, and at the lower altitudes, these rays are obscured by ozone in the earth's atmosphere. One of NASA's major projects is the Orbiting Astronomical Observatory (OAO), designed to take stellar photographs as it orbits the earth far above the distorting atmosphere. The X–15 will play a vital supporting role in the stellar photography program, as a precursor to OAO and as a flying test bed for checking out the type of equipment to be used in OAO. It is planned to make a series of X–15 stellar photographic flights to altitudes above 40 miles, to obtain preliminary information pertaining to the origin and composition of the stars.

For these flights, new instrumentation will be installed in the X–15. It consists of a gimbaled platform containing four cameras, mounted in the instrument bay behind the pilot's cockpit. Clamshell doors covering the bay can be opened by a cockpit control as the X–15 exits from the atmosphere. The pilot then maneuvers the X–15 into the desired position for photography of a target star. As the airplane follows its ballistic trajectory "over the top," the cameras can take a continuous series of photographs in different ultraviolet wavelengths. The instrumentation weighs only 200 pounds; the stability equipment, needed to get the desired aiming accuracy, weighs about 160 pounds and the cameras another 40 pounds. The number of photos which can be taken on a given flight, of course, depends on how long the X–15 stays above the filtering ozone in the atmosphere. On a flight to 400,000 feet, for instance, there would be available 4 minutes of exposure time, which is considered ample for this type of experiment.

In another mission to come, the X–15 will carry a horizon scanner to study light across the spectrum. The purpose of this investigation is to acquire data on means for accurate sensing of the horizon at extreme altitudes. This information can be used in the development of improved attitude and guidance references for earth orbiting spacecraft.

In still another experiment, an ionization gage will be mounted in a small pod on the X–15 wingtip, for measurements of atmospheric density above 100,000 feet. For an investigation of micrometeoroids, another similar wingtip pod will be employed.

The follow-on program also involves evaluation of advanced systems and structural materials. For example, a new airborne computer, designed to enable the pilot to plan his landing pattern from reentry to touchdown, will be tested.

These follow-on experiments, and others in the proposal stage, will be conducted jointly by NASA and the Air Force, with funding shared between the two agencies. The extended program added at least 35 flights to the original schedule, and will require another 2 years or more.

Early in 1963 a decision was made to rebuild the X–15 No. 2, damaged at Mud Lake in November 1962. In rebuilding, the aircraft will be modified to give it a Mach 8.0 speed capability. This will be accomplished by adding jettisonable external propellant tanks.

What comes after the X–15?

Despite the incredible performance capabilities of the X–15, there is a need for a still more advanced research airplane. Although the X–15 has achieved hypersonic speed, it has penetrated only the lower limits of the hypersonic range. For detailed studies of hypersonic flight characteristics, much use could be made of a vehicle capable of flying in the Mach 8–10 speed range. Such a research craft could play an important role in the development of a recoverable space booster and, in the distant future to which NASA scientists are already looking, a hypersonic commercial transport. Toward this end, NASA and the Department of Defense are studying the possible need for an advanced research craft.

As planning for future hypersonic vehicle proceeds, the X–15 will continue to add new volumes to man's knowledge. The more than $200 million invested in the program to date has already paid enormous dividends, and more will be forthcoming. The "most successful research airplane ever built," the pathfinder of manned, maneuverable, hypersonic flight, will some day take its place in the National Air Museum of the Smithsonian Institution along with the other great aircraft and spacecraft in the national treasury, but in the intervening years it bids fair to add new milestones to the march of scientific progress.

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