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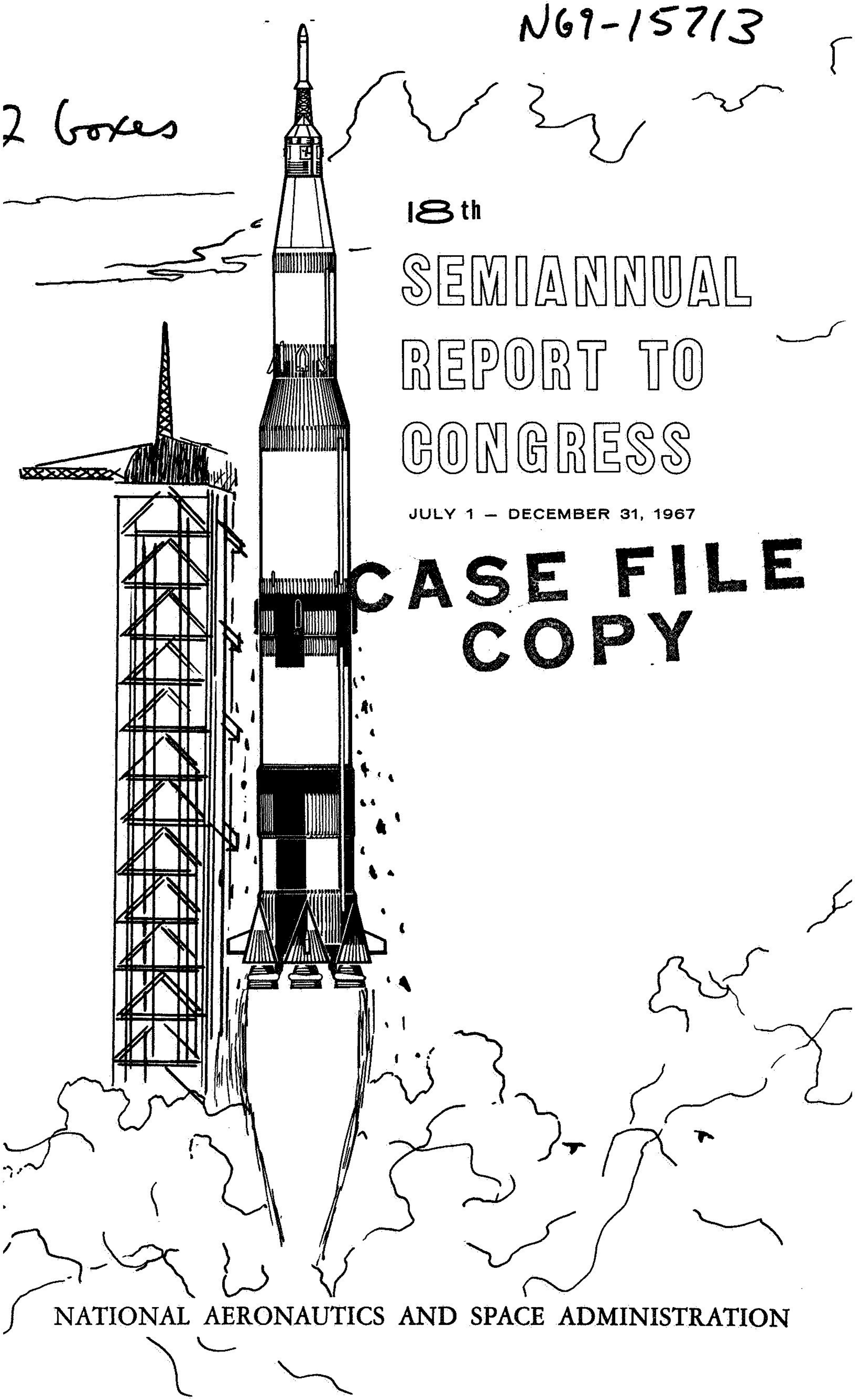

18th SEMIANNUAL REPORT TO CONGRESS

JULY 1 — DECEMBER 31, 1967

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

TO THE CONGRESS OF THE UNITED STATES:

I am transmitting today the Sixteenth, Seventeenth, and Eighteenth Semi-Annual Reports of the National Aeronautics and Space Administration covering the period between July 1, 1966 and December 31, 1967.

The events recorded here are both tragic and encouraging; sobering and inspiring.

The eighteen-month period saw success and failure and then success again as a proud agency moved forward with renewed determination.

The Gemini missions were completed; Lunar Orbiters I and II transmitted thousands of clear pictures of the moon; new communications and meteorological satellites were orbited.

Then came tragedy. Three brave American astronauts were killed in the Apollo fire.

Initially stunned, NASA then went to work to overcome the flaws in the Apollo system. Soon, impetus was restored to this crucial part of our space effort. Other great space achievements followed such as the Apollo 4 flight.

I commend these reports to your attention. They contain, I believe, concrete evidence that NASA is moving forward, and that America is contributing mightily in the worldwide effort to conquer space for the benefit of all mankind.

Lyndon B. Johnson

THE WHITE HOUSE,

Oct 11 1968

Eighteenth

SEMIANNUAL REPORT TO CONGRESS

JULY 1 - DECEMBER 31, 1967

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D. C. 20546

Cover: Artist's sketch of Apollo 4 launch
on November 9, 1967.

For sale by the Superintendent of Documents, U.S. Government Printing Office
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THE PRESIDENT

The White House

OCTOBER 7, 1968

DEAR MR. PRESIDENT:

This Eighteenth Semiannual Report of the National Aeronautics and Space Administration, for the period July 1 through December 31, 1967, is submitted to you for transmittal to Congress in accordance with section 206(A) of the National Aeronautics and Space Act of 1958.

The space program made encouraging progress during these months. Impetus was restored to the Apollo Program with the near-perfect flight of Apollo 4 on November 9, and the pace of lunar mapping and research was accelerated as orbiting spacecraft photographed the Moon and others landed to analyze its surface.

These accomplishments and the many other activities detailed in this Report give us reason to view the progress of our Aeronautics and Space Program with renewed optimism and to anticipate continued advances in the future.

Respectfully yours,

JAMES E. WEBB
Administrator

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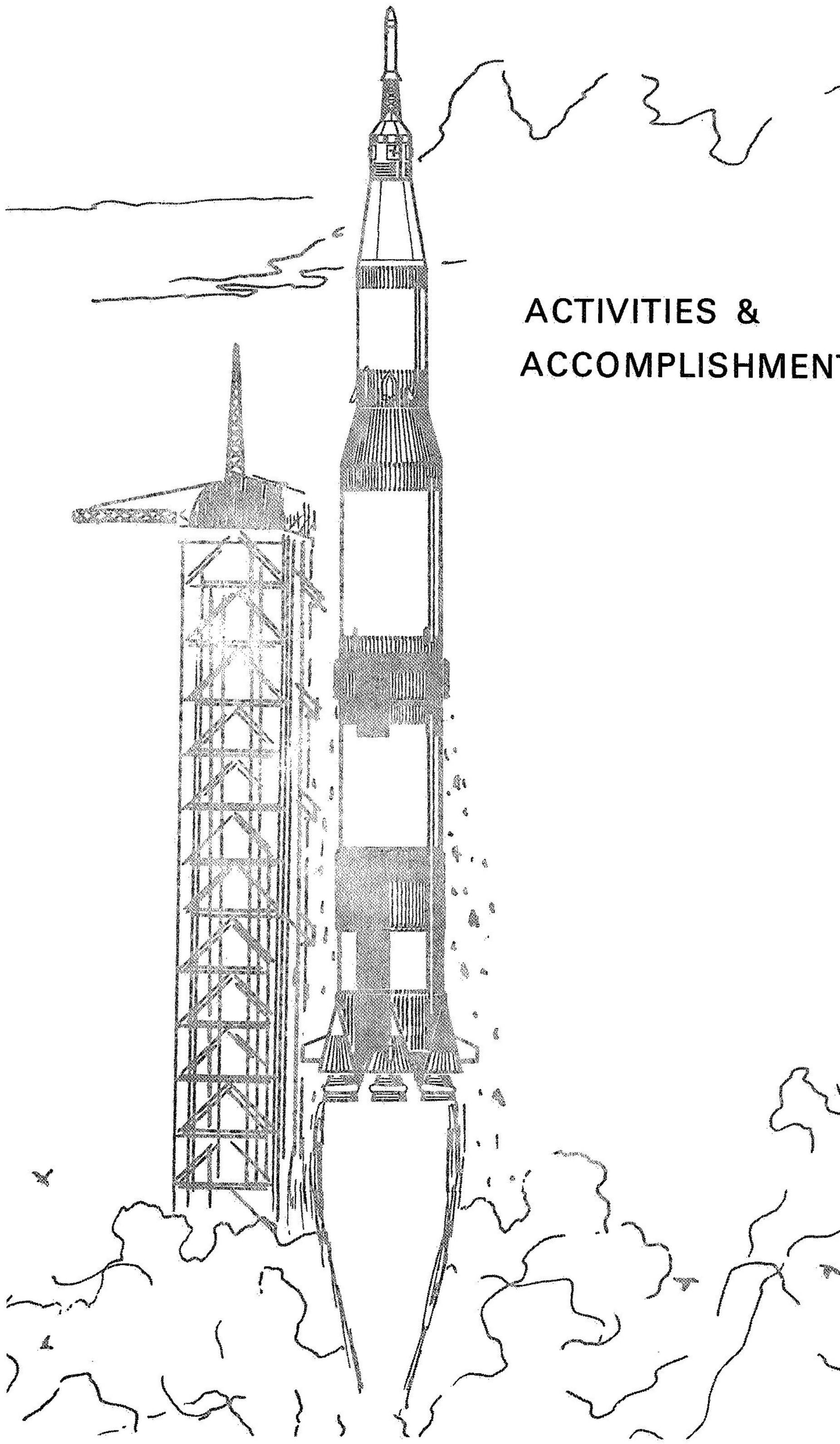
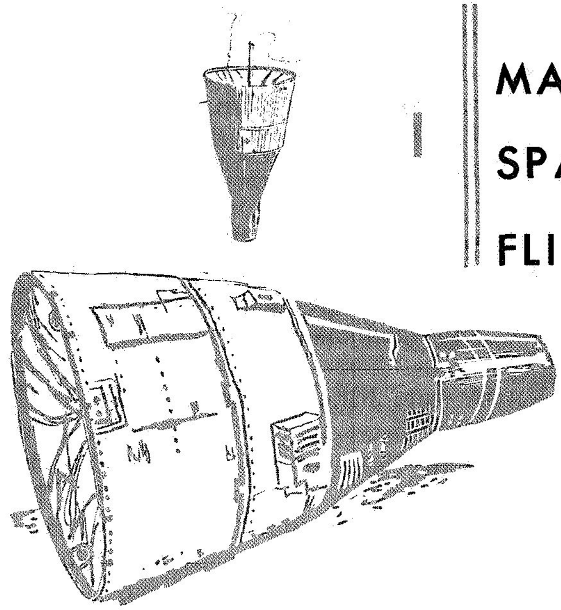


ACTIVITIES & ACCOMPLISHMENTS



MANNED SPACE FLIGHT

During this reporting period, the Manned Space Flight Program progressed significantly toward the attainment of national objectives. The major achievement was the successful first unmanned flight test of the Apollo-Saturn V space vehicle on November 9. This was a key milestone in the Apollo Program, and its great success furnished a basis for increased optimism and encouragement.

Emphasis was continued on the technical and engineering improvements identified as necessary following the Apollo 204 accident. Further progress was made in improving the management efforts, organization, and operating procedures associated with the Apollo Program, in addition to the design changes in the spacecraft itself.

In the area of post-Apollo missions, planning continued for the follow-on Apollo Applications Program. By the end of the period, development of hardware and experiments and operations planning for initial earth-orbital missions was well under way.

APOLLO PROGRAM

NASA achieved a critical point in the Apollo Program with the Apollo 4 flight on November 9. In an all-up launch of the Apollo/Saturn V, the flight demonstrated that the spacecraft, heatshield and lunar rocket met program requirements. This exceedingly difficult research and development feat also demonstrated the competence of the Apollo team.

The success of Apollo 4 and the near readiness of Apollo 5 for a planned January (1968) launch clearly indicated that the Apollo Program has regained much of the momentum lost following the Apollo 204 accident. As the initial result of the accident, the Apollo Spacecraft designs, materials, and test procedures were comprehensively re-evaluated. Changes were defined and corrective actions continued throughout the last half of the year.

In November, NASA established a revised Apollo launch schedule after a thorough reassessment of program requirements and capabilities. The pacing items in the revised schedule were identified as the Command, Service, and Lunar Modules. The new schedule calls for up to 3 Saturn IB and 3 Saturn V flights in 1968 and five Saturn V flights in 1969. This revised base includes as mainline missions an additional Unmanned Lunar Module Development Mission and a third Unmanned Saturn V Mission. Although this planned program reduces the total number of flights preceding the lunar mission, it still enables the Agency to capitalize on success or to respond effectively in case of problems.

Specific Program Objective

The Apollo Program is a major step in the Agency's total program to develop a broad capability for the manned exploration of space. The specific objectives of Apollo are to enhance United States leadership in space by building a broad based capability for manned space flight and to demonstrate this capability by landing men on the moon and returning them safely to earth in this decade. The capabilities developed by Apollo will be employed for future scientific investigations, for applications in the national interest, for exploration of space, and for further advancement of United States space flight capability and leadership.

Apollo Program Phasing.—The Apollo flight mission phasing provides for flight test missions to verify the hardware, train flight crews, and validate all of the supporting systems required to accomplish lunar landing. Apollo-Saturn missions fall into seven flight development phases, each mission being designed to accomplish a specific flight objective. Saturn IB launch vehicle and Command and Service Module (CSM) development phase consisted of unmanned earth orbital flights. This phase was completed with Flights AS–201, 202, and 203 in 1966.

CSM operations phase makes use of the Saturn IB to test the Command and Service Module in manned earth orbital missions (Fig. 1–1). This phase should verify crew operations in an Apollo CSM for missions up to ten days. The SA–205 launch vehicle and the first Block II Command and Service Module 101, scheduled for launch during the second half of 1968, will be the first in this series.

The Apollo 5 AS–204 mission (planned for January 1968) and a second mission (if required) using AS–206 are to be unmanned Lunar Module development flights.

Saturn V launch vehicle and spacecraft development is being conducted concurrently with Saturn IB missions. Apollo 4 (AS–501) was the first launch in this phase of flight development. Apollo 6 (AS–502), scheduled for launch in the spring of 1968, will employ a Saturn V launch vehicle and Command and Service Module 020. This spacecraft will be equipped with a new unified hatch, handrails, and a Block II configured (modified Block I) heatshield. A Lunar Module (LM) test article (LTA–2R) will also be carried. The schedule provides for a third unmanned flight using AS–503 if results of the Apollo 6 mission show that a third flight is necessary.

CSM–LM operations include manned flights to verify the operational soundness of the lunar configuration. If the Saturn V development encounters unforeseen difficulties, these objectives

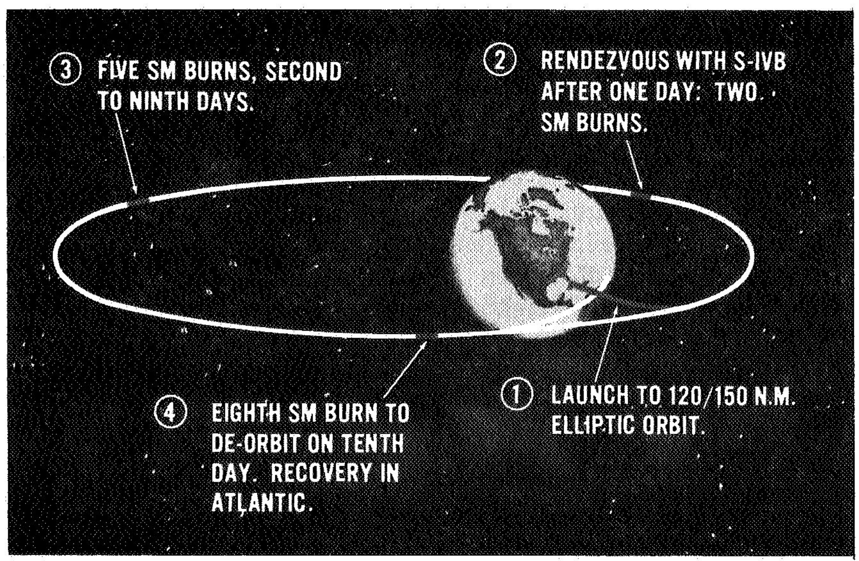


Figure 1–1. Mission Sequence—Manned CSM operations.

could be accomplished by alternate missions on Saturn IB vehicles. The alternate missions would be similar to the portion of the flight that would have occurred after the initial docking of a CSM and LM launched by a Saturn V but would be launched on two Saturn IB vehicles.

The Lunar Mission Development phase should demonstrate the lunar mission capability of the Apollo space vehicle, crew, and ground support by simulation of that mission in earth orbit.

Lunar missions will demonstrate lunar distance mission capability, lunar landing, exploration, and safe return to earth.

One mission (Apollo 4) was successfully accomplished in the second half of 1967 (Fig. 1–2), and four unmanned Apollo flights were being scheduled for the first half of 1968. The first will be Apollo 5 (AS–204), a Lunar Module development flight, the next will be Apollo 6 (AS–502), the second launch of Saturn V, which will continue the Saturn V launch vehicle and Command/Service Module development phases. The third flight scheduled is also a Saturn V (AS–503) tentatively intended to continue development of the launch vehicle. The fourth is a Saturn IB (AS–206), continuing development of the Lunar Module. The final objectives and schedules of AS–503 and AS–206 depend upon the results of Apollo missions 5 and 6. In the event Apollo 5 achieves its objective sufficiently to validate the LM for manned flight, the AS–206 mission will not be required. If Apollo 6 provides a sound basis, AS–503 will be rescheduled and planned as the first potential manned Saturn V mission.

Apollo 4 Mission.—The main purpose of this mission was to evaluate the Saturn V launch vehicle and the Apollo Spacecraft combination, the Command Module heatshield at lunar return conditions, and systems performance.

Although the launch vehicle used for the first test of the Saturn V was similar to that to be used for the lunar mission, there were some differences. The second stage structure was different from the lightweight structure which will be incorporated in later flights beginning with AS–504. The Emergency Detection System was flown in a passive mode, research and development (R&D) instrumentation was flown on all stages, and a dummy Lunar Module was installed. The Block I Command and Service Module was modified to include a Block II heatshield and certain improvements in the wiring, environmental control system, and the changed hatch window. The Command Module cabin was filled with gaseous nitrogen.

After liftoff, the third stage (S–IVB), instrument unit, dummy

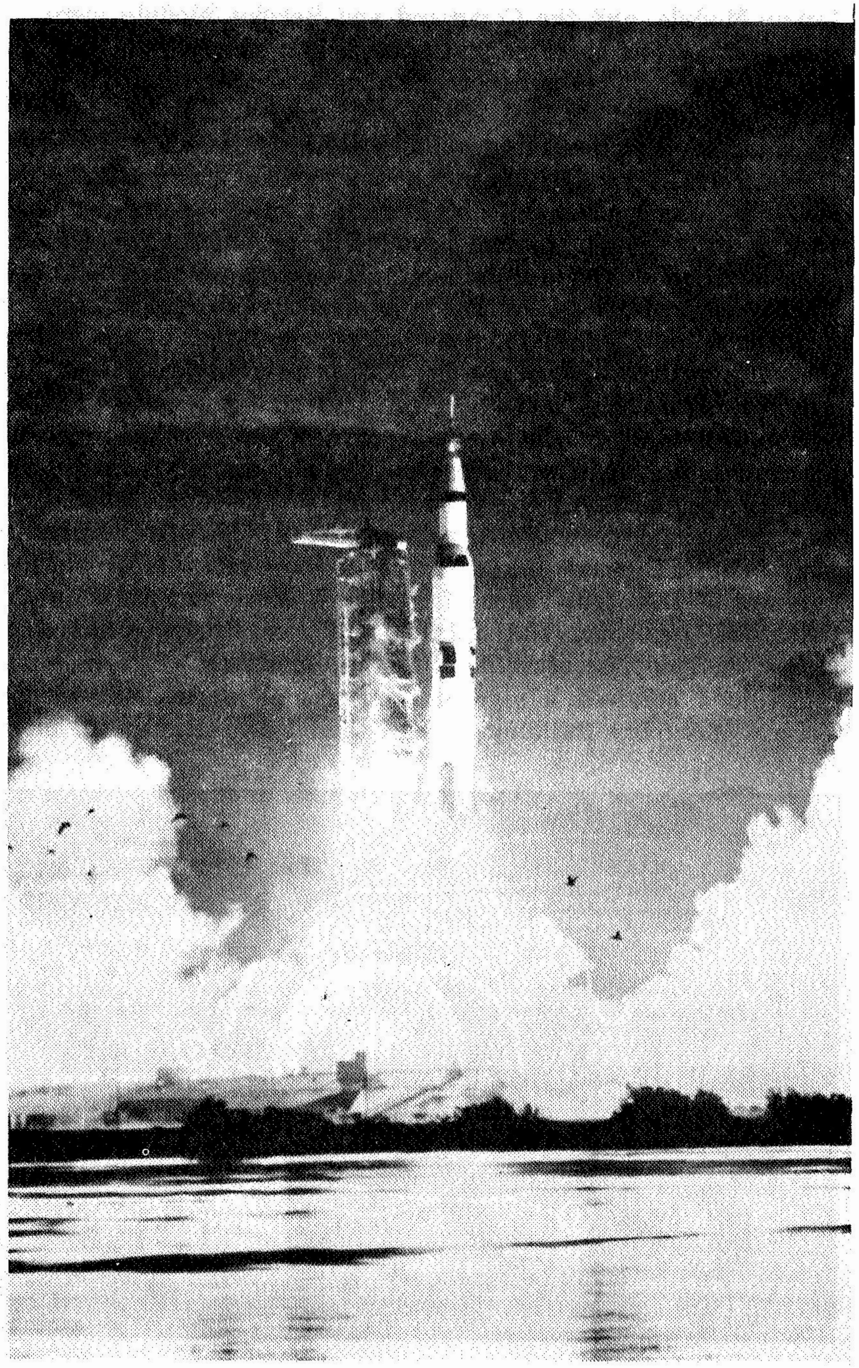


Figure 1–2. Apollo 4 launch, November 9, 1967.

Lunar Module, and the Command and Service Module were inserted into a low earth parking orbit. Two revolutions later the S–IVB stage was re-ignited for a simulated translunar injection burn, placing the S–IVB stage and spacecraft into a highly elliptical earth intersecting orbit. Following S–IVB/CSM separation, the Service Module propulsion system was ignited for a short duration and the CSM aligned to the desired attitude. During the descent, the Service Module propulsion system was re-ignited for a long duration burn, accelerating the spacecraft to simulate conditions equivalent to atmosphere reentry after a lunar mission. CM/SM separation and orientation of the CM to the entry attitude followed. The CM successfully reentered and was recovered. (Fig. 1–3).

The first flight of the Apollo Saturn V space vehicle marked the culmination of more than seven years of design, development, fabrication, and test by the thousands of individuals in government and industry who are part of the Apollo team. Apollo 4 placed 278,699 pounds into earth orbit. However, this is only one measure of the significance of Apollo 4. More important is the industrial, scientific, and management competence required to assure the complete attainment of the objectives.

Apollo 4 received a vigorous and complete checkout in the Vehicle Assembly Building at KSC and again during its more

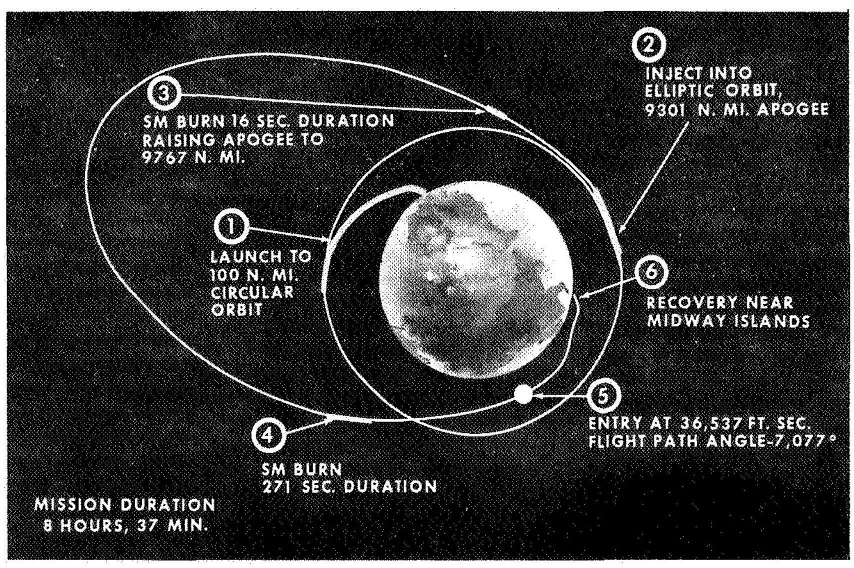


Figure 1–3. Mission sequence, Apollo 4.

than two months on the launch pad. An unmanned flight is in many respects more difficult to execute than a manned flight because mechanical or electronic devices must replace the crew, and many of the redundant systems used in manned missions cannot be used.

Overall performance of the Apollo 4 space vehicle, the launch vehicle, and the spacecraft—together with the ground support and control facilities—was very satisfactory and all primary test objectives were accomplished. The highlights included all-up launch of the Saturn V with the Apollo spacecraft; liftoff within one second of the planned time; Command Module recovery from a point less than five miles from the planned landing point; validation of the Block II Apollo spacecraft heatshield; restart of the 3rd stage in earth orbit, an essential element of the lunar mission; Service Module ignition, cutoff, and re-ignition in vacuum to power the Command Module at lunar return reentry speeds; testing of the flexible thermal shields to be used in the new quick release hatch for the Command Module; testing of the Apollo ground organization with its vast array of facilities and equipment to launch, control, and track launch vehicles and spacecraft; and initial launch from Launch Complex 39.

Although data indicated totally satisfactory performance of all space vehicle systems, and all primary objectives were achieved, some anomalies did occur during the mission. The more significant anomalies and the corrective action are described below.

During the S–IVB restart and second burn sequence, repressurization of the fuel tank was about 10 percent lower than expected. Though not detrimental to system performance, this anomaly was corrected through redesign of the pressurization system and relocation of pressure sensors. After cutoff, the pressure decay in the ambient helium bottles, which contain the gas for tank pressurization, appeared to be greater than predicted. The pneumatic control module associated with these bottles was redesigned to eliminate leakage sources.

The launcher tail service masts, the engine service platform winches, and the ground level elevator shaft of the launch complex received major damage. The electrical power distributor for the mobile launcher, the engine service transporter, the engine servicing platform, and the Launch Umbilical Tower level platform were also damaged. To reduce damage of this type during future launches, certain redesigning and repositioning were undertaken for added protection.

The fact that this was the first flight test of a three stage rocket of this complexity and size under the "all-up" concept is noteworthy. Unlike the smaller Saturn vehicles which were flight tested in increments until the ultimate configuration was reached, the three propulsion stages of the Apollo Saturn V were completely assembled for its first flight. Use of the "all-up" concept is expected to yield the data necessary to achieve the capability for lunar landing earlier and more economically than would be possible by serial flight tests of the component stages.

Apollo 4 was an extremely important milestone in a program which faces many critical milestones. Its success permits rapid progress toward future milestones and provides a legitimate basis for renewed confidence in the capabilities of the Apollo organization to cope with the challenges of the lunar program.

Apollo 5 Mission.—The objectives of Apollo 5 are to evaluate Lunar Module staging, to verify operation of the Lunar Module structure, to demonstrate operation of the descent and ascent propulsion systems, and to evaluate launch vehicle performance.

The Saturn IB AS–204 launch vehicle stages and components will be operationally configured, except that R&D instrumentation will be added to each stage and Instrument Unit, and the engine thrust will not be at the operational level. The Lunar Module will differ somewhat from the operational configuration. It will not have the abort guidance system, landing gear and crew provisions; it will have only part of the environmental control, communications, and display systems; it will have the R&D instrumentation and programmer; and its exterior will have a fire suppressant coating. The rendezvous radar and the landing radar will be inoperative, and the Adapter will be the operational configuration except for modified panel deployment and LM separation systems. A nose cone will replace the Command and Service Module.

After insertion into orbit, the nose cone will be jettisoned, and the Lunar Module (LM) will separate from the S–IVB stage, using the LM Reaction Control System. Two Descent Propulsion System (DPS) burns will be performed. The second DPS burn will be followed by a fire-in-the-hole Ascent Propulsion System (APS) burn for a short duration, staging the LM. This action will simulate a lunar landing abort where the two stages are separated and the ascent stage engine is ignited simultaneously while the descent propulsion system is being shut down. An additional APS burn will be made to use up the remaining propellant.

Apollo 6 Mission.—The objective of Apollo 6 (AS–502) is to demonstrate the structural and thermal integrity and compatibility of the launch vehicle and spacecraft, to verify operation of the various subsystems, to evaluate performance of the space vehicle Emergency Detection System, and to demonstrate mission support facilities and operation.

The Saturn V 502 launch vehicle configuration will be the same as that of the Apollo 4 Mission. (Fig. 1–4). The Block I Command and Service Module will be equipped with R&D instrumentation, a programmer, a Van Allen belts dosimeter, a unified hatch, handrails, a post-landing vent valve, and a Block II heatshield. A non-operational LTA will be carried.

After insertion into circular orbit, the S–IVB stage and spacecraft will have the attitude adjusted during first orbit to assess propellant dynamics and thermal response of launch vehicle system. Following this checkout, the S–IVB will restart and inject the spacecraft into a simulated translunar trajectory and separate from the Command and Service Module. The Service Propulsion System will be operated to reduce apogee and to achieve lunar return entry conditions.

Apollo Management

The reassessment of certain facets of Apollo Program Management, initiated following the Apollo 204 accident, continued through 1967, resulting in some changes in organization and procedures.

Increased attention was devoted to those management systems and procedures most directly related to the activities surrounding the AS–204 spacecraft fire. Among these were test procedures, hardware configuration management, and safety reviews. Management emphasis and controls for assured safety indicated the need to establish an Apollo Program Safety Office in addition to the Manned Space Flight Safety Office. Responsibility for all safety aspects of Apollo were centralized within this office.

Quality and Reliability Assurance.—Apollo quality and reliability assurance efforts continued to stress tight control of hardware manufacturing processes, of reliability support in design reviews, of tracking and resolving failures and discrepancies, of parts and materials, of intensive training, and of maintaining high standards in inspection personnel.

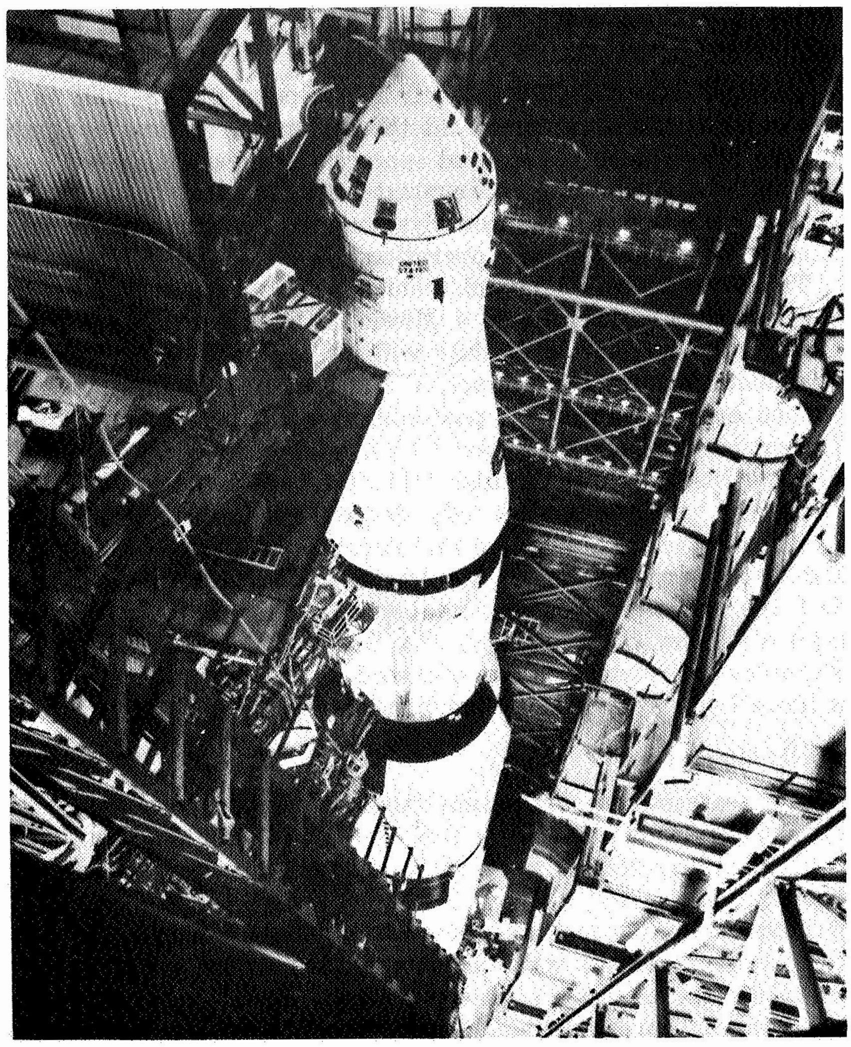


Figure 1–4. Apollo 6 in Vehicle Assembly Building, KSC.

Among the changes made to assure effective reliability and quality control were the addition of detail in inspection specifications to reduce the need for personal judgment; the introduction of mandatory inspection points for a general "shakedown" inspection of the vehicle prior to entering major manufacturing and test phases; the requirement for special quality audits of major contractors; the assignment of the quality and reliability support contractor in the role of "Apollo Quality Contractor" to enhance program management assessment; and strengthening management directives, nonconformance reporting and corrective action, human and procedural error control, and single failure point identification and analysis.

Configuration Management.—Configuration management makes certain that technical design requirements and hardware configuration baselines are complete and accurate on a mission by mission basis. Control of changes to Apollo ground and flight systems was tightened to meet the greater needs of overall program management during flight tests and operations. Also, steps were taken to make sure that only necessary changes are made.

Logistics.—The Agency focused special attention on Apollo Program mission logistics support requirements at the Kennedy Space Center. The availability and accounting of required spare parts, equipment modifications and related services, and launch readiness were markedly improved as a result.

Apollo Data Management System.—The Apollo Data Management System policies and procedures were being applied to all Manned Space Flight programs and activities. The proven features of the Apollo System were being extended still further for NASA-wide application.

Characteristics of Materials Test Data Listing.—To derive maximum benefit from the materials evaluation effort of the spacecraft flammability test program, NASA prepared a listing of the Characteristics of Materials Test (COMAT). This listing of approximately 2800 entries is already the largest collection of data based on uniform test procedures, the ignition, flame spread, and some pyrolysis characteristics of practical materials in oxygen. Such data should benefit other major programs within NASA and the Air Force.

Procurement.—NASA issued revised Apollo schedules in November, and the contract schedules were realigned accordingly. By December, final agreement was reached on most of the contract changes issued through August for the Lunar Module, and through September for the Command and Service Module. Negotiations for the basic contract for ten S–II stages were completed early in the second half of 1967.

The Air Force/NASA single-manager concept agreement for procurement, distribution, and management of certain propellants and pressurants went into effect. The Air Force currently fulfills the majority of NASA's requirements for liquid oxygen, liquid nitrogen, and RP fuels. The provision of helium to Kennedy Space Center was being evaluated at period's end.

Design Status

The redesign of certain areas of the Block II Command and Lunar Modules continued throughout the last half of 1967. The increased weight of the Command Module forced changes in the Earth Landing System (ELS) (such as dual parachute reefing and redesigned drogue parachute risers). The increase in spacecraft weight also made it necessary to review land landing and water impact in the event of an abort from the launch pad. Out of this review came a land and water impact test program.

In June (1967) NASA undertook an intensive special test program to define and solve the Lunar Module Ascent Engine combustion instability. Several new injector designs were fabricated and tested during this period. The contractor made significant progress in defining and understanding the injector stability problem, and in increasing the fuel flow in test hardware. An injector design which meets specification requirements for stability, compatibility, and performance was released for production, and a combined design verification and qualification test program was underway. Two engines with this injector design, scheduled for LM-2 and LM-3, were delivered in December to the Lunar Module contractor.

To provide added insurance that production of a qualified injector would not cause an unacceptable Apollo Program delay, steps were taken to design, develop, and qualify a back-up injector. Excellent progress was made, and the contractor was in the process of releasing a production design for design verification testing.

Development Production and Test

Command and Service Module.—The Command and Service Module underwent extensive design and procedural changes as a result of the Apollo 204 accident. Existing test articles and vehicles were modified to incorporate these changes, and new test articles were identified. Block I flight and ground test articles which had either flown or completed certain Block I missions were being modified and recycled back into the program as a part of the Block II Ground Test Program. Modules in production were recycled to incorporate the changes. The modifications and the associated testing continued to make the spacecraft the Apollo Program pacing item.

The Agency revised the Block II Spacecraft ground test program to accommodate the redefined test requirements. The tests which now constrain the initial manned launch include thermal vacuum, earth landing system, land and water impact, post landing flotation, vibration, propulsion, flammability and structural tests. These tests—as well as the total Apollo Program—are paced by the delivery of test articles. Several test vehicles were completed in the latter half of 1967; however, others were delayed because of the many changes and the heavy work load.

The changes required in Command and Service Module 2TV–1, the Block II thermal vacuum test spacecraft, have delayed the delivery of this vehicle to the Manned Spacecraft Center almost one year (to April 1968).

A test program was in progress to assure that land or water impact will not endanger the astronauts. Because land impact is possible following an abort before or immediately after launch from Pad 39A, the land impact tests constrain the CSM 103 mission. A series of water drop tests were also planned to make sure that the structural integrity and flotation capability of the Command Module can be maintained with the higher weight/higher impact load condition.

The Agency intends to use the Command and Service Module 105 for acoustic vibration testing at the Manned Spacecraft Center to verify Block II structural integrity. It will also use this module in a series of tests with a lunar module test article (LTA–3) to validate the docking interface under a variety of mission conditions.

Another change in the Block II spacecraft test program is the requirement to test-fire the service module rocket engine of a fully configured flight article. Service Module 102 was delivered to the Kennedy Space Center in December for such testing. Command Module 102 was used to verify Block II spacecraft checkout procedure at the plant.

One of the most important additions to the Block II ground test program was the flammability testing to determine the flame resistance and propagation characteristics of the materials in the refitted cabin area. Initial tests were started in December. Additional changes in spacecraft materials may be required when these tests are completed in the spring of 1968.

Structural integrity of the unified hatch, shown in Fig. 1–5, will be verified in ground tests on Command Module 004B. The static structural test series, using the Block II 2S–2 vehicle, will be completed during the summer of 1968.

NASA completed more than 80 percent of the Block II subsystem certification tests by the end of 1967. Of those remain-

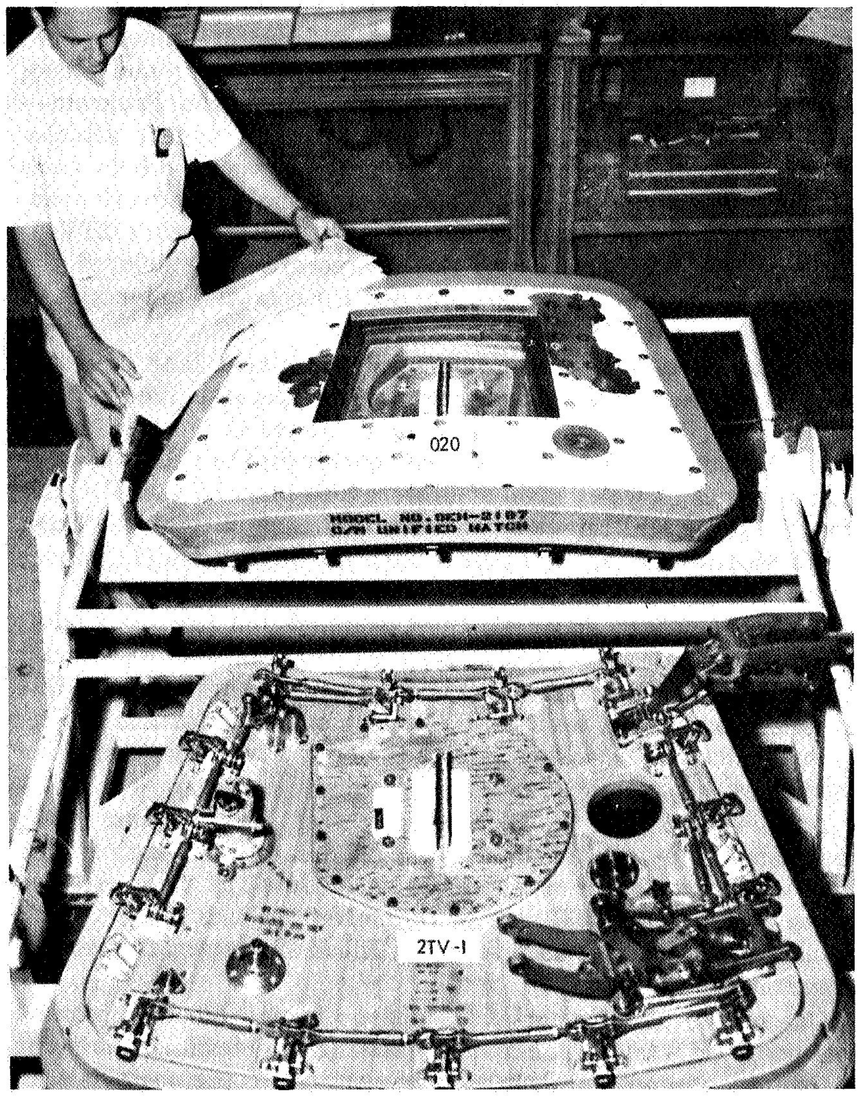


Figure 1–5. Unified hatch assembly.

ing, the Environmental Control System (delayed because of component qualification failures) and the Space Suit (for which design verification testing has been completed) were of primary concern. Both should be qualified by mid-1968.

The Command and Service Module program was redefined and the manufacturing was completed on Command Service Module

2TV–1 (for thermal vacuum testing) and the first manned spacecraft (Command and Service Module 101). In October, NASA and the contractor agreed to a new delivery schedule based on a comprehensive definition of required changes.

The last Block I spacecraft, Command and Service Module 020, was delivered in November for the Apollo 6 mission.

Command and Service Module 101 will be delivered to the Kennedy Space Center in the spring of 1968 for the first manned Block II mission. Spacecraft 102 was diverted for use in verifying factory checkout procedures and for Service Module static firing at the Kennedy Space Center. It will be recycled into the production line for later delivery. Command and Service Module 105 was assigned to the Acoustic Vibration Test Program at the Manned Spacecraft Center.

The remaining flight vehicles, (103 and on) were in various stages of fabrication and checkout at the contractor's plant. The contractor assigned vehicle managers to each flight article in the production line. This technique was proving effective in enabling the contractor to improve his performance.

Improved fabrication and manufacturing concepts, more efficient work planning and scheduling, more rigid and better defined specifications and procedures, and quality control techniques were instituted, markedly benefitting quality and production.

Delivery of flight software programs for the Command and Lunar module guidance systems was delayed because of redefined requirements and development problems. NASA and the contractors established revised schedules, incorporating improvements in program development and testing.

Lunar Module.—The Lunar Module underwent certain design changes as a result of the Apollo 204 fire. Modification and certification testing were underway during the period. Some of the planned 1967 major activities in the Lunar Module Program were not completed because of hardware and materials reevaluation. The ground tests in support of manned Lunar Modules 3, 4, and 5 and the qualification of production hardware are examples; these activities slipped into mid- or late 1968. Of the Lunar Modules ordered, both Flight Test Articles 10R and 2R and the Lunar Module-1 (to be flown on Apollo 5) were delivered.

Lunar Module–1 (delivered to Kennedy Space Center in June) was undergoing checkout preparation during the period. At the end of 1967, it was on the pad ready for the launch of

Apollo 5. Propellant leaks did delay the checkout; however, improved tank and flange seals were installed and are to be used on subsequent vehicles.

Factory checkout of Lunar Module–2, the vehicle for the second unmanned mission, was nearing completion in December. It will be ready for shipment to Kennedy Space Center in February 1968.

Assembly of Lunar Module–3 was complete and factory checkout was in progress. This vehicle is to be delivered to the Kennedy Space Center in the spring of 1968 for the first manned Command and Service Module/Lunar Module mission on a Saturn V. All other Lunar Module flight articles were moving through production as scheduled.

The flammability test vehicle, M–6, shown in Fig. 1–6, (delivered in June), underwent ground tests in November to assess the flammability and propagation characteristics of the entire cabin as it is now configured and outfitted with fireproof and flame-resistant materials. These tests were successfully com-

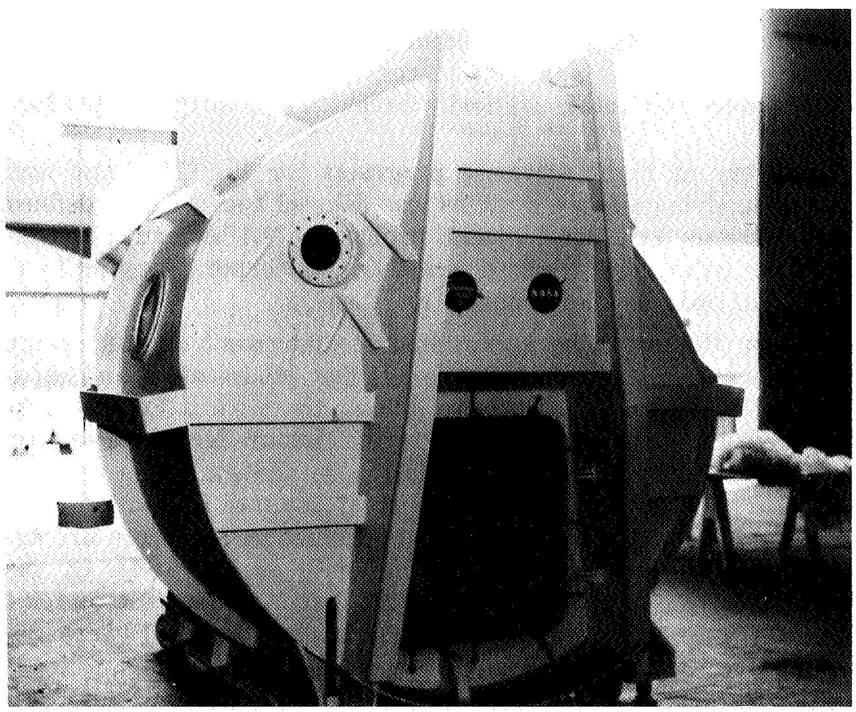


Figure 1–6. Flammability test mock-up.

pleted to support the thermal vacuum test vehicle, Lunar Module Test Article 8, for manned operations. This LTA was delivered to Manned Spacecraft Center in September, where it was being prepared for manned testing in the vacuum chamber (Fig. 1–7).

All LTA's have now been delivered. LTA–10R was successfully flown on Apollo 4, and LTA–2R will fly on Apollo 6.

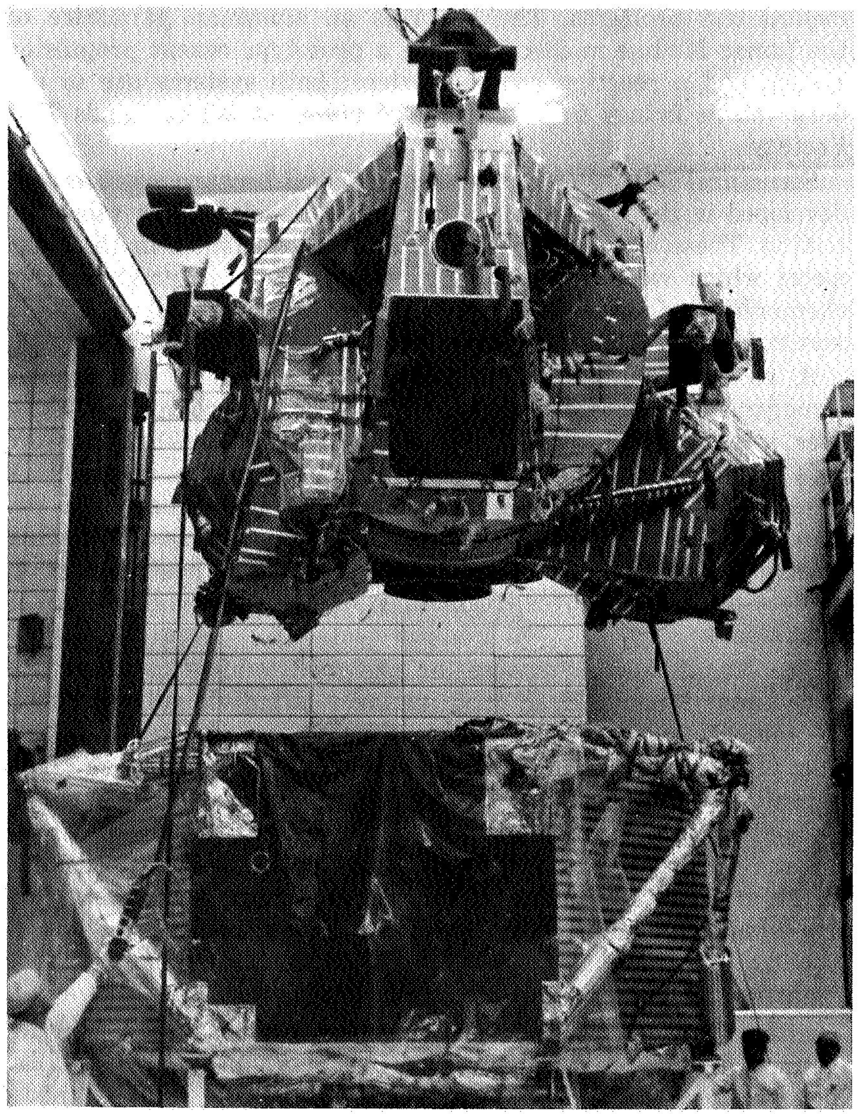


Figure 1–7. Lunar Module Test Article, LTA–8.

Ground testing of the descent stage of the LTA–5D propulsion system was delayed because a heat exchanger failed. The damage made it necessary to refurbish the test article. Steps were taken to correct the faulty weld which caused the failure, and testing was resumed to support all Lunar Module missions.

Ascent stage engine testing on PA–1 also was rescheduled to accommodate additional test requirements and to solve developmental test problems. The PA–1 is an aluminum structure of the Lunar Module midsection with a prototype ascent propulsion system and a reaction control system; both systems are to undergo static firings in an altitude chamber at White Sands Test Facility.

Structural testing of LTA–3 was delayed because small cracks developed in the descent stage structural panels during vibration testing. These cracks were traced to small scratches in the sheet metal which were aggravated by the etching material used in chemmilling of the panels. Corrective actions were taken, LTA–3 was refurbished, and testing was resumed.

A recent examination indicated that a number of tubular structural members were experiencing stress corrosion. However, a test program verified that the Lunar Module–1 tubes were safe enough for the flight loads, and the schedule of Apollo 5 would not be delayed. Additional testing was performed to determine an improved design for future flight vehicles. Following these tests, NASA decided to use a different heat treatment process which improves resistance of the material to stress corrosion.

The Lunar Module contractor assigned vehicle managers to each Lunar Module. Each such manager is individually responsible for all aspects of his vehicle through production, test, and on-schedule delivery. Basic improvements in checkout and test procedures were initiated to improve production flow.

One significant problem, not yet completely resolved, is the injector configuration for the ascent stage engine. Occasional instability was encountered during an overstress evaluation technique termed "bomb testing." This technique consists of detonating small dynamic bombs inside the engine to confirm that the resulting pressure rise is quickly damped out.

Although the initial injector design was adequate for unmanned flight, a higher degree of confidence in engine stability under extreme conditions is required for manned flight. A modified injector design—meeting specification requirements for stability, compatibility, and performance for manned flight—was released for production. A combined design verification qualification test program was well underway. Two engines with the newly designed injector were delivered; one was installed in Lunar Module 2 and the other will be installed in Lunar Module 3. Because of the criticality of this engine, a contract was also awarded for the design, development, and qualification of a backup injector. Excellent progress was made, giving evidence that an injector meeting specifications will be qualified without adversely affecting Apollo launch schedules.

Launch Vehicles

Saturn IB Launch Vehicle.—There were no Saturn IB launches during the last half of 1967. Apollo 5 (SA–204) was on Launch Complex 37 undergoing final checkout for launch in mid-January of 1968. (Fig. 1–8, 1–9, 1–10). Only minor launch vehicle problems were evident, although propellant leaks in the Lunar Module ascent stage propulsion system delayed the checkout.

Saturn IB hardware production was completed as scheduled. However, actual deliveries of Launch Vehicle SA–205 and subsequent launch vehicles to Kennedy Space Center were deferred because of the schedule changes following the accident.

The fabrication of hardware for the 12-Vehicle Apollo/Saturn IB Program was complete with the exception of the last three Instrument Units, which were in various phases of manufacture. As for the S–IB vehicles: SA–201 thru 203 had been successfully launched before this report period; SA–204 was ready for launch; SA–205 and 206 were being readied for delivery for the first manned Block II spacecraft mission and the second unmanned lunar module mission, if required. SA 207 and 208 were available. Two additional first stages (S–IB/1 209 and 210), the remaining four second stages (S–IVB/1 209 thru 212), and one Instrument Unit (S–IVB/1 209) were also made available for delivery. All units not being prepared for delivery were placed in storage and plans were developed to insure that they retain their built-in reliability. Assembly of S–IB 211 and 212 was complete and final factory checkout was in progress.

When removed from storage for either the Apollo Program or the Apollo Applications Program, each stage will undergo a modification and reverification period of two to four months. Necessary changes will be made and a reverification checkout will be conducted to make certain that all systems work properly.

Apollo programming is based on the plan to transfer manned flight from the Saturn IB to the Saturn V vehicle as soon as the

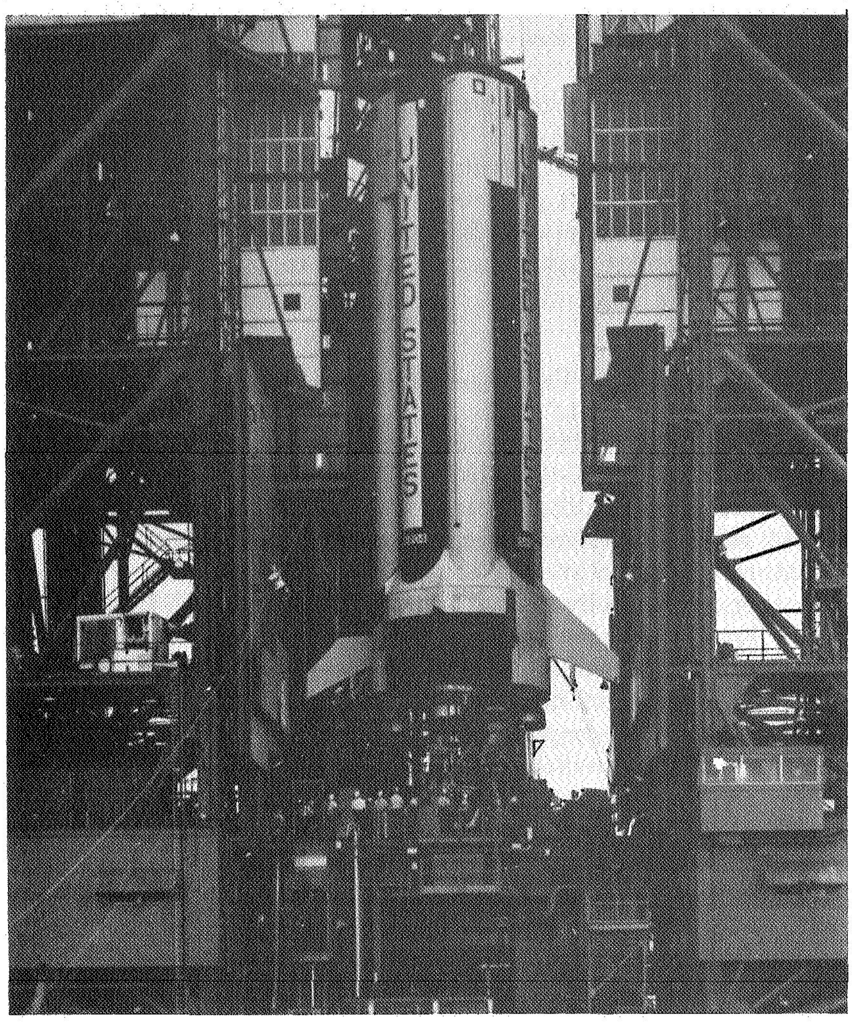


Figure 1-8. Saturn IB first stage.

Saturn V vehicle is ready for manned flight (following successful Apollo 5 and 6 missions and the first manned Saturn IB). When the manned Apollo missions are transferred to Saturn V, the remaining Saturn IB launch vehicles will be released to the Apollo Applications Program. If additional Saturn IB's are required for the manned Apollo missions it will be on a dual launch basis. One vehicle will launch the Lunar Module while the other will launch the manned Command and Service Module. The two spacecraft will rendezvous to perform a simulated lunar mission.

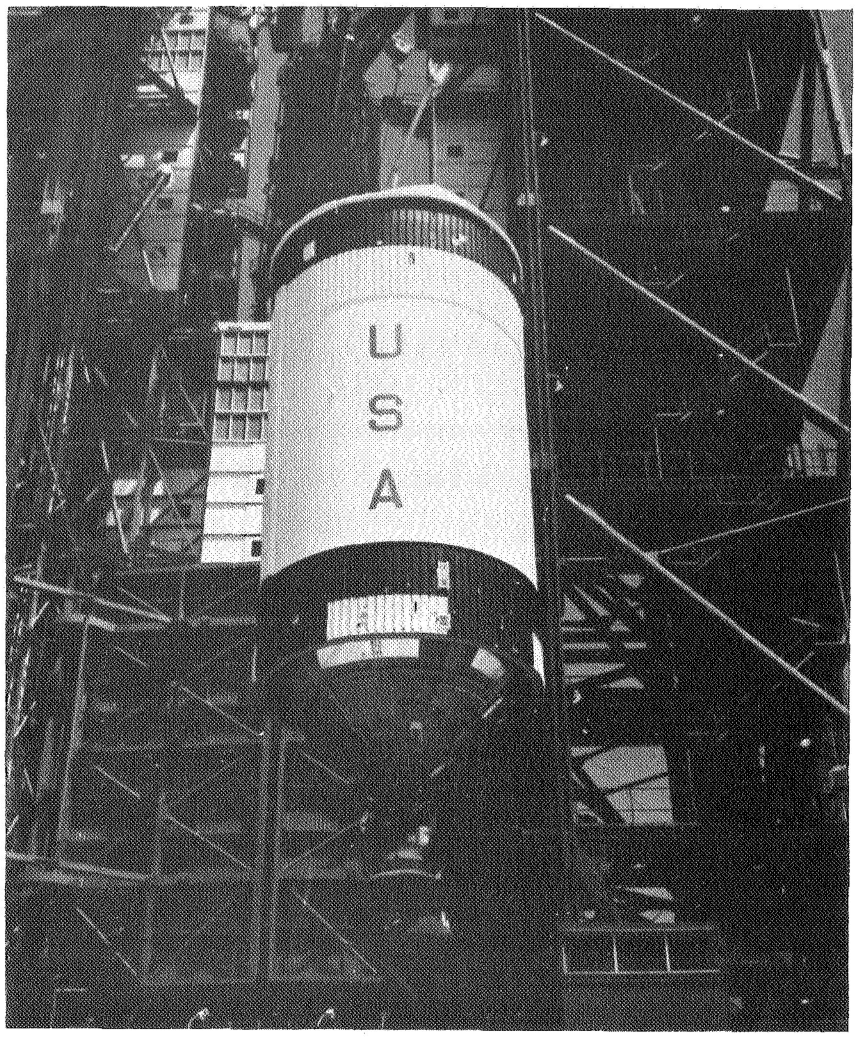


Figure 1–9. Saturn IB second stage.

Saturn V Launch Vehicle.—The successful all-up launch of the first Saturn V vehicle in the Apollo 4 mission was the major accomplishment in the Saturn V program this year. Essentially all of the major 1967 planned accomplishments in the Saturn V Launch Vehicle Program were completed.

For example, stages for Saturn V launch vehicles 502 and 503 were delivered to the Kennedy Space Center and were being readied for launch. (Fig. 1–11 and 1–12). The fourth vehicle, SA–504

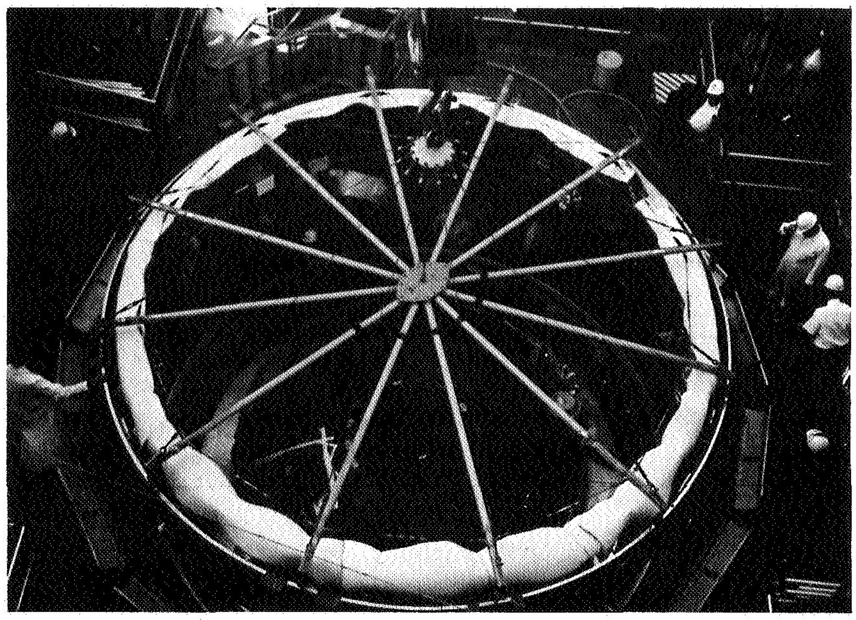


Figure 1–10. Saturn IB instrument unit.

will be delivered in the spring of 1968 with production of subsequent stages on schedule.

A safety evaluation of the SA–501 vehicle was made after the Apollo 204 accident to evaluate operational procedures against the plans, requirements, interfaces, and configuration. The minor discrepancies identified were corrected. S–II (2nd stage) insulation and welding problems were reduced. For the former, a spray-on type of insulation was substituted for the complex honeycomb type insulation which sometimes separated from the main structure when the tanks were pressurized. For the latter, the welding quality was significantly improved. Extensive electrical rework was also accomplished on the S–II–4 and subsequent stages to improve their fire resistance.

The Saturn V Dynamic Test Program was successfully completed at the Marshall Space Flight Center in July. This series of tests determined the dynamic characteristics of the Saturn V launch vehicle under simulated flight conditions, helped to verify the structural integrity of the Saturn V launch vehicle, and confirmed the positioning of control systems and instrumentation. Three configurations were tested: total launch vehicle and spacecraft; 2nd (S–II) and 3rd (S–IVB) vehicle stages, Instrument

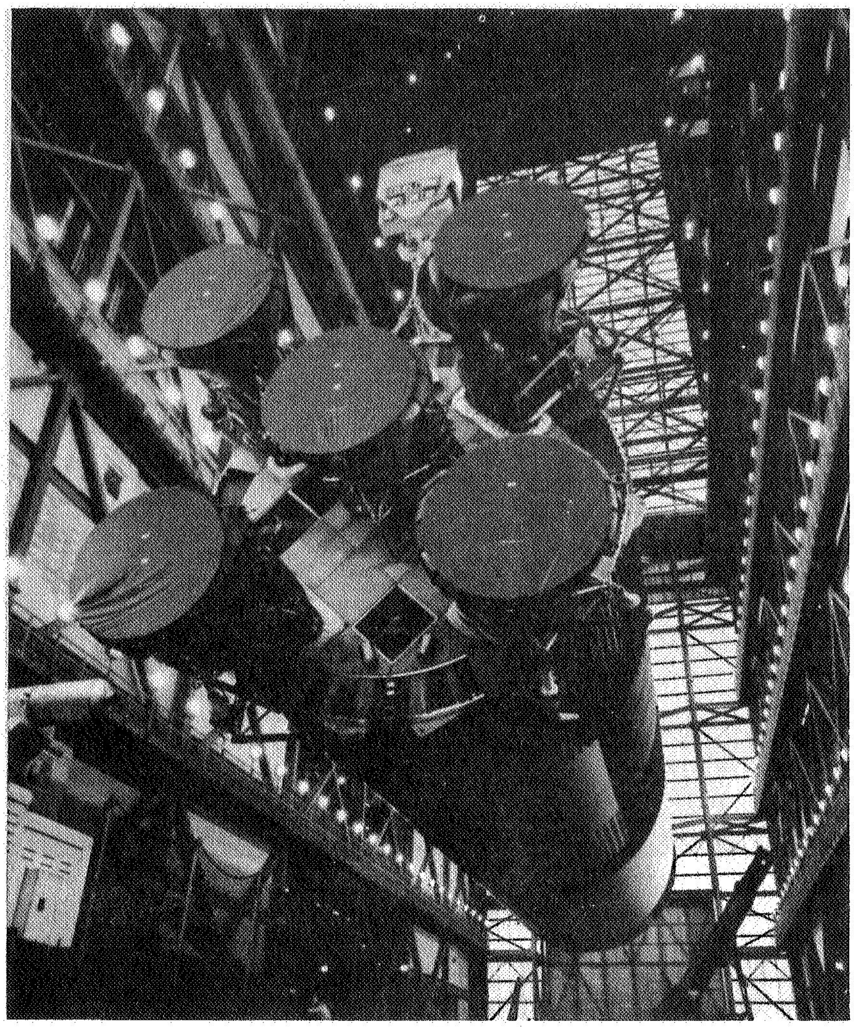


Figure 1-11. Saturn V first stage.

Unit and spacecraft; and 3rd (S-IVB) flight stage, Instrument Unit and spacecraft.

Two potentially critical areas were revealed as a result of these tests. The flight control rate gyro mounting plate was subjected to distortion loads, and the Command Module-to-Service Module attachment structure was inadequate. Minor changes to correct these deficiences were completed before the Apollo 4 flight.

As the period ended, there were no major Saturn V stage design problems, with the S-II (2nd stage) lightweight test pro-

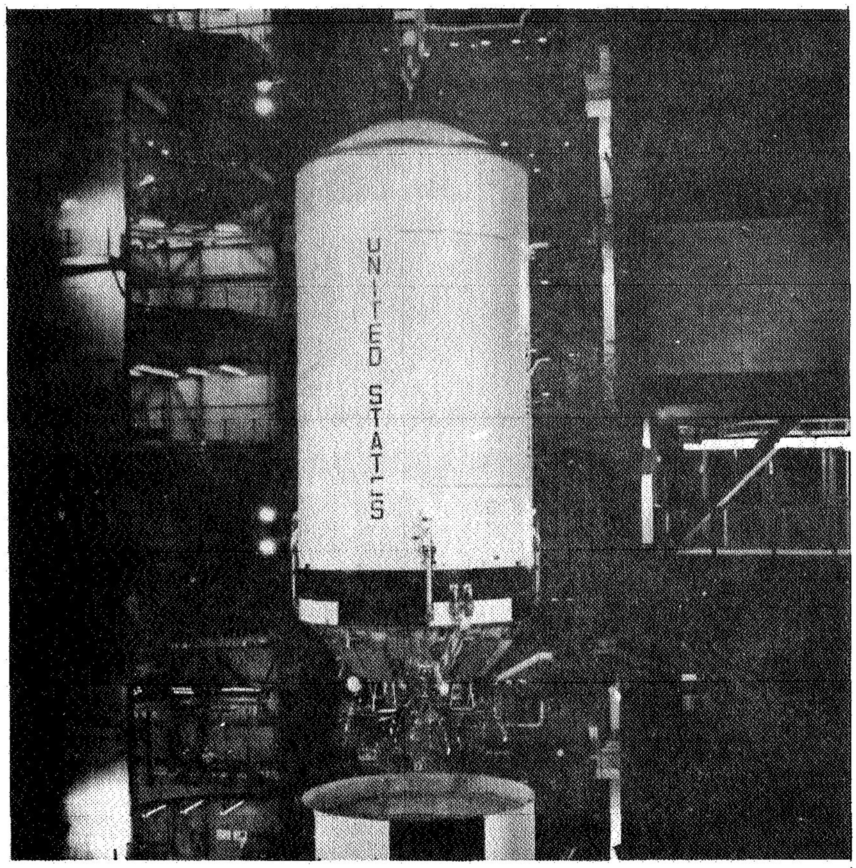


Figure 1–12. Saturn V second stage.

gram scheduled for 1968. An additional proof test of the S–II stage fuel tank with cryogenic hydrogen was inserted in the test sequence for manned flight stages to provide further proof of high quality fabrication. First launch of the lightweight S–II is on the SA–504 mission.

The Saturn V delivery schedule was stretched out because of spacecraft changes, and contract negotiations were initiated to put the revised schedule in force. Of the fifteen Saturn V vehicles under contract, one was launched (Apollo 4), two were at KSC, and the remaining twelve were in various stages of checkout or production.

Checkout, Test, and Launch Operations Facilities

Launch Vehicle Checkout Facilities.—Activation of the stage checkout facilities to support Saturn V continued as planned. All static test stands and factory post static test facilities were operational for checkout of all stages and the instrument unit.

The Beta 3 test stand at Sacramento, California (damaged in the S-IVB-503 explosion in January 1967) was reactivated. The Mississippi Test Facility became fully operational for Saturn V first and second stages. Activation of the second factory checkout station (at Seal Beach in July 1967) provided the capability to handle the maximum planned flow rate of the Saturn V 2nd stage.

Spacecraft Factory Checkout Facilities.—The last of four factory Command and Service Module checkout stands (including 3 Automatic Checkout Equipment Stations) for Block II capability is to be activated in the spring of 1968. All four Lunar Module integrated test stands (including 3 Automatic Checkout Equipment Stations) were activated in 1966 at the contractor's Bethpage, New York facility.

Checkout and Launch Facilities, Kennedy Space Center.—Modification of checkout facilities at KSC were either completed or were nearing completion. Necessary ground support equipment was installed and activated to support the first unmanned Lunar Module (LM-1). NASA procured two additional automatic checkout stations (total of six) at Kennedy Space Center to support the flow of spacecraft through the industrial and launch facilities.

The two KSC Altitude Chambers for CSM and LM checkout will become operational early in the spring of 1968. They will be able to check out the Block II configuration. Both chambers were extensively revised to include additional fire protection and other safety modifications.

The two automatic checkout stations (one for the CSM and one for the LM) at the Manned Spacecraft Center in Houston, are to be used in the Thermal Vacuum Test Program.

Launch Complexes 34 and 37 underwent a number of changes following the Apollo 204 accident. The rapid reacting access arm was modified, lights were added, a redundant power source was provided, and an improved access path to the spacecraft area was arranged. A slide wire evacuation system was designed and test qualified. Necessary changes to Launch Complex 34 should be completed early in 1968.

Launch Vehicle SA-204 (Apollo 5) was placed on Launch Complex 37 after the accident. LM-1 began undergoing checkout in the Industrial Area, then moved to the pad for additional checkout with the launch vehicle. Apollo 5 was in the final phases of checkout, preparatory to a scheduled launch in January 1968.

Pad A of Launch Complex 39 (LC–39) was the site of the successful Apollo 4 launch. The remaining LC–39 facilities were to be activated by mid-1968 with completion of Pad B, the third Launch Umbilical Tower and its swing arms, and the third Firing Room and High Bay 2. High Bays 3 and 1 were the first ones activated in the VAB.

Summary of Major Program Problems

Command and Service Module Production: Making necessary changes and subsequently rescheduling checkout delayed the delivery of Flight and Ground Test Vehicles. Actual modifications and checkout times continued to exceed the original estimates. Late delivery forecasts resulted from procedural problems and additional spacecraft changes.

To enforce the more rigid procedures needed to solve these problems, NASA and the contractors assigned senior test teams and key engineering personnel on an around-the-clock basis. Spacecraft changes were placed under closer scrutiny. (Late delivery of CSM's 101 and 103 will delay the planned launch of AS 205 and AS 503.)

Spacecraft Weight Growth: Increase of spacecraft weight (both the CSM and LM) was such that the current tanks might not hold sufficient propellants to produce the required spacecraft propulsive thrust. Changes following the Apollo 204 accident investigation (and other design reviews) increase safety and ease of operation but add weight. A plan to control this weight was initiated, and the spacecraft velocity change requirements were being reviewed for specific missions and a lower lunar parking orbit. Continued inert weight growth could severely limit lunar site accessibility.

Land and Water Impact Testing: The heavier Command Module (approximately 13,000 pounds) will descend at a faster rate during parachute recovery. This higher rate of descent may produce excessive structural loads during land or water landing following a pad abort. To solve this problem, KSC was conducting land and water impact tests, using a boiler plate spacecraft and Command Module 008. (Also, the crew couch support was being modified to increase the impact limits.) Any structural changes will result in production delays, affecting particularly CSM 101 and 103.

Lunar Module Ascent Engine Instability: Injector stability problems have kept the Lunar Module Ascent Engine from qualifying for the Apollo requirements. The contractor, supported by a NASA evaluation team, initiated an intensive special test program in mid-1967. Subsequently, a promising design was produced and began undergoing tests. As additional insurance, a second contractor was engaged to design, develop, and qualify a backup injector. Progress achieved by the end of the period indicated that Apollo launch schedules will not be adversely affected.

CSM and LM Ground Test Constraints: A potential problem confronting the Apollo Program was completion of CSM and LM ground tests in support of flight missions. To solve this problem, CSM 2TV–1 was being expedited, and steps were taken to increase discipline during checkout.

Qualification of Modified Block II Earth Landing System (ELS): The basic ELS was designed for a CM weight of 8,500 pounds. However, the CM weight continued to increase, requiring modifications to the ELS for a recovery weight of 13,000 pounds. The modified ELS experienced several failures during requalification tests, indicating design deficiencies. Failures occurred in the pilot riser assembly, the drogue parachute reefing ring attachment, and the programmer chute, causing loss of the Parachute Test Vehicle (PTV) and damage to the backup. As a result, testing was delayed approximately one month. To correct the deficiencies, NASA redefined test procedures and redesigned the drogue parachute riser. Another PTV was being fabricated and the damaged one was being repaired.

APOLLO APPLICATIONS

Through the Apollo Applications Program (AAP), NASA continued defining objectives for manned space flight activities in the post-Apollo period.

Program Objectives

The Apollo Applications Program continued working toward the same objectives and making maximum use of the elements started with previous years' funds. Since first proposed, Apollo Applications planning has involved earth orbital missions for long duration flights for scientific, technological, medical, and human factors; and for solar astronomy and extended lunar exploration missions. The program has four primary objectives.

Long Duration Space Flight of Men and Systems.—Long duration flights of men and systems involve the use of the unique capabilities of man as a participant in space flight activities. Systems and subsystems of space vehicles will be evaluated for long duration flights in a series of steps of increasing duration, complexity, and capability.

Scientific Investigations in Earth Orbit.—The first step in terms of a major application of a Manned Space System to science will be in solar astronomy. Later, earth and stellar astronomical observations will also be conducted for scientific purposes.

Applications in Earth Orbit.—Applications experiments include studies in meteorology, earth resources, and communications. The proper relationship between manned and unmanned applications operations will be determined.

Future Programs.—Another program objective is to provide an effective and economical approach to the development of a basis for potential future space programs.

AAP Management

Budget limitations made it necessary to delay many aspects of the AAP and to reduce the number of space flights. However, the early portion of the program remains substantially the same.

The *17th Semiannual Report* described the Saturn I Workshop, the Apollo Telescope Mount, and other earth orbital experiments in detail. However, some elements of the program were deferred, other activities were curtailed, and some experiments and flights were deleted. The Saturn I Workshop was deferred to 1970, and the Apollo Telescope Mount to 1971.

Nevertheless, the Apollo Applications Program maintains maximum flexibility for increased future activity. The new scheduling will allow transfer of the Apollo management, technical, and operational resources to the Apollo Applications effort on a stable, conservative basis. Further, the Agency still proposes to extend the Workshop concept for the evolution and development of a Saturn V Workshop capability for the scientific, technological, and operational needs of the nation.

Program Status

Apollo Applications mission concepts are based on making maximum use of existing hardware as well as launch vehicles and spacecraft of the Apollo Program. In addition, concepts of revisit, reuse, resupply, and repair of equipment in earth orbit will be evaluated from economic and crew capability standpoints.

Saturn I Workshop Mission.—Initial operations with the Saturn I Workshop are planned to take place in 1970. The Saturn I Workshop will be set up inside the empty hydrogen tank of a spent S–IVB stage. That is, after its actual use as part of a launch vehicle, the 2nd stage will serve as the Workshop, providing living and working quarters for the crew.

The Saturn I Workshop mission requires the launch of two Saturn IB vehicles. An unmanned flight, consisting of a Saturn IB with an Airlock Module and a Docking Adapter, will be launched first and designated AAP–2. A second Saturn IB launch occurring approximately one day later, will be manned and designated AAP–1. The manned Apollo Command Module and the Service Module will rendezvous and dock with the S–IVB stage of the first flight. The hydrogen tank of the unmanned S–IVB stage will have been modified so that it can be made safe for the crew.

This mission is expected to help determine and evaluate man's support requirements for performing work in space over extended periods. Planned mission duration is 28 days, after which the equipment in the Workshop will be placed in a standby mode, and the crew will return to earth in the Command Module.

Workshop Revisit Mission.—The first Workshop revisit (AAP–3A) mission is to use a single Saturn IB launch of a three-man Command Module and Service Module to rendezvous and dock with the previously stored Workshop. The missions's planned duration of 28 to 56 days is the next step in testing and evaluating the ability of both man and spacecraft to function effectively for long periods in space. One of the principal purposes of this mission will be to conduct a comprehensive medical test program on the crew.

Solar Astronomy Mission.—The third mission, planned for 1971, is to use the original Saturn I Workshop as a base of operation for a manned solar observatory. One Saturn IB will launch a three-man Command Module and Service Module configured for a 56-day mission (AAP–3). A second Saturn IB will launch the unmanned Apollo Telescope Mount (ATM) and its payload of solar instruments (AAP–4). After the Command and Service Module and ATM rendezvous and dock with the Workshop, the crew will activate the ATM and Saturn I Workshop, thus beginning the operational phase of the mission. This mission will be the first flight test of equipment and operating concepts for future manned and man-tended astronomical observatories using high resolution solar telescopes and spectrographs for observing dynamic phenomena on the surface and in the corona of the sun.

Workshop/Observatory Revisit Missions.—Previous plans in the Apollo Applications Program included a second series of flights with a second Saturn I Workshop and a second Apollo Telescope Mount and several revisits. Because of budget limitations, the plan now calls for the Saturn V Workshop to follow the first flights as early as possible. Funds which had been planned for the second Saturn I Workshop flights will be redirected to the Saturn V Workshop.

Saturn V Workshop.—The knowledge and experience gained during the Saturn I Orbital Workshop mission can best be exploited in a workshop-like space station assembled and outfitted on the ground. Such a system will be launched into earth orbit on the first two stages of the Saturn V and will be tailored to the payload mass and volume of the third stage (S–IVB) of the Saturn V. This arrangement will permit the use of the entire Saturn V launch and checkout complex with minimum modifications.

Such a workshop would use developed equipment and experience where practical. It is in line with the President's Science Advisory Committee Report of February 1967, entitled *The Space Program in the Post Apollo Period,* which stated: "We recommend that programs of studies and advanced developments be initiated promptly with the objectives of a launch in the mid 1970s of the first module of a space station for very prolonged biological studies of man, animals, and other organisms in earth orbit. Such a station should be designed with considerations of its possible role in support of earth orbital astronomy . . ."

Over the past several years, NASA, with supporting effort from many contractors, has conducted a series of studies of the configuration and use of such an orbital facility. Plans call for defining the specific approach to the Saturn V Workshop during 1968. This effort should be directed toward the Workshop, itself; toward its scientific, engineering, and medical payloads; toward operations plans; toward resupply and supporting systems; and toward overall program plans.

Hardware

During this reporting period the Apollo Applications Program continued to move forward in developing and modifying major hardware items and in developing experiment hardware prototypes.

Saturn IB Workshop.—The basic pieces of hardware required for the Workshop were well into their development phase as the period ended. A contractor was modifying the basic S–IVB so that, once spent, it could become the Workshop. A preliminary design review, using the S–IVB full-scale mock-up, was held at MSFC in December. The results of this government-industry study will form the design baseline to proceed into the final development and fabrication phases of the workshop.

Airlock Module.—The Airlock Module was also being developed, with a cost-plus-fixed fee contract to be awarded early in 1968. (To date, the Airlock has been under a fixed price contract.) The Airlock under this contract consisted of a simple tunnel and truss structure which provided access to the S–IVB Workshop from the Command and Service Module, with subsystems to distribute power from the Command and Service Module to the Workshop, to provide environmental control, and to offer limited instrumentation.

The newer Airlock, resulting from the past year of program evolution, is considerably more complex. It now incorporates the electric power conditioning, storage, and distribution system for the entire cluster; the central Environmental Control System; and the central command and instrumentation center for the Orbital Workshop. It has a planned operating time of 308 days, allowing for five revisits of 56 days each after the initial 28-day mission. These increased demands on the systems, made to significantly enhance the utility of the total orbital configuration, have required a major reappraisal of the system components, and a general realignment of the Airlock testing philosophy. An extensive preliminary design review was held at the contractor's facility. This review was preceded by individual reviews of the various subsystems.

Multiple Docking Adapter.—The Multiple Docking Adapter was being developed and fabricated in-house at MSFC. Design of this unit has been in process for a year. An engineering mock-up was built, and a structural test unit was being fabricated.

Monthly management meetings were initiated and a preliminary design review was conducted late in this period. The tempo of MDA hardware production was increased. The 1–G trainer structure was completed, and installation work started on such items as mountings for the experiment airlock and vacuum valve.

The trainer should be ready for the January astronaut walk-through inspection. The engineering mock-up structure was completed, and parts were being produced for the structural test article and the neutral buoyancy trainer. Manufacture of the initial flight unit will begin during the latter half of 1968, and it should be completed late in 1969.

Apollo Telescope Mount.—Work was also in process on the Apollo Telescope Mount at MSFC, with major subsystem development having been underway for a year. Fabrication and assembly of a complete mock-up was initially completed in early 1967 and was updated during this period to incorporate results of the continuing design work. The overall ATM preliminary design review was conducted by NASA in November. A mid-term review was held at MSFC with representatives of other NASA offices and contractors to identify ATM systems requiring modifications for future payloads.

The Apollo Telescope Mount experiment effort was being conducted on a three-step basis. Step 1, completed during the period, included design through breadboard fabrication and testing. Step 2, beginning early November and running into the first half of 1968, covers delivery of a qualified prototype and flight unit. Step 3 will include flight support and data analysis. Five specific experiments have been selected for the Apollo Telescope Mount and are being fabricated.

Preliminary design reviews of the AS&E X-ray spectrograph, the Goddard X-ray telescope, and the High Altitude Observatory (HAO) coronagraph were completed and hardware fabrication effort authorized. Also completed were contract negotiations for developing both H-alpha telescopes and the High Altitude Observatory experiment.

Following the design review of the UV Coronal Spectroheliograph, NASA decided to eliminate the full-scale design verification units, thus reducing costs.

In addition to the experimental instruments, subsystems for the Apollo Telescope Mount are under contract to several firms. The contractor for an ATM Control Moment Gyro delivered the first engineering-model wheel assembly to MSFC for testing and has a second wheel in test. Approximately 600 hours of running time were accumulated on the two wheel assemblies with no major problems encountered.

All of the preliminary design reviews of MSFC in-house ATM subsystems were completed.

The Lunar Module (LM) ascent stage modifications were in the detailed design definition phase at the contractor's facility.

Launch Vehicles.—The initial flight missions of the Apollo Applications Program will use those Saturn IB and Saturn V launch vehicles procured within the Apollo Program but which are not expected to be required to accomplish the manned lunar landing. The current Apollo Applications mission plan assumes availability of Apollo Saturn IB vehicles 206 through 212 and follow-on production of two vehicles per year beginning with 213. Apollo Saturn V–515 has been designated for Apollo Applications with follow-on production also at the two-per-year rate.

Launch vehicle procurement remained the responsibility of MSFC and will rely on the same contractors that produce the stages and engines for the Apollo vehicles.

ADVANCED MANNED MISSIONS

The Advanced Manned Missions Program Office continued to study all aspects of potential future manned space flight systems and missions. Study results, planning activity, and flight experience have convinced NASA that the development of the manned earth-orbiting space station is a logical and necessary milestone in the evolution of manned space flight. Therefore, the Agency has focused considerable attention on studies which can contribute to space station concepts.

The first comprehensive plan for man-supported orbital telescopes and detectors was produced in a study of an orbital astronomical support facility which could follow the current Apollo Applications Program and remain productive through the 1980's. Astronomy is one of the most important and potentially fruitful scientific areas which can be exploited from a space station. Astronomical observations would be free of distortions caused by the atmosphere, and those portions of the electromagnetic spectrum which the atmosphere obscures from earth-bound observers would become accessible.

The study identified instrument concepts and examined their supporting requirements which affect the craft that would house them. Analyses showed that, with the exception of radio telescopes and high energy particle detectors, the instruments should be housed in modules which could operate while detached from the station for extended periods. Maximum flexibility would be obtained if man could inhabit the modules so the instruments and recording cameras could be replaced, modified, checked, or calibrated, and exposed film replaced. In identifying the requirements of such a facility, the Advanced Manned Missions Program Office systematically analyzed current major astronomical problems, extending the process sufficiently to project a potential sequence of orbital activities.

This type of systematic analysis and projection of critical activities was later extended into the areas of oceanography and meteorology. In these areas, facility concepts were not studied but instrument requirements were assessed for making critical measurements, whether made on the earth's surface, from airplanes, or from spacecraft.

As missions become increasingly ambitious, more ambitious tasks may require crewmen to work outside or away from their spacecraft. Erecting and maintaining large structures, such as telescopes and antennas, is one such task; maintaining or replacing external structures and components is another. While the potential for extravehicular activity was demonstrated in the Gemini program, it was apparent that the procedures, techniques, and equipment which would allow operational application must be developed for each particular type of extravehicular activity. Astronaut locomotion and crew and cargo transferral are fundamental to most such activities. Efforts were underway to define experiments that would have to be accomplished before the astronauts could fully execute these extravehicular missions.

Escape and rescue system studies were conducted during this reporting period to identify manned space flight hazards and to investigate the feasibility of alternate escape and rescue concepts in the light of current and projected technology. Specific concepts investigated included orbital based systems located either in an earth orbiting station or in a nearby orbit, systems based on logistic vehicles, and earthbased systems which can be used for rescue purposes. As a result of these studies, additional analytical and conceptual design effort is to be placed on escape systems using logistics vehicles, and on bailout-and-reentry capsules.

In the area of advanced lunar missions, alternative means of conducting lunar exploration following the first successful manned lunar landings were defined and analyzed. The 1967 Summer Conference of Lunar Science and Exploration at Santa Cruz, Calif., brought together a large group of NASA personnel and consultants drawn primarily from universities, non-profit research organizations, and other Federal agencies, to consider such exploration.

Definition studies, feasibility tests, and simulations were continued on such items as wheeled roving vehicles, rocket-propelled flying vehicles, lunar recovery systems, moderate depth lunar drills, and lunar cargo delivery vehicles. Parallel studies were conducted on lunar surface material properties, on the ability to travel over the surface, and on the means of securing engineering data.

Manned planetary mission studies completed during this reporting period indicate that it is feasible to accomplish manned single and multi-planet encounter (flyby) missions by using chemical propulsion corresponding to Saturn stages and by extending the capability of Apollo systems. A definition study of an experimental test program for a manned Mars excursion module was also completed. The most significant conclusion of this study was that a manned landing module can be qualified in the near earth environment, making it possible to move to an actual Mars landing without a prior unmanned landing test of the module at the planet.

CONSTRUCTION OF FACILITIES

During the second half of 1967 construction and activation continued on schedule. The essential plant and related equipment to support the manned lunar landing was in being, with sufficient built-in capability to support follow-on programs at minimal cost. Most key facilities in the timetable for planned programs were complete and operational. Construction of the Lunar Receiving Laboratory at the Manned Spacecraft Center, Houston, Texas, was essentially completed, and outfitting was progressing satisfactorily. NASA placed increased emphasis on effective and efficient maintenance to protect the government investment in facilities.

Kennedy Space Center

At Kennedy Space Center, the successful first Saturn V launch proved the soundness of the overall launch facilities design and construction. Work was continuing on schedule for outfitting the High Bay #2 of the Vehicle Assembly Building, Launch Complex 39, the Launch Umbilical Tower #3, and Launch Area B. Work was completed on the additions to the Flight Crew Training Facility, Medical Dispensary, Central Heating Plant, Communications Distribution and Switching Center, and Central Instrumentation Facility. In addition, the Propellant Systems Components Laboratory became operational.

Manned Spacecraft Center

At the Manned Spacecraft Center, construction of the Lunar Receiving Laboratory was essentially completed in August, except for certain equipment installations which should be completed early in 1968. However, the Agency must conduct shakedown tests, develop procedures, and train operating personnel before the facility can become fully operational.

Marshall Space Flight Center

The Marshall Space Flight Center and all locations under its cognizance (Michoud Assembly Facility, Mississippi Test Facility, and the various Government-owned or -operated industrial facilities that are used to develop, manufacture, and test spacecraft, engines, and stages) are fully operational. During this period, a deep injection well—with its associated pumps and piping to dispose of chemical wastes generated in manufacturing Saturn stages—was completed at Michoud.

Plant Engineering

Significant progress was achieved in plant engineering and maintenance activities at all MSF installations. Utilities conservation was one of the major areas where savings resulted from scheduling various tasks and work requirements to control electrical demand periods. Steps were taken to plan Manned Space Flight activities so as to enable the Center to take advantage of the lowest possible utility rates. Costs of general maintenance services were reduced by closely monitoring the frequency of custodial support, by controlling the requirements for emergency and stand-by crews during off-duty hours, and by carefully managing equipment and instrumentation purchases.

OPERATIONS ACTIVITIES

Flight crews for the first three manned Apollo flights were selected, and by the end of the year, the first crew had completed 45 percent of its training schedule. The remaining astronauts continued to be heavily involved in spacecraft design and testing. The third Apollo mission simulator and the two LM mission simulators were accepted from the contractor, and the three lunar landing training vehicles were delivered. Acceptance and flight test of the latter were underway at the year's end.

Three modern Bell 47G helicopters were acquired as replacements for the two training helicopters (one borrowed from the

Navy and one given to NASA by the Army) used up to now by NASA. The operating and maintenance costs of the new craft are expected to be significantly less than those of the older vehicles, and their availability for flight training is expected to be greater.

Operations Support Requirements

The joint NASA/DOD MSF Support Requirements Documents were redefined to make them more compatible with the Universal Documentation System being developed by the National Ranges. NASA continued its associate membership on the DOD Inter-Range Documentation Group, working closely with the Group to develop compatible formats for the Unified (NASA/DOD) Documentation System.

The Launch Support Team and Flight Support Team processing of late changes was under study to improve configuration control after the Flight Readiness test has been completed. Also, the Requirements/Support Documentation System satisfactorily supported Apollo 4.

Mission Control Systems

The Mission Control Center (MCC) at Houston provided program development, mission simulation, and pre-mission testing for Apollo missions 4 and 5, as well as real-time flight control for Apollo 4. Changes were initiated to significantly improve system reliability and backup capability in support of an active mission. These include adding the fifth computer in the Real Time Computer Complex and installing computer switchover and restart hardware for use in case of a primary computer failure.

System demonstrations were conducted for a prototype digital television display system, video multiplexing system, and digital scan converter. This prototype television display system will materially aid in developing operational equipment for transmitting, receiving, and displaying (in real time) mission operational data in the MCC.

Compatibility and performance evaluation testing of the Spacecraft Communications System and ground station equipment continued, with some system configuration tests being completed. This activity will continue until all operational modes and system configurations have been carefully tested and the results analyzed. Firm plans were made to conduct compatibility and performance evaluation tests with an operationally-equipped Apollo Range Instrumentation Aircraft.

Launch Information Systems at KSC

Launch information systems in Launch Complex 39 at KSC were first used for operational support of Apollo 4. These include meteorological, acoustic, hazard monitoring, lightning warning, telemetry, display, data recording, and computation systems.

The computer complex in the Central Instrumentation Facility was expanded to permit real-time operational support of two major test operations, and to provide backup for a single major test or launch. Following a detailed review of computation requirements at KSC in early 1967, limited additional computing equipment was authorized. Launch information systems for Firing Room 3, Mobile Launcher 3, Vertical Assembly Building Bay 2, and Pad B (Flow 3) were installed. These will become operational early in 1968.

Operations Communications at KSC

The new radio frequency voice communications system at Launch Complex 39 performed very effectively in support of the first Saturn V launch. A few system improvements will be installed during 1968.

Following the Apollo accident investigation, it was decided to completely refurbish the operational intercommunications system at LC–34 and the Central Instrumentation Facility. Work began in 1967 and will be completed in 1968 in time to support the first manned launch. Improved and expanded voice recording systems were installed, and central communications testing and monitoring facilities were being implemented for more rapid malfunction detection and isolation.

During the Apollo 4 launch, a control subsystem failed in the LC–39 operational TV system. Control subsystem improvements will be installed early in 1968 to improve the system reliability.

Huntsville Operations Support Center (HOSC) at MSFC

The HOSC, manned by MSFC engineers, provides realtime consultative support to KSC during prelaunch and launch operations, and to the Houston Mission Control Center during flight operations. The increasing use of the HOSC during the first three Saturn IB flights of 1966 revealed the need for a modest expansion of this facility. This expansion was completed in 1967, was used to support the Apollo 4 operations, and will support the planned Apollo missions scheduled in 1968.

SPACE MEDICINE

The NASA space medicine mission continues to support manned space flight. During the period, a review of the roles, missions, and management of the Agency's life sciences program resulted in the publication of a management instruction defining the medical responsibilities and management interfaces between Headquarters and the MSF Centers. The Agency designated a staff medical officer at each Center to advise management on medical matters and to provide interface with Headquarters.

Meanwhile, the scope of the medical review was broadened to include all of the life sciences program. Subsequently, an agency Life Sciences Working Group was formed comprised of representatives of the three Life Sciences Directorates, the Office of Organization and Management, and the Office of Programs. This Working Group is intended to provide a basis for determining courses of action in the life sciences studies, including delineation of roles, missions, and authority; integration of program planning and execution of review; mechanisms for resolving programmatic interface; and effective use of external competence. The project was nearing completion at the close of the period, with a target date of March 1968 for submission of findings and recommendations.

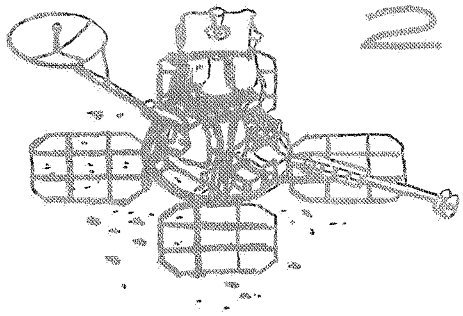
Space medicine scientists and management continued a close relationship both in and out of the government. The Space Medicine Advisory Council—a consultant group to the Director of Space Medicine consisting of scientists from universities, medical research foundations, clinics, and the Federal Government—met at regular intervals. During the period, that Council, together with medical members of the OMSF Science and Technology Committee (STAC), was absorbed into a Biomedical Subcommittee of STAC. The Subcommittee now serves as the principal biomedical advisory body for all organizational elements of manned space flight programs, including manned space flight centers.

There were significant medical contributions to the Apollo lunar landing program during this reporting period. The Interagency Agreement on Back Contamination was signed by the Administrator of NASA; Secretary of Agriculture; Secretary of Health, Education, and Welfare; Secretary of the Interior; and the President of the National Academy of Sciences. The Interagency Committee also developed a document entitled "Quarantine Schemes for Manned Lunar Missions," which provides that lunar samples will be handled according to rigid containment standards currently in use both at Fort Detrick, Md., and at the Naval Biological Laboratory. Two major problem areas still under study were the allocation and distribution of returned lunar samples for quarantine studies, and the certification of the Lunar Receiving Laboratory as a true containment facility.

Revised manned flight schedules affected the medical experiments program. Two Gemini follow-on experiments are to be conducted on Apollo missions: the *Bone Density Study* and the *Cytogenetic and Immunological Blood Studies*. A third experiment, the *Lower Body Negative Pressure Study*, was designed to develop a test procedure for the pre- and post-flight functional assessment of the cardiovascular system. Other medical investigations postponed as a result of Apollo program changes may be carried out if they do not interfere with the individual missions. Inflight medical monitoring will be conducted on a more limited basis than in Gemini.

Medical experiment definition efforts for the Apollo Applications Program are directed toward areas of human body function: Neurological, cardiovascular, respiratory, metabolic and nutritional, endocrine, hematological, microbiological and immunological, and behavioral.

Despite marked restrictions in weight and power, the AAP workshop concept presents an opportunity to resolve a series of medical problems concerning man's capability to perform in space flights extending from two weeks to one year. Definition of the Integrated Medical and Behavioral Laboratory Measurement System was begun. The system is essentially a flight laboratory console that can make physiological, biochemical, microbiological, and behavioral measurements. Designed on a modular basis to accommodate additional and interchangeable measurements and experiments, the system can be used in the Command Module, Lunar Module, or Orbital Workshop. The design phase will be initiated in the near future.



2 SCIENTIFIC INVESTIGATIONS IN SPACE

As evidence of this Nation's increasing skill in developing automated spacecraft, NASA launched two satellites of the Observatory class, an interplanetary Explorer, and a Pioneer space probe. Other complex spacecraft launched were the last of the Lunar Orbiter photographic laboratories, three Surveyor soft lunar landers, and Mariner V which flew by Venus. Also, the second Biosatellite was launched, remained in orbit for almost two days, and was recovered; it provided information about the biological effects of weightlessness and radiation on various life forms.

PHYSICS and ASTRONOMY PROGRAMS

Orbiting Observatories

The fourth Orbiting Geophysical Observatory, OGO–IV, was launched on July 28 (fig. 2–1). Like OGO–II in October 1965, it was placed in a low altitude, polar orbit ranging from 250 to 560 miles enabling it to view the entire surface of the earth daily. Its mission: to study the relationships between solar phenomena and solar radiations and the terrestrial environment during a period of increasing solar activity.

OGO–IV serves as a platform for the instruments providing data for its 20 experiments. (The satellite—stabilized in three axes—maneuvers as it rotates to keep the same face toward the earth.) The experiments measure the composition, density, and temperature of the atmosphere, and the incoming solar electromagnetic radiation and particles responsible for chemical and physical changes in the atmosphere. They also observe emissions from airglow and aurorae and continue the World Magnetic Survey of the earth's magnetic fields.

OGO–IV proved to be the most successful of the four Orbiting Geophysical Observatories, although more than half of the ex-

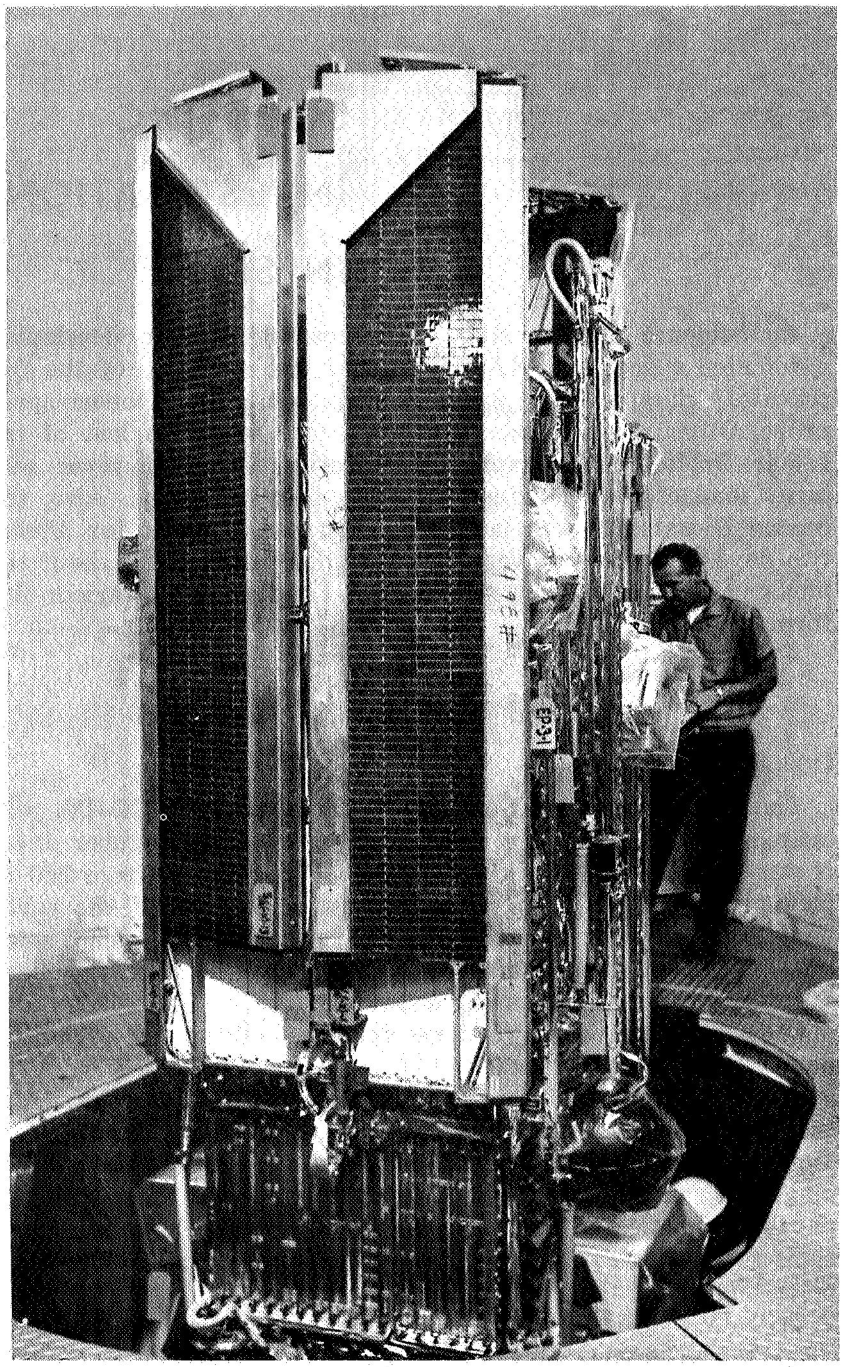


Figure 2–1. NASA's fourth Orbiting Geophysical Observatory (OGO–IV).

periments aboard OGO–I and III (launched in September 1964 and June 1966, respectively) still provide data. OGO–II, launhced in October 1965, operated until November of this year.

The fourth Orbiting Solar Observatory (OSO–IV) was launched on October 18. Like its predecessors, OSO–IV observes the sun from a circular orbit (between 337 and 359 miles) above the atmosphere of the earth. One part of the spacecraft points steadily toward the sun, the other part rotates like a wheel allowing its experiments to sweep across the entire circle of the sky. The pointing section carries instruments for observing ultraviolet radiation and X-rays emitted by the sun. The wheel section is largely instrumented to investigate the same radiations which fail to penetrate the atmosphere and reach the earth's surface. On November 23, OSO–IV met the objectives of its mission; at that time seven of its nine experiments were still operating.

OSO–III, orbited March 8, continued to operate with seven of its nine experiments still functioning. It found that solar radiation in the X-ray region between 7,000 and 210,000 electron volts is extremely variable even in a period of low solar activity.

Pioneer

On December 13 Pioneer VIII was sent into an orbit 92,131,930 to 101,130,940 miles about the sun. The third in the recent Pioneer series, it measures magnetic fields, electric fields, cosmic rays, the solar wind, and electron density in space. The 145-pound spacecraft can also measure fields and particles when it is many millions of miles from the earth. (Fig. 2–2).

Pioneers VI and VII, launched in 1965 and 1966, were still functioning and providing nearly simultaneous measurements from widely separated regions.

Explorer Satellites

To investigate magnetic fields, cosmic rays, solar wind plasma, and interplanetary dust and micrometeorites, Explorer XXXV was launched on July 19 (fig. 2–3). The 230-pound satellite was inserted into a loose lunar orbit, between 500 and 5000 miles above the moon's surface. It supplied the best data yet obtained on earth's magnetic field and the interactions of the solar wind with the moon. It also measured different lunar positions relative to the earth-sun line as the moon made its monthly revolution about the earth. During each revolution, the moon carried Explorer XXXV through the magnetic tail of the earth once at

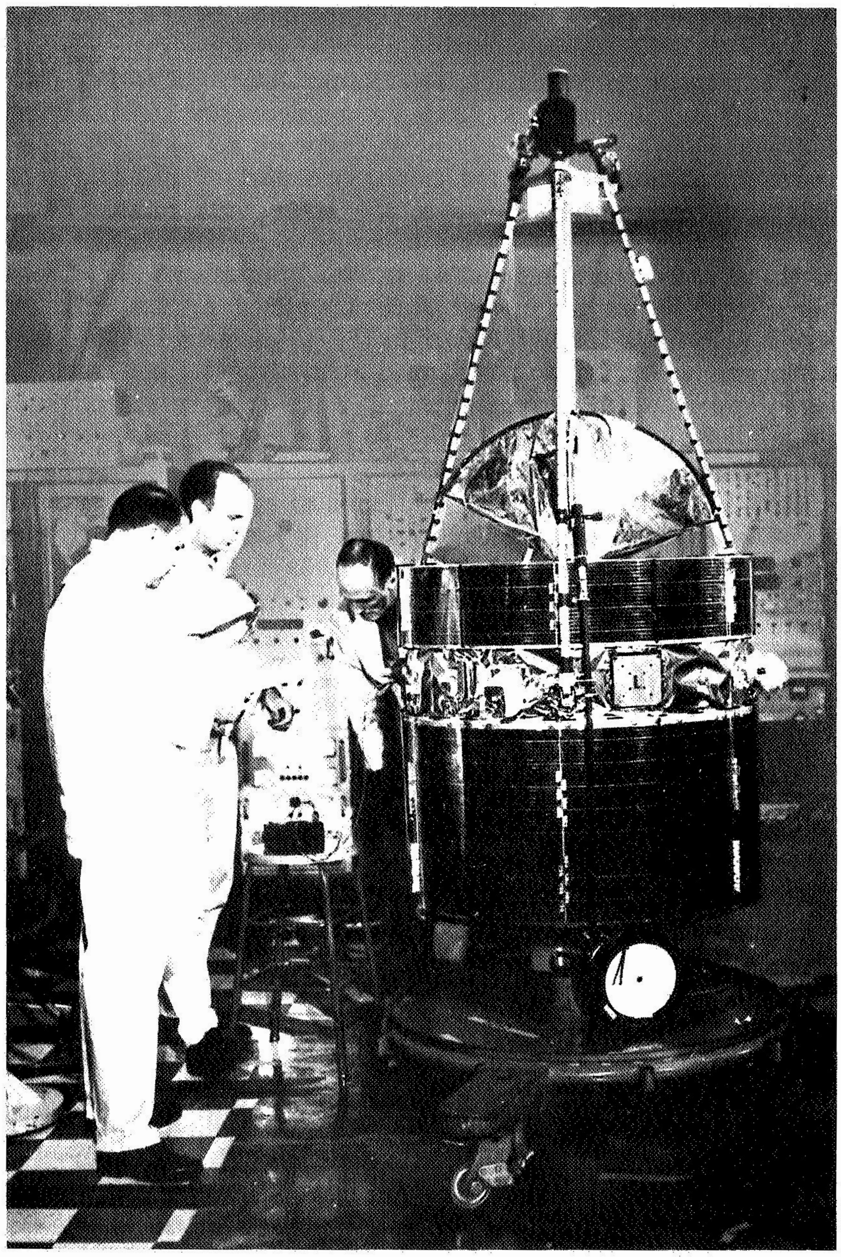


Figure 2–2. The Pioneer VIII spacecraft.

the distance of the lunar orbit. Other spacecraft were able to measure this tail in only one period during their operating lifetimes.

Sounding Rockets

Fifty-two sounding rockets were launched in the earth's upper atmosphere to carry out scientific experiments. Increasingly, the experiments were coordinated with those on board satellites,

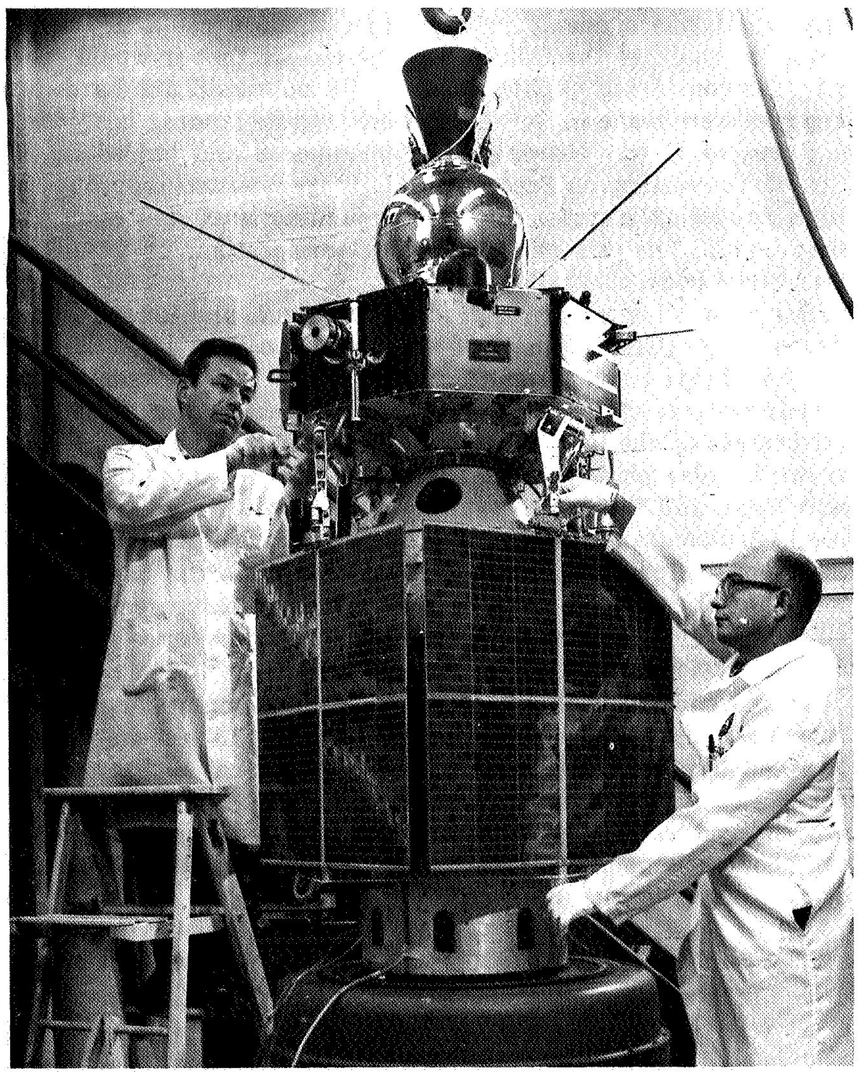


Figure 2–3. Explorer XXXV satellite (Interplanetary Monitoring Platform-E).

such as OGO–IV, OSO–III, Alouette I, and Explorer XXXI, as the latter passed overhead. Also, improved pointing control systems for sounding rocket experiments were flight tested.

LUNAR and PLANETARY PROGRAMS

Surveyor

Surveyor IV was launched on July 14. Its flight was flawless until about 3 minutes before it landed, when contact with the spacecraft was suddenly lost. An investigation could not determine the cause of the failure, but the chance that it would reoccur was considered slight; consequently no significant hardware changes were made in Surveyor V nor was its landing postponed.

Surveyor V was launched on September 8 and landed in the Sea of Tranquility on September 11. It transmitted thousands of high resolution pictures of the surrounding area and made the first on-site analysis of the chemical composition of an extraterrestrial body.

Surveyor VI was launched on November 7, and landed in the Sinus Medii (Central Bay) of the moon two days later. During the first lunar day, two earth weeks, the spacecraft transmitted 30,065 pictures of the area immediately adjacent to it, as well as panoramas of the lunar surface to the horizon. (Fig. 2–4.) Surveyor VI also photographed the stars Sirius, Canopus, Capella, and Vega, and the planets Jupiter and Earth. Its alpha-scattering instrument analyzed the lunar soil for 27 hours to verify the Surveyor V finding that the soil was similar to the basalt commonly found on earth—a hard rock made up of oxygen, carbon, silicon, sodium, magnesium, aluminum, sulfur, and an iron-cobalt-nickel combination.

On November 17, on command from earth, Surveyor VI rose from the lunar surface to an altitude of about 13 feet and moved to a new location. This marked the first time that such a maneuver had been carried out on the moon. During the following lunar day the spacecraft was revived and transmitted engineering data for about 2½ hours. Appendix table Q summarizes the results of the Surveyor investigations.

Lunar Orbiter

The fifth and last of NASA's unmanned Lunar Orbiter spacecraft was orbited about the moon in August. Its photographic system consisted of a moderate and a high resolution film camera, a film processor, and a scanning light beam film readout unit.

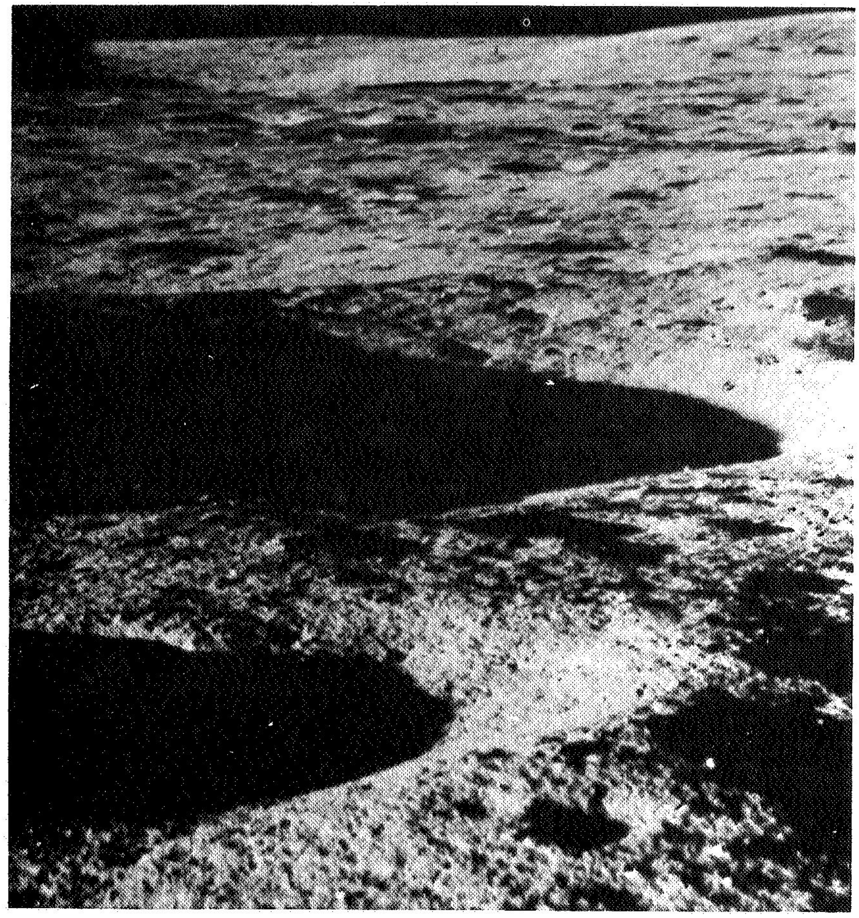


Figure 2–4. Surveyor VI photograph of the moon's Central Bay.

The spacecraft also carried instruments to measure micrometeoroid flux and radiation dose levels.

The primary objective of Lunar Orbiter V was to obtain detailed photographs of selected areas on the front and far sides of the moon of major interest to scientists, and to supplement photographic coverage of potential landing sites for Apollo spacecraft. (Fig. 2–5). Its secondary objectives were to measure meteoroids and radiation in the environment near the moon, supply data on the lunar gravitational field, and provide a moon-orbiting spacecraft with radio frequency equipment to support checkout and training for the manned space flight network, communications network, and orbit computing programs at the Manned Spacecraft Center.

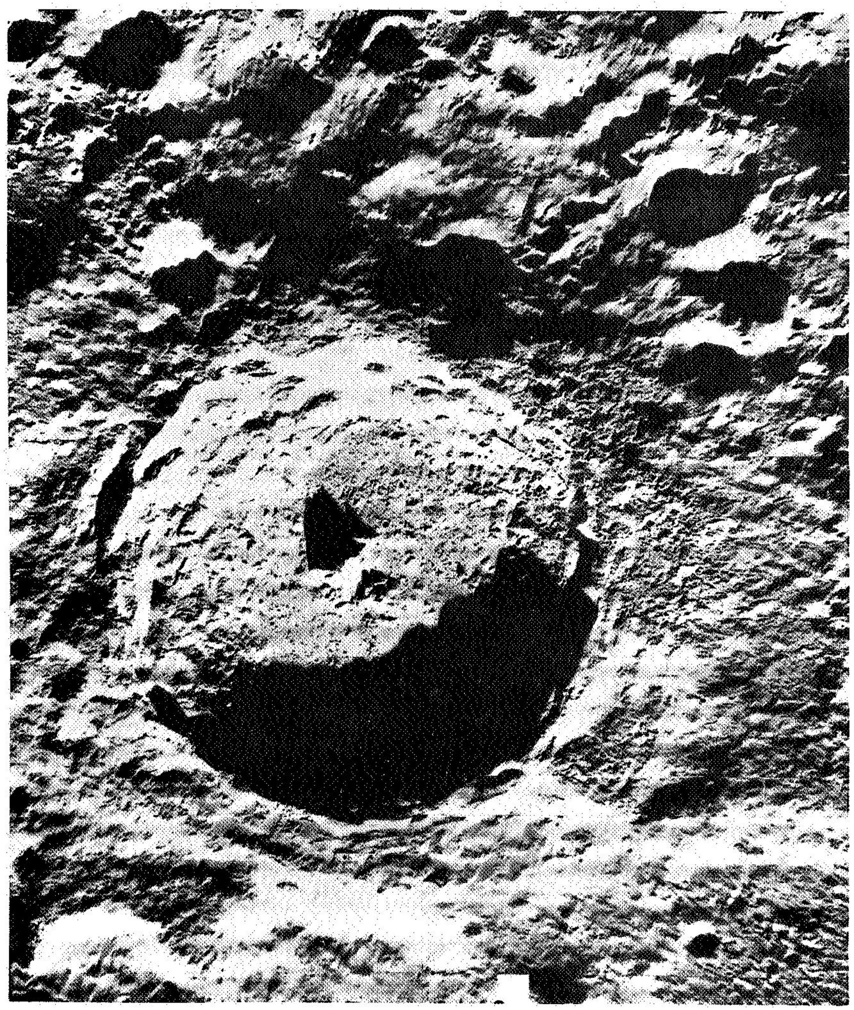


Figure 2–5. Lunar Orbiter V photographs the floor of the crater Tycho.

In its final close-in orbit about the moon, Lunar Orbiter V provided scientific observers with high resolution and wide angle pictures of 36 selected areas on the front side and supplemental photographs of five candidate landing areas.

Lunar Orbiters I, II, and III provided data on specified lunar surface areas and made it possible to select eight candidate sites for early manned lunar landings and sites for the Surveyor soft landings. They were joined by Lunar Orbiters IV and V which supplied complete photographic coverage of the front side of the moon and mapped the entire hidden side. The Orbiter photographs were ten times clearer than views obtained by earth-based telescopes.

The Orbiters also supplied invaluable scientific data for lunar exploration. In addition, each spacecraft supplied information on micrometeoroid flux and radiation levels near the moon and radio tracking data which added to scientists' knowledge of the lunar gravitational field. Further, the Lunar Orbiter series helped train and qualify manned space flight network tracking and data specialists who will be involved in the Apollo flights.

Mariner

Mariner V, launched on June 14, passed within 2,600 miles of the surface of Venus on October 19 (fig. 2–6). The spacecraft approached the planet's dark side, flew behind the planet as seen from the earth, and emerged on the sunlit side. Venus was then about 49 million miles from the earth.

For about 2 hours as it passed around the planet, Mariner V made measurements to determine the properties of the Venusian atmosphere and the interaction between the planet and the interplanetary medium. The spacecraft also measured the interplanetary medium before and after it flew by the planet.

A preliminary analysis of the data supplied by Mariner V showed—

- An interaction of the solar wind with Venus; the wind flowed around the planet without striking its surface.
- An absence of energetic particles and radiation belts around the planet; a magnetic moment less than 1 percent of the earth's.
- An amount of atomic hydrogen in the upper Venusian atmosphere comparable with that in the upper atmosphere of earth; the atomic hydrogen corona much less extended than that of earth; and no atomic oxygen.
- A weak ultraviolet airglow on the planet's night side.
- The probability that the lower atmosphere of Venus contains 75 to 90 percent carbon dioxide.
- The mass of Venus to be 0.815003 ± .000018 the mass of the earth.

Mariner V will continue to orbit the sun and return to within communications range of the earth in August 1968.

Mariner IV.—Orbiting the sun for the second time, Mariner IV came closest to the earth on September 8 of this year when

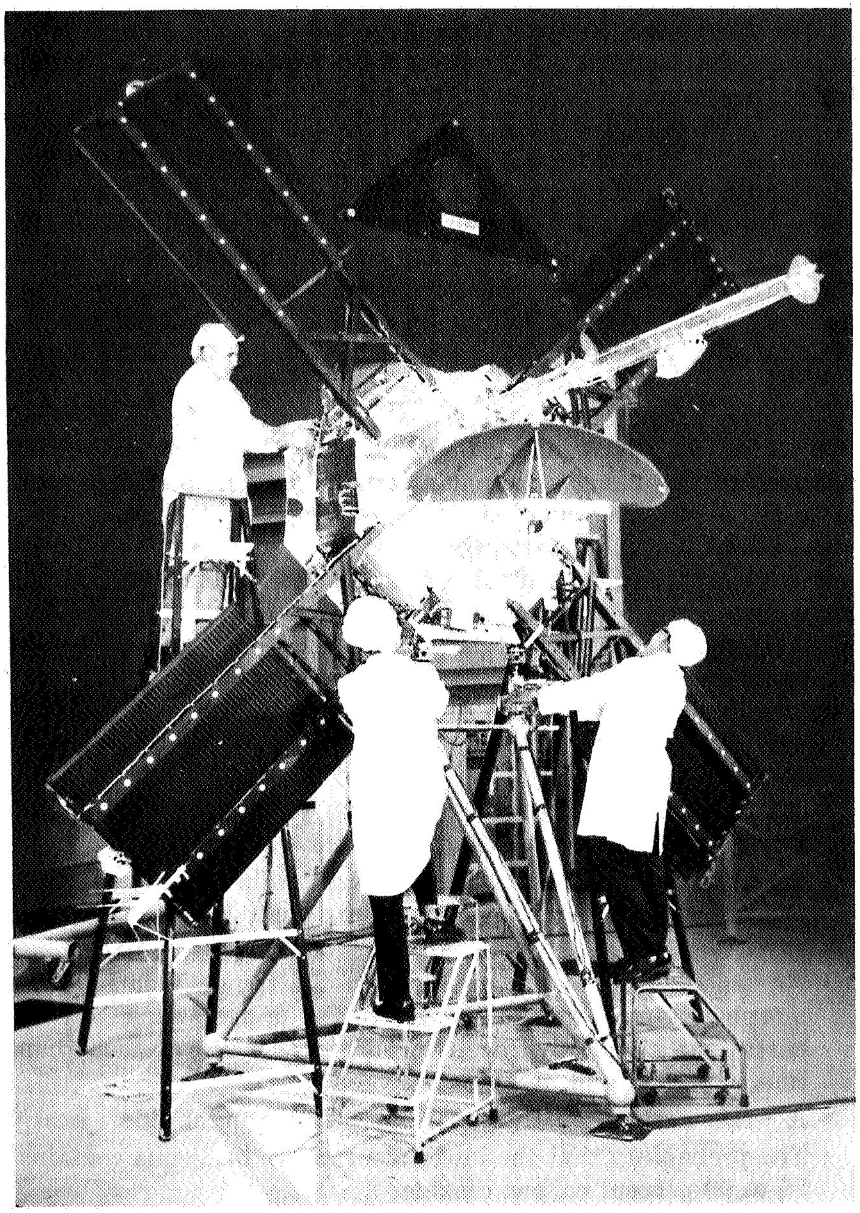


Figure 2-6. Mariner V flew by Venus in October.

it was about 29 million miles away. The spacecraft passed within 6,120 miles of Mars in July 1965.

In August and September 1967 when Mariner IV and V and the earth were aligned along a common radial line extending from the sun, the two spacecraft operated together to study solar energy propagation during a period of increasing solar activity. Also, in October tests were conducted to evaluate the performance of the Mariner IV subsystems after a prolonged period in deep space. The spacecraft responded properly to each command, and its tape recorder played back picture data recorded during the 1965 Mars encounter.

In December, telemetry data indicated that the attitude control gas was exhausted and that the spacecraft had probably encountered a significant number of micrometeorites and was oscillating about all three axes. Tracking was discontinued on December 20. During its lifetime Mariner IV travelled more than 1.5 billion miles and transmitted a substantial amount of data on Mars and its environment and on interplanetary space.

Mariner Mars 1969 Program.—Two Mariner spacecraft of identical design are scheduled to flyby Mars between August 1–10, 1969, to provide data on the planet's physical, chemical, and thermal properties as the basis for future experiments (particularly the detection of extraterrestrial life.) These highly sophisticated spacecraft will carry two TV cameras, an infrared spectrometer, infrared radiometer, and an ultraviolet spectrometer mounted on a movable scan platform.

ADVANCED PROGRAMS and TECHNOLOGY

Advanced Studies

Studies were completed of two possible types of Venus entry probes for flights during 1972. One study indicated that an entry vehicle could be designed to measure the characteristics and composition of the planet's thick atmosphere; another suggested that this entry vehicle might be modified enabling it to survive impact on the surface and continue transmitting atmospheric data to earth for about an hour.

Other studies continued to show that swingby trajectories past Jupiter could greatly conserve launch vehicle energy, since Jupiter's gravity permits a passing spacecraft to be deflected sharply in almost any desired direction. Potential swingby missions of the planet could include probes climbing high out of the ecliptic plane to pass back over the sun, interplanetary probes escaping the solar system, and a unique "Grand Tour Mission" flying in turn past Jupiter, Saturn, Uranus, and Neptune. This latter mission opportunity will occur in 1977 and 1978, but not again for approximately 180 years.

Studies of possible Jupiter atmospheric probes indicated that their entry velocity will be very high due to the strong attraction of the planet's gravity forces. However, about 10 percent of the entry probe's initial weight could survive as useful payload.

Advanced Technical Development and Sterilization Program

A special chamber was being designed for testing sterile assembly and for repairing a typical small entry system. This technique may increase the reliability of planetary capsules by eliminating the need for repeated heat sterilization cycles. In addition, several other design concepts for sterile insertion and repair were evaluated. One of these methods would use heat sealing of plastic films to permit asceptic penetration of a container with a sterilized interior.

Significant progress was made in developing other subsystems and instruments to withstand the heat sterilization cycle required for planetary capsules. Over 400 polymeric products (such as rubber, plastics, and adhesives) were screened for possible spacecraft applications, and more sensitive screening techniques were developed to evaluate parts faster and at lower cost.

BIOSCIENCE PROGRAMS

Biosatellites

Biosatellite II, launched on September 7, was placed into an orbit ranging between 187 and 202 miles. Carrying 13 experiments to study the biological effects of weightlessness and of weightlessness combined with an onboard gamma radiation source, the satellite was recovered in mid-air by an Air Force plane over the Pacific 45 hours later (fig. 2–7). Less than five hours from then scientists at the laboratories of Hickam (Hawaii) Air Force Base received the first of the experiments. They found all of them to be in good condition.

About 50 days after the flight the investigators presented some preliminary results. The biologists observed the greatest effects of weightlessness in young and actively growing cells and tissues. They also found that rapidly dividing cells with high metabolic activity were more affected than mature cells which divide more slowly. Irradiation during weightlessness modified these effects in some organisms.

The experimenters studied the effects of radiation on cell division and differentiation, cell development and growth, chromosome damage and mechanics, genetic mutations, and the

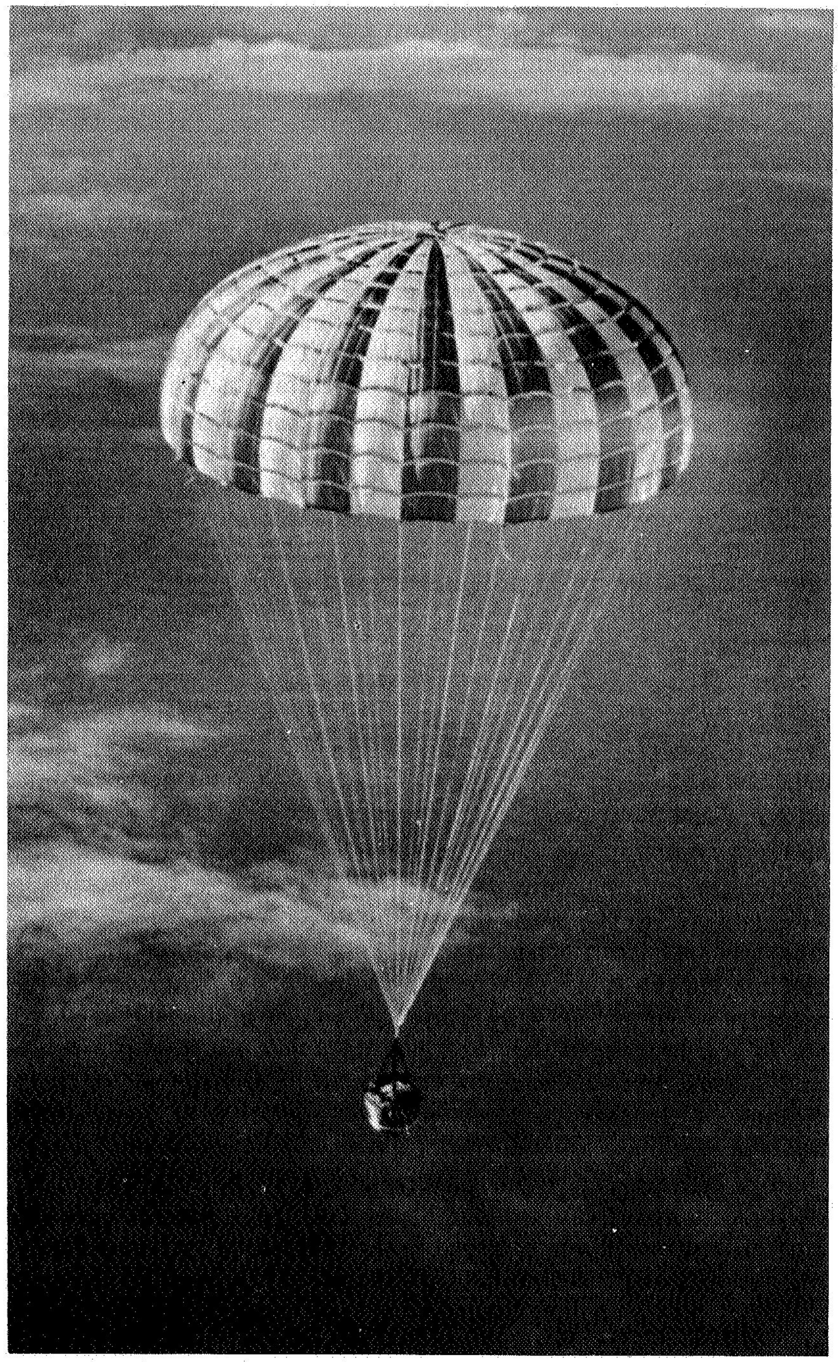


Figure 2–7. Biosatellite II just before its mid-air recovery.

biochemical regulation of cell nutrition and metabolism. Radiation effects in the weightless environment of the orbiting Biosatellite II were seen to depend on the nature of the organism. In some cases the effects combined with weightlessness were greater than those in earth-based controls, and in some cases the effects were less.

Radiation and weightlessness in the flour beetle experiment worked together to produce a greater effect than each did acting alone. They also combined to cause defects in male parasitic wasps hatched from flight-laid eggs and chromosome abnormalities in vinegar gnat larvae. Several months will be needed to evaluate completely all of the Biosatellite II experiments.

Spacecraft for the 30-day Biosatellite D and F missions and for the 21-day Biosatellite C and E missions were being fabricated and their individual components and subsystems undergoing qualification tests. The hydrogen-oxygen fuel cell—the main source of electrical power for the spacecraft—operated successfully for 1,000 hours in a qualification test in December.

Exobiology

Bioscientists have synthesized biologically significant organic compounds in the laboratory to help them understand the sequence of events leading to the origin of life on the primitive earth and presumably on any other primitive planet with a similar history. Next they must look for evidence of a similar sequence of events on the moon and the other planets.

To aid in this search a variety of ultrasensitive chemical techniques under development in the laboratory were being used to analyze terrestrial rocks and sediments—many dating back to within a billion years of the earth's formation. Such techniques have uncovered evidence of organic molecules and biological fossils to suggest that life has existed on the earth for more than 3.5 billion years. Developed under NASA sponsorship, some of these methods have wide applications in university and industrial laboratories. They also will be essential in analyzing lunar samples brought back by astronauts within the next few years, and in the more distant future for analysis of planetary surfaces by unmanned probes and for analysis of returned planetary samples.

These instruments and techniques were being developed for automated chemical and biological analyses of the surfaces of the moon and the planets in the search for life or life-related molecules. Instruments like the mass spectrometer and gas chromagraph, under development for these exploratory missions, will be able to detect and identify organic compounds in very small amounts. Coupled with more biologically-oriented experiments, such as the detection of metabolic activity, they will provide conclusive evidence of extraterrestrial life. Teams of scientists in various disciplines from universities, Government laboratories, and industry will determine what measurements are expected to be provided by planetary exploration and design the instruments to supply these data.

Investigators were also studying the response and behavior of microorganisms to environmental extremes which could compare with planetary environments such as that of Mars. These microorganisms—living in such harsh environments as deserts, arctic tundra, and mountain peaks—may help scientists understand how living matter can survive and reproduce in extreme temperatures, high salt concentrations, and in a limited amount of water. Such information will be extremely valuable in designing instruments and planning techniques to detect extraterrestrial life.

Planetary Quarantine

Recent developments may help solve the complex problems of spacecraft sterilization and assure substantial savings at the same time. Lunar and planetary quarantine must control the transfer of living matter from the earth to the moon and the planets in order not to compromise experiments designed to detect extraterrestrial life or related molecules—a primary objective of space exploration. In addition, the eventual contamination of the planets by life forms from the earth must be delayed as long as possible to avoid complicating the quarantine of returning astronauts.

Scientists analyzing the probable growth of terrestrial organisms on Mars considered the possibility of reducing the estimated probability of growth to one chance in 1,000. Also, data transmitted during the Mariner V flyby of Venus in 1967 enabled investigators to reduce the estimate of probability of growth on that planet's surface to a very low value. The probability of growth in the outer dense atmosphere remains to be assessed.

Incomplete research data on the probability of release of organisms from the interior of solids suggests that the number expected to be released from planetary probes may be drastically reduced. If true, spacecraft would no longer have to be heated to kill these buried organisms; instead, outside or mated spacecraft surfaces might be sterilized by using a low dry heat exposure or by the use of liquid and gaseous sterilants.

Environmental Biology

Acceleration Studies.—Studies at the University of California (Davis) indicated that the way animals respond to altered gravity in the environment resembles their response to other environmental changes. In general, if the change is great enough, it proves to be toxic or weakens the animal in some way. However, in time the condition disappears as the animal adapts physiologically and approaches normal.

The chronic acceleration experiments at the University of California showed that certain acceleration changes can lead to changes in muscle size much as exercise does. A definite ratio between the sizes of extensor and flexor muscles under normal gravity conditions was established by the experiments. The increased weight of normal gravity caused the extensor (the antigravity muscle) to work harder and increase in size. If weightlessness reduces the size of this muscle, scientists may be able to predict the effects of weightlessness mathematically.

Simulated Weightlessness.—Clinostats (mechanical systems) are used to simulate weightlessness or greatly reduced gravity in experiments with living organisms, expecially plants. A special clinostat was developed by scientists at Argonne National Laboratory to investigate this type of relationship between gravity and response. Laboratory experimenters found that most organisms detect the direction and strength of the gravity field to which they are exposed, responding in certain ways such as sending stems up and roots down. Since investigators do not understand how the organisms can respond as they do, they use the clinostat to nullify or compensate for the effects of gravity so that they can study the reactions.

Simulated Spacecraft Environments.—Significant biochemical changes took place in animals exposed to a continuous environment of 100 percent oxygen at 5 psia pressure for a month in experiments at Oklahoma City University. The animals reacted by using an alternate method to metabolize sugar, decreasing the supply for such vital biochemical constituents as amino acids and proteins. This altered method of sugar usage also cut down on the biosynthesis of important fatty acids. In addition, the adrenal glands of the animals increased hormone production to indicate an increased response to stress.

Behavioral Biology

Biologists sought to add significantly to their knowledge of the effects of the space environment on behavior with the launching in December of the first of four Aerobee rockets to study the reactions of animals to artificial gravity. (The amount of artificial gravity, if any, to be "built into" manned spacecraft is a major problem of designers.)

Scientists at the University of Kentucky planned this experiment with white rats to find out if it would be feasible to carry out longer-term investigations of animals free to choose their gravity levels during weightlessness in space. The Aerobee rocket (fig. 2–8) created artificial gravity of below 1 g for five minutes by extending and spinning the two arms of its payload while in flight. The two white rats on board selected their gravity levels by walking along tunnel runways in the two extended arms. When a rat was at the end of the runway nearest the axis or center of rotation, it was exposed to low gravity. At the end of the runway farthest away from the center of rotation, the rat was exposed to higher gravity. In ground-based tests at the University, white rats preferred earth's gravity when exposed to gravity fields of 1 g and above.

Brain-Behavior Relationships.—Noteworthy advances were made in developing the apparatus and techniques to study brain-behavior relationships. At Emory University (Atlanta, Ga.) a brain stimulator-monitor system transmits radio signals to stimulate an animal's brain and then verifies receipt of the signals. The system also telemeters heart, respiratory, and brain activity records and is able to transmit to and from the animal without restraining or restricting its activity.

The apparatus is used to explore the possibilities of manipulating various forms of behavior important for survival. For example, aggressive behavior in monkeys is among the emotional states induced by electrical stimulation of specific brain areas. A man seated at a control console can electrically stimulate a monkey through electronic equipment mounted on its head to cause it to attack a non-stimulated monkey.

Stages of Sleep.—In addition, studies of various stages of sleep, particularly investigations of neurophysiological and biochemical changes associated with rapid eye movement, promise greater insight into man's behavior in space and on earth. Relationships between the requirements for sleep, the process of fatigue, and the effects of gravity remain almost totally unexplored. Studies on the use of an electroencephalogram (EEG) to assess these relationships and associated behavioral changes point up the sensitivity of the EEG and its potential for revealing vastly more information on the workings of the brain.

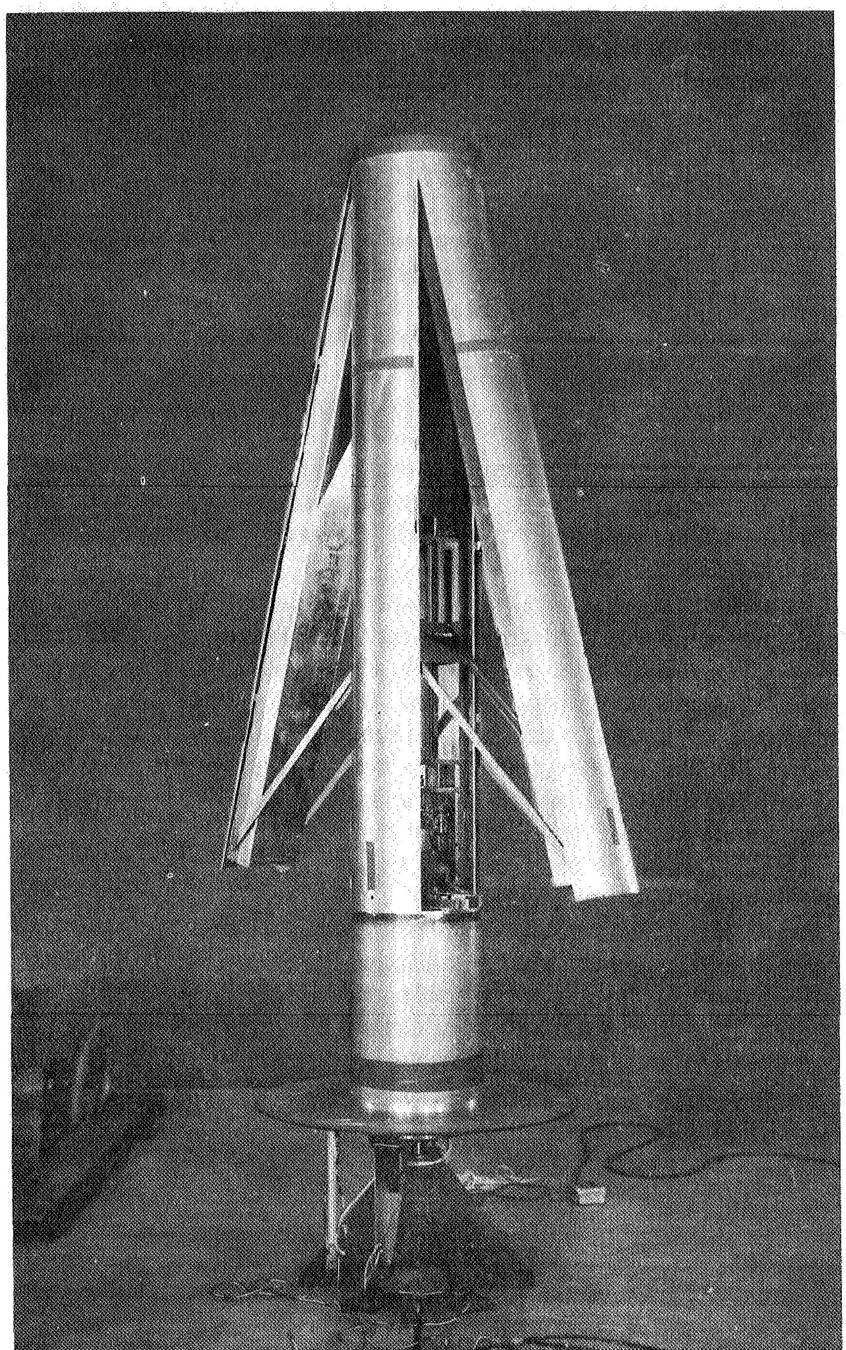


Figure 2–8. Rocket used to study animal behavior in artificial gravity.

Extensive sleep research data collected during the last decade indicated three distinct "states of existence"—wakefulness, sleep, and rapid eye movement (REM) sleep, a state of frenzied internal activities resembling alert wakefulness in many ways. A new research project on REM sleep was begun at Stanford University (Stanford, Calif.), where earlier studies revealed that it was possible to selectively deprive a man or an animal of this stage of sleep. These studies added knowledge of the role of rapid eye movement sleep and its vital importance in maintaining the body's normal functions.

Stanford scientists found that animals deprived of sleep became more aggressive, were hypersexual, and more susceptible to seizures. Other effects included changes in heart rate and blood pressure, indicating the tremendous importance of REM sleep in moderating drive behavior and physiological function.

Additional information on the relation of REM sleep to long-term human behavior of the type experienced during prolonged manned space flights was being supplied through applied research. It was found that human subjects deprived of rapid eye movement sleep undergo changes of mood, experience difficulty in performing assigned tasks, and behave aggressively. Consequently, investigators sought to learn as much as possible about this stage of sleep, not only for its importance to space research, but also for potential application in other areas. For example, certain forms of psychosis may be manifestations of part of the REM sleep process, and this stage of sleep could also be related to anginal attacks at night or to coronaries.

Physical Biology

Biophysics and Molecular Biology.—In research on cell damage by radiation, investigators at Pennsylvania State University found that some components of the membranes of irradiated bacteria cells can "leak out". The radiation damage may change the membrane's lecithin and eventually disorganize the whole cell in the damaged area. Lecithins—found in all living organisms—are used in margarine, chocolate, and in the food industry in general and are also valuable in treating rickets, diabetes, anemia, and tuberculosis. Further research was planned on this type of X-irradiation damage on cells.

In other studies, the relationship of biochemical molecules to the evolution of life on earth was under investigation at the University of California (Berkeley). Experimenters studied one of the essential cell proteins—cytochrome *c* containing 104 amino acids in a single sequence—in animals and some plants. Similarities of cytochromes in these living organisms is one of the best bits of evidence that all living forms on earth descended from a common ancestor which lived at least a billion years ago. Comparisons of cytochromes in human heart muscle and common bread mold point toward the same ancestor, since about 60 percent of the structure of the heart cytochrome is identical with the structure of mold cytochrome in terms of sequences of amino acids.

At Stanford University, optical methods were used to study the properties, structure, and functions of amino acids and proteins. In the investigations, a protein crystal was made fluorescent by a dye. Then, using an ultrafast light-measuring device (a fluorometer operating at a billionth of a second) researchers looked at very rapid reactions on the protein. They discovered that a number of proteins have defined, rigid, three-dimensional structures; the information helps advance understanding of evolutionary processes.

APOLLO LUNAR SURFACE SCIENCE PROGRAM

Among the many scientific activities of the Apollo Lunar Surface Science Program are the selection of landing sites on the moon, the Apollo Lunar Surface Experiments Package, and field geology investigations.

Based primarily on data from the Lunar Orbiter and Surveyor spacecraft, 5 three-by-five-mile landing areas were selected. Two sites are in the Sea of Tranquillity (Mare Tranquillitatis), a third in the Central Bay (Sinus Medii), and the fourth and fifth in the Ocean of Storms (Mare Procellarum).

The Apollo Lunar Surface Experiments Package, ALSEP, is a geophysical station to be placed on the moon by astronauts where it will transmit lunar data back to earth (*17th Semiannual Report*, p. 55). Of its 10 experiments, to be flown in various combinations or Arrays (A, B, and C), prototype model testing of Array A was completed in December. Integration of the experiments for the qualification model for this array was proceeding on schedule. Two of the SNAP–27 radioisotope thermoelectric generators which provide ALSEP power were qualified and in storage. Prototype field geological equipment was evaluated.

LIGHT and MEDIUM LAUNCH VEHICLES

For its unmanned space missions NASA used Scout, Delta, Agena, and Atlas-Centaur launch vehicles.

Scout

Scout vehicles successfully carried out three missions—an experiment to measure radio attenuation during reentry on October 19, and two missions for the Defense Department on September 25 and December 4.

Delta

Deltas were used in six launches, maintaining an average of a mission a month for the last 18 months and achieving an overall record of 51 successes in 55 attempts. This launch vehicle orbited Explorer XXXV around the moon in July, and successfully launched Biosatellite II and Intelsat II-D in September. These were followed by the OSO-IV scientific satellite in October, the ESSA-VI weather satellite in November, and the Pioneer VIII spacecraft in December.

Agena

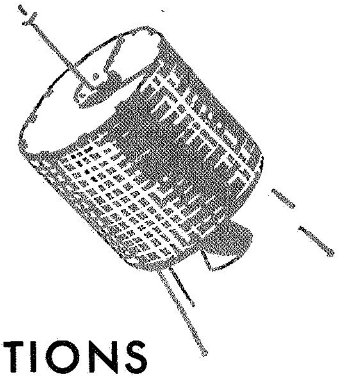
Agena succeeded in three launch attempts. On July 28 a Thor-Agena placed the Polar Orbiting Geophysical Observatory into earth orbit. The final launch in the Lunar Orbiter program was carried out by an Atlas-Agena on August 1, and an Applications Technology Satellite was placed into a synchronous trajectory by another Atlas-Agena on November 5.

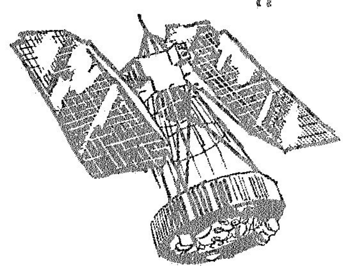
Launch Vehicle Status.—Atlas-Agena will be phased out early in 1968 after it launches an Orbiting Geographical Observatory. Thor-Agena will continue to support NASA's unmanned space missions. It will launch Nimbus meteorological satellites and Polar Orbiting Geophysical Observatories, and be used in Space Electric Rocket tests.

Atlas-Centaur

Atlas-Centaur vehicles launched three Surveyor soft lunar-lander spacecraft (p. 48), Surveyors IV, V, and VI. The first uprated Atlas booster (SLV–3C) was successfully flown on the Surveyor V launch, and all future Atlas-Centaur flights will fly this booster. Three Atlas-Centaur flights were scheduled for 1968—the last in the Surveyor series, an Orbiting Astronomical Observatory, and an Applications Technology Satellite.

3 SPACE APPLICATIONS





An ESSA spacecraft was orbited to maintain the Nation's operational meteorological satellite system, and another Intelsat spacecraft joined the national commercial communications satellite network. The first tests of satellites for aircraft and ship navigation-traffic control were successful. Also, experiments with a new satellite (ATS-III) resulted in excellent full color pictures of the earth and demonstrated the feasibility of improved two-way voice communications with aircraft, multiple-access communications techniques, and transpacific and global color telecasts. Still other spacecraft provided data on the earth's gravitational field, size, and shape.

METEOROLOGICAL SATELLITES

ESSA and TIROS

On November 10, NASA orbited ESSA VI at the request of the Environmental Science Services Administration (ESSA). Launched to maintain continuous worldwide Automatic Picture Transmission (APT) coverage, the spacecraft performed remarkably well, joining ESSA II, III, and V in the operational satellite system to satisfy requirements for meteorological satellite data.

TIROS-M—representing the next generation of operational weather satellites—was being developed by NASA in cooperation with ESSA. System design and detail designs of the subsystems for this spacecraft were completed. The mechanical test model and the thermal test model were delivered by the contractor and were undergoing tests. Fabrication of components for the TIROS-M and the first two operational flight spacecraft was begun.

Nimbus

After successfully completing 19½ months in orbit on December 31, all of the basic spacecraft subsystems of Nimbus II including power supply, controls, command, real-time telemetry and thermal systems still operated satisfactorily. (*17th Semiannual Report*, p. 59.) The spacecraft has far exceeded its design lifetime of six months, and the Automatic Picture Transmission system on board continued to transmit good quality pictures to ground stations around the world. One of these, taken over Mexico on September 20, shows Hurricane Beulah and tropical storm Monica (fig. 3–1). Because of tape recorder failure, the satellite's Advanced Vidicon Camera System, AVCS, was operating over North American ground stations in real time only.

Nimbus B, the third Nimbus, was scheduled to be launched during the second quarter of 1968. (Fig. 3–2.) The flight spacecraft was assembled and all of its experiments delivered and installed in the spacecraft's sensory ring. Nimbus B will carry the SNAP–19 radioisotope thermoelectric generator experiment to determine the desirability and feasibility of using nuclear power for meteorological and other satellite applications. The Nimbus B launch vehicle will also carry a Sequential Collation of Range (SECOR) geodetic satellite for the Department of Defense. A full-scale model Nimbus B spacecraft was mated with its launch vehicle and launch handling operations were conducted during rehearsals in December.

Nimbus D continued on schedule for a 1970 launch. All contracts for its major subsystems and experiments were awarded. Some engineering model components were delivered, and a structural layout model of the sensory ring completed. The integration and test contracts were being negotiated.

Meteorological Sounding Rockets

NASA launched sounding rockets to obtain meteorological measurements and explore the region 20 to 60 miles over the earth (above altitudes reached by sounding balloons and below

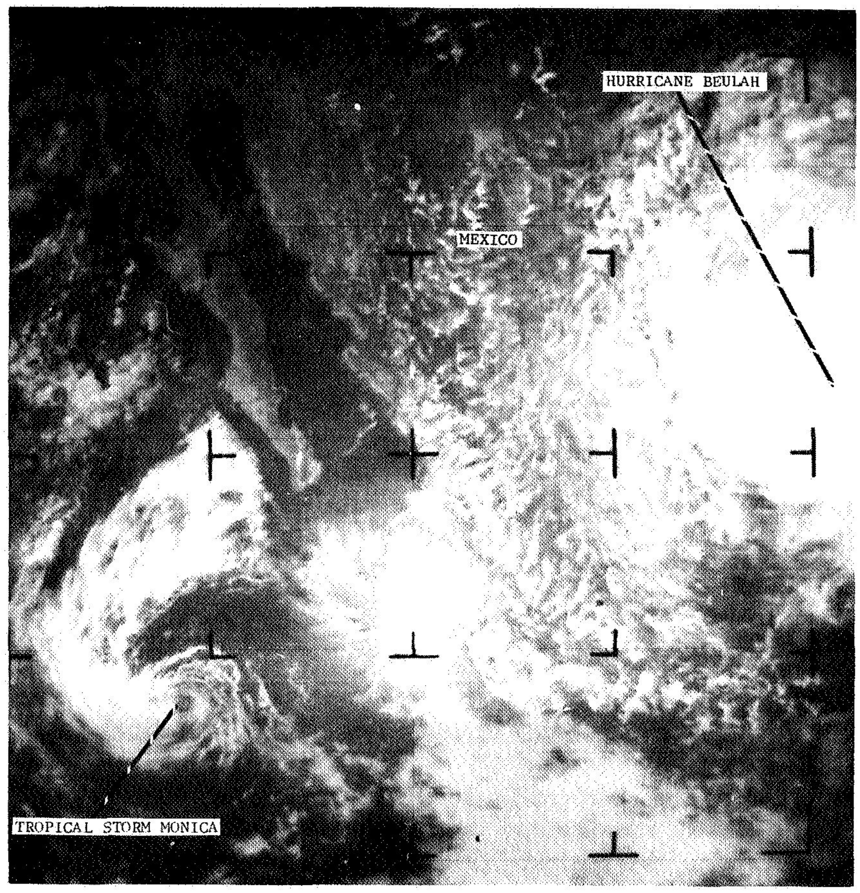


Figure 3–1. Nimbus II photographs a hurricane and tropical storm over Mexico.

those of satellites). These research sounding rockets used acoustic grenades, pitot-static tubes, and light-reflecting or luminous-vapor experiments in exploring the upper atmosphere.

The grenade experiments being launched from Natal, Brazil (*17th Semiannual Report*, p. 62) were continued, as were pitot-tube experiments from Ft. Churchill, Canada. Five vapor-trail experiments were launched from Wallops Station, Va.

NASA and the U.S. Army were developing an inexpensive meteorological sounding rocket system to provide routine atmospheric data at altitudes between 20 and 60 miles for range support, research, and network operations. Also, in an international cooperative program (ch. 7) Argentina, Brazil, India, Pakistan,

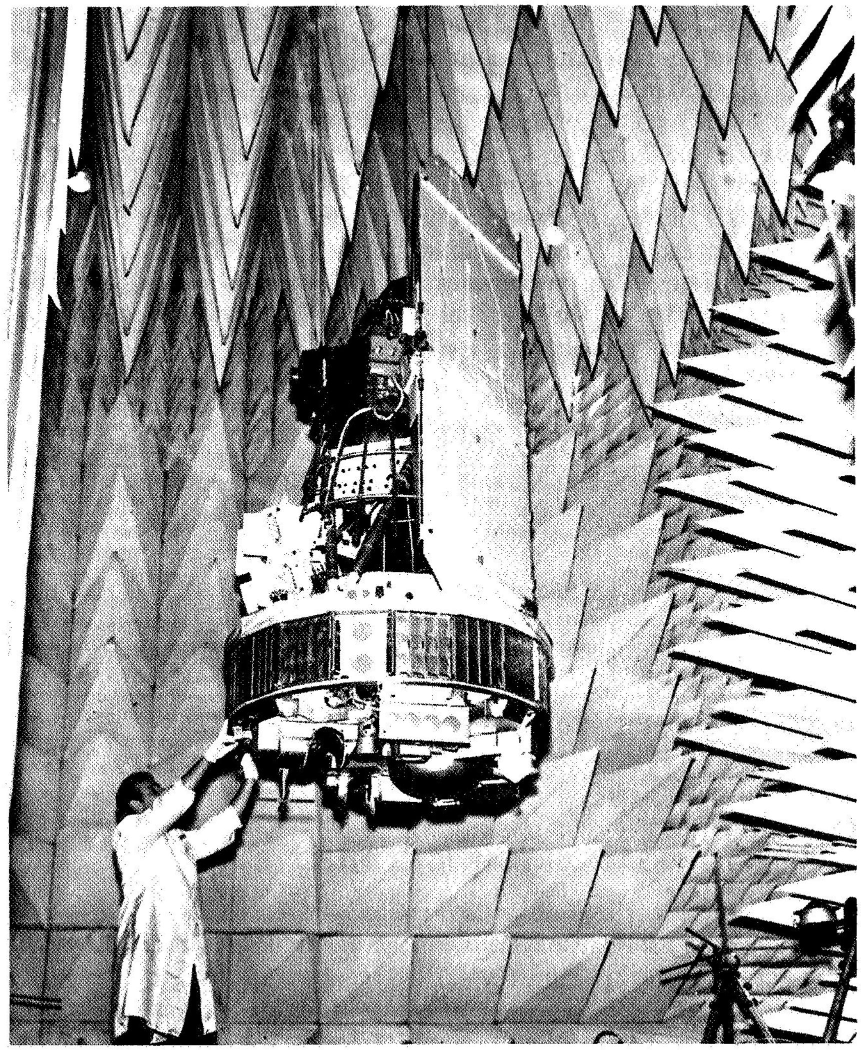


Figure 3–2. Nimbus undergoes radiofrequency interference tests.

Japan, and Spain cooperated with NASA in sharing the costs of sounding rocket research to obtain useful meteorological data.

COMMUNICATIONS SATELLITES

Intelsat

NASA launched Intelsat II–D for the Communications Satellite Corporation (ComSat) on September 27 raising to four the number of operational commercial communications satellites in orbit—two serving the Atlantic Basin and two for transpacific communications. (Table 3–1.) Three of these satellites will also support the Apollo lunar landing program.

Late in 1967 the Agency and ComSat began discussions of launch support for the Intelsat III and IV satellite series. The first Intelsat III launching was planned for the third quarter of 1968; the first Intelsat IV for the third quarter of 1970.

In addition to its launch support to ComSat, NASA provided technical advice to the Federal Communications Commission on communications satellites.

Table 3–1. NASA launches for the Communications Satellite Corporation [1]

Satellite launched	Launch date	Weight in orbit (lbs.)	Effective power (watts)
Early Bird	April 1965	85	10
Intelsat:			
II–A [2]	October 1966	192	20
II–B	January 1967	--do--	Do.
II–C	March 1967	--do--	Do.
II–D	September 1967	--do--	Do.

[1] Other NASA services to ComSat include technical consultation, post-launch orbital data acquisition support as requested, tracking and data acquisition network support as needed, and facilities and support for pre-launch integration and checkout of spacecraft.

[2] Failed to achieve stationary orbit.

NAVIGATION-TRAFFIC CONTROL SATELLITES

Initial aircraft and ship navigation and traffic control tests of NASA's Omega Position Location Experiment (OPLE), flown on Applications Technology Satellite III, showed that OPLE (performing in relation to a fixed site) can provide a position location accuracy of about a mile. Test units for a Federal Aviation Administration airplane and a Coast and Geodetic Survey ship, to be used in future cooperative tests in the OPLE experiment, were delivered to NASA and were being checked out before installation.

Five aerospace companies submitted proposals for a navigation experiment to use range signals between an airplane and Applications Technology Satellites I and III, and the contractor should be selected early in 1968. The FAA and commercial airlines have asked NASA to take part in these tests. Two aerospace companies were selected for parallel advanced mission systems studies of a satellite-aircraft system to provide navigation, traffic control data, and communications.

APPLICATIONS TECHNOLOGY SATELLITES

ATS–I

In October, Applications Technology Satellite I (ATS–I) relayed to the U.S. TV transmissions of the state visit of Japanese Premier Sato to Australia, and in December it provided coverage of the memorial services for Australian Prime Minister Holt as well as of the Davis Cup Tennis Match finals in Australia.

ATS–I still performed successfully in orbit at about 150° West Longitude, continuing the tests conducted during the first six months of 1967. River level and cumulative precipitation data were collected from three remote stations by the spacecraft in a successful hydrology experiment, and the Weather Facsimile Transmission Experiment, WEFAX, was continued (*17th Semiannual Report,* p. 66).

ATS–II

ATS–II—the first three-axis gravity gradient stabilized spacecraft, orbited in April—was turned off since the satellite failed to attain its planned 6,900-mile circular orbit.

ATS–III

Launched November 5, ATS–III arrived on station in its synchronous orbit at 47° West Longitude two days later. All of its experiments operated as scheduled with minor exceptions. The satellite's multicolor camera took over 100 color pictures of the visible disc of the earth's surface from a distance of 22,300 miles, clearly identifying major geographical features of North and South America and other continents. (Fig. 3–3.) The image dissector camera provided monochrome pictures of the same areas.

The linear VHF transponder was used in a successful test of the engineering model of an Omega Position Location Experiment (p. 68). Also successful was the performance of the spacecraft's hydrazine thruster, an important advance in satellite technology because it is more efficient and reliable to operate than the hydrogen peroxide previously used. The ATS–III self-contained navigation system was scheduled to be tested in the spring of 1968.

GEODETIC SATELLITES

PAGEOS

PAGEOS–I, a highly reflective 100-foot diameter sphere of the Echo type, completed over 1½ years in orbit and was being

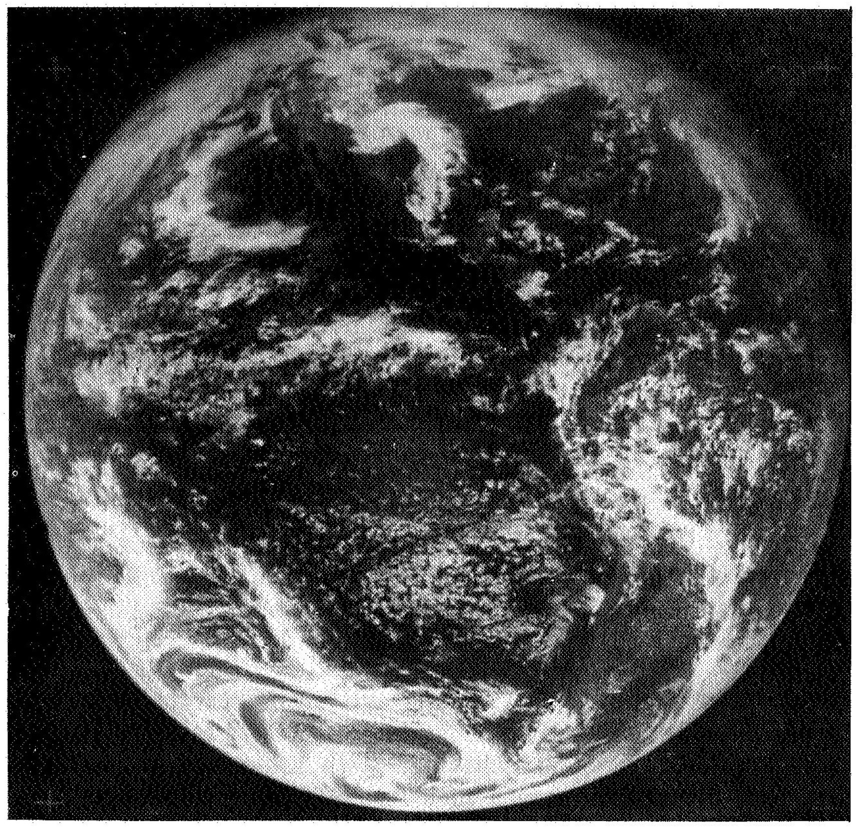


Figure 3-3. The earth as seen by Applications Technology Satellite III.

observed by more than 40 ground stations around the world. The balloon showed no signs of degradation. Earth-based observers used this passive satellite as an orbiting point source of light to help determine the positions of continents, islands, land masses, and other geographic points in setting up a global control reference system. The first data based on these satellite observations were forwarded to the Geodetic Satellites Data Service at Goddard Space Flight Center.

GEOS

Launched November 1965, GEOS-I (Explorer XXIX), became nearly inactive as a geodetic instrument in December 1966, but continued to supply limited data. Its five instrumentation systems helped define the geometry and the gravitational field of the earth, and thousands of the spacecraft's high-quality photographic and electronic observations were being sent to the Geodetic Satellites Data Service.

The next active geodetic satellite, GEOS–B, was scheduled to be launched in January 1968. (Fig. 3–4.) In addition to the instruments duplicating those on board GEOS–I, this GEOS will carry radar to extend the range of its measurements, and a detector to measure a laser beam transmitted from the ground.

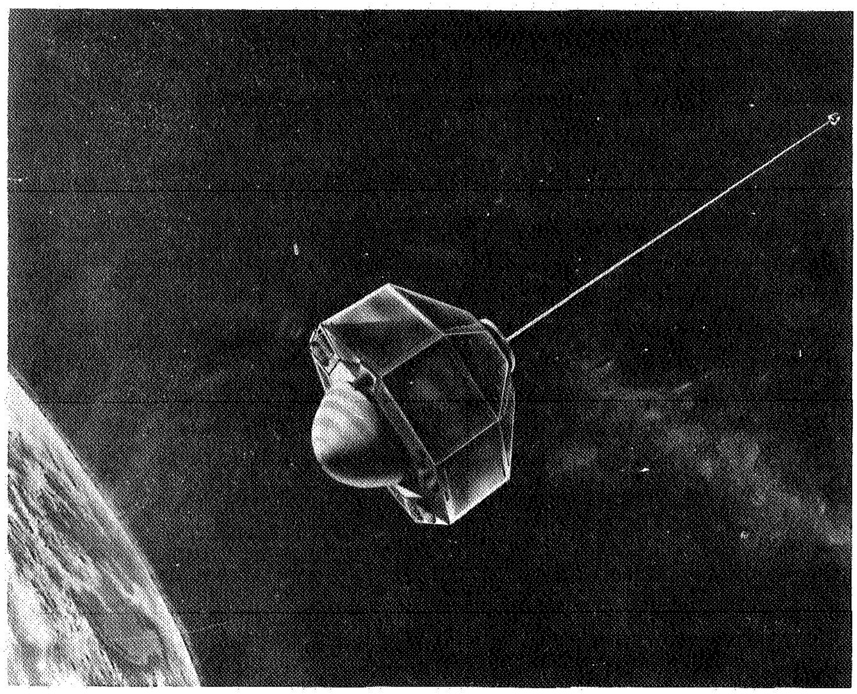


Figure 3–4. Sketch of the GEOS-B geodetic satellite in orbit.

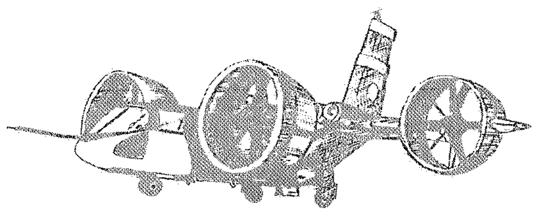
EARTH RESOURCES SATELLITES

Cooperating with the Departments of Interior, Agriculture, Commerce, and Navy, NASA continued to study the possible use of space-acquired data in surveying the world's natural and cultural resources. In these investigations various types of aircraft flew special cameras, infrared imagers, microwave radiometers, radar, and other remote sensors over a network of ground test sites to provide geoscientists with earth resources information. The Government agencies used these data, as well as those supplied by Project Gemini photographs and Nimbus spacecraft, to develop methods for analyzing and interpreting this information in terms of earth resources phenomena.

For example, pictures from Nimbus II showed for the first time the eruption of a volcano. The erupting volcano (the recently formed island of Surtsey, about 25 miles off the south coast of Iceland) was monitored simultaneously from the ground, from aircraft, and from space. This technique may be applied to future studies of volcanoes elsewhere on earth.

NASA was also developing other prototype remote sensor instruments and was defining possible space missions designed to collect and transmit a wide variety of earth resources information.

4 ADVANCED RESEARCH AND TECHNOLOGY



The Office of Advanced Research and Technology plans and directs the research which leads to new aircraft and space vehicles. Its responsibilities include: developing meaningful technologies for future aeronautical and space vehicles; helping solve problems in vehicles being used or under development; and increasing scientific and engineering knowledge for application to space vehicles and their operation. The work of this Office is carried out at all the NASA centers but is generally concentrated at the Research Centers which are staffed by a balanced team of 12,000 civil servants and 24,000 contractor employees in universities and industry. The accomplishments described in the following sections are representative of the tasks entrusted to OART.

SPACE VEHICLES PROGRAM

Space Radiation Effects Laboratory

The NASA Space Radiation Effects Laboratory at Newport News, Va. was in full-time operation three shifts per day, seven days per week during this period. It was used for NASA research requirements in radiobiology, nuclear physics, radiation effects on spacecraft materials and components, radiation shielding and dosimetry, and instrument calibration for manned and unmanned space vehicles. Requests for use of the large cyclotron exceed available time.

Meteoroid Simulation

Advances were made in techniques for the laboratory simulation of meteoroids. A newly designed shaped-charge accelerator accelerated a 2-gram simulated meteoroid to a velocity of about 12 km/sec—a 50 percent increase in the capability of shaped-charges. Also, a relatively new concept, the two stage explosive driver gun, was developed and tested. It accelerated a 0.2 gram simulated meteoroid to about 12 km/sec. Although neither device has been developed to its limit, the two devices are just reaching the velocity range of the lowest velocity meteoroids. Plans were made to continue work on these and other meteoroid simulation techniques.

Thermal/Vacuum Test Technology

Goddard Space Flight Center developed a vacuum pumping system which eliminates the need for mechanical roughing pumps which are a troublesome source of contamination in space simulation facilities. The system, which uses cryogenic condensation of air on cold molecular sieve chamber walls, ran into some difficulties in pumping residual quantities of helium and argon (normally present in air), but the problem was solved by first purging the chamber with pure nitrogen, which is condensable.

In research on thermal scale modeling techniques, which could greatly reduce requirements for very large space simulation facilities, a contractor investigated electroplating as a means of providing materials suitable for transient thermal scale modeling of spacecraft. Varying thicknesses of the electroplated copper were used to control the thermal conductivity and heat capacity of the one-fourth scale models of simplified systems. Temperature changes were accurately predicted.

Lifting-Body Flight Program

The 3 vehicles in the lifting-body research program embody configuration concepts developed by NASA (M–2 and the HL–10) and the Air Force (X–24A). The M–2 vehicle was damaged in a landing accident in May 1967, and it has not yet been decided whether repairs will be undertaken. The HL–10 was modified to correct a control deficiency that showed up in its first flight, and flight testing will continue at the Flight Research Center. The Air Force delivered the X–24A to FRC in September, and checkout of the vehicle and the installation of research instrumentation was begun.

Advanced Gliding Parachutes

NASA's continuing wind-tunnel and flight research on flexible parachute-like gliding wings concentrated on the near-triangular parawing and the higher aspect ratio sailwing. (*17th Semiannual Report*, p. 76). The Langley Research Center conducted extensive wind-tunnel tests and parawing research flights with wings up to 24-foot keep length; with the flights in this period, the number of such tests reached a total of over 500. A contract research program now underway will include flight tests of parawings having payloads of 5,000 and 15,000 pounds. The number of manned sailwing flights accomplished by industry increased to 200, and the Manned Spacecraft Center continued flight tests of a 90-foot-span sailwing sized for a 5,000-pound payload.

Planetary Entry Parachute Program

The Langley Research Center completed the first phase of this program to investigate candidate parachutes for soft landing an instrumented capsule on Mars. Parachutes ranging from 30 feet to 84 feet in diameter were flight tested in an overall total of four balloon and nine rocket-launched flights; parachute deployment speeds of Mach 2.6 were achieved for the smaller parachutes. Test results indicated that parachutes can be used to control and decelerate an entry capsule, and in conjunction with terminal rockets can provide a reliable and relatively simple means of landing on Mars.

Large Space Structures

The design and construction of the very large structures which will be required for many future space missions are essentially beyond present experience and call for new technology. Advanced research to develop such technology is being concentrated on establishing the feasibility of large space structures. One example of such work is a study of the elements of a large orbital radio telescope which could receive natural radio signals in the 1—10 MH_z bandwidth and could be used to study phenomena throughout the universe which emit radio signals not receivable on earth. The antenna element of such a telescope would have to be almost one mile in diameter and parabolic in form. The concept proposed for the antenna calls for thin metallic ribbons arranged in a large open grid and spaced at 2 foot intervals. The antenna is to rotate slowly (1 revolution in 16 minutes) about its axis to maintain structural rigidity. The grid design and supporting wires from the central mast provide the parabolic form of the structure.

Computer studies of the structural behavior under various conditions were completed. A scale model of the central mast was built and tested, and it was found that meaningful test data can be derived from scale models of portions of such large structures. Applications of the mast concept to other structural uses were identified, and it was being evaluated as a radio tower for possible military applications.

Advanced Pressure Vessels

A new type of construction for pressure vessels, developed for the Lewis Research Center, consists of a metal tank overwrapped with glass filaments. An optimum level of precompression is induced in the metal by appropriate tension in the glass fibers. Experimental tanks demonstrated increased reliability and substantial weight savings in high pressure applications over temperatures ranging from room temperature down to that of liquid hydrogen ($-423°$ F).

Space Vehicle Design Criteria

The Langley, Lewis, and Electronics Research Centers and the Goddard Space Flight Center, the four lead Centers, continued work on the formulation of uniform design criteria for development of reliable and efficient space vehicles. Design criteria monographs on propellant slosh structural loads, mechanical shock structural loads, solid rocket motor insulation, solid rocket motor igniters, and magnetic disturbance torques applicable to the design of attitude controls were drafted and reviews were begun. Also, draft monographs on the meteoroid environment for earth orbit and cislunar space, and on the Martian atmosphere were being reviewed.

SPACECRAFT ELECTRONICS and CONTROL

Communications and Tracking

During the high speed entry of a spacecraft into a planetary atmosphere, the high temperature created causes an ionized sheath which envelops the spacecraft and prevents communications. RAM C–1 launched on October 19, proved that at reentry velocities around 26,000 fps, the injection of water into the sheath alleviates the communications blackout at the VHF, C-band, and X-band frequencies. Another flight, scheduled for 1968, will provide more data on conditions causing the blackout so that additional ways of alleviating the problem can be developed. More effective materials, higher frequencies for communication, and possible combinations of the two will be investigated in the laboratory and verified by flight tests if they appear promising.

Under a MSFC study contract, a number of plans were examined for developing the optical technology needed for space missions requiring optical communications and large diffraction limited telescopes. The study emphasized cost economies, proposed conceptual flight hardware, and defined two broad areas of optical work which require space testing. One area would prove the concept and provide developmental hardware for a high bit-rate optical communication system using lasers and diffraction limited telescopes. The other would provide a space experiment to develop and prove the techniques for building a large manned orbital telescope in 1980–85. The techniques include mirror finishing and figure measurement methods, thermal control, super-accurate pointing methods, and active optical systems for maintaining mirror accuracy to a millionth of an inch in space.

Ground research will be conducted in each of the technology areas to insure that the flight experiments are confined to those which must be tested in space, and the specifically proposed flight experiments will be further defined to prepare for the preliminary design phase.

Control and Stabilization

Goddard Space Flight Center engineers conceived and designed a new family of rotating electrical machines, including a brushless D.C. motor developed several years ago and now in use in the Apollo spacecraft, and a recently developed variable field motor. Such machines are needed to increase reliability, lifetime, and electronic controllability, to reduce friction, and to eliminate brush sparking; plans were made to integrate both into designs of complete equipment such as control moment gyros, reaction wheels, and antenna drives. The variable field motor, with laboratory performance proven, was awaiting application to attitude control systems with a design goal of three years space life.

A new testing facility for evaluation of advanced attitude control designs for astronomical and other scientific spacecraft became operational at the Ames Research Center. The facility, which contains a high precision air bearing table with one arc second accuracy, removes restrictions on testing time because of advanced gimbal and air bearing design. It also makes possible direct tests of new theoretically derived concepts, offering improvements in stability and efficiency over present designs. For example, an improvement for the AOAO, which will allow rapid and stable slewing from one star to another, was being evaluated.

Guidance and Navigation

Hand-held navigation instruments (sextants) which must be sighted through a spacecraft window introduce a source of error which can render navigational sightings useless. Ames Research Center developed analytical and experimental techniques to determine the window induced sighting errors. Errors for a particular window are determined analytically by a computer-mechanized ray-trace program and experimentally by using special optical apparatus. Agreement between the computer-mechanized ray-trace and the experimentally derived results was excellent, and the analytical program is believed to be sufficiently general so that it can be used to investigate window-induced measurement errors for any spacecraft window. The techniques should reduce costs associated with spacecraft window design and error measurements.

Instrumentation

Conventional spring scales or balances cannot be used to obtain "weight" information for physiological experiments in space under zero g conditions. However, ARC designed a device consisting of a rigid, light weight platform supported by wires, which can oscillate in one specific direction. A capacitance detector senses the motion and vibration of the platform. The device can measure masses between 1 and 50 grams with an accuracy of .05 percent and specimens as small as 10 milligrams with accuracy of 10 percent. It is simple to operate and can handle large numbers of specimens rapidly.

Using the same principle, GSFC designed a system to monitor vacuum contamination in a solar simulator. A crystal micro balance measures particles deposited on the surface of a quartz crystal. The deposit changes the mass of the crystal, decreasing its natural resonant frequency; the latter can be measured and calibrated to give the mass. The crystal is part of an oscillatory circuit operated at cryogenic temperatures and can detect mass changes as low as 10^{-9} grams. In this manner, residuals such as carbon dioxide or water can be measured. The new system makes it possible to measure contamination levels quantitatively well below levels previously detectable only qualitatively by the standard (mirror reflectivity) method.

To measure load distributions on a deploying parachute under simulated atmospheric entry conditions, LaRC developed special strain gage load cells for measuring the strain in the fabric when tested in the full scale tunnel. Data obtained in this manner were more realistic than predicted theoretical values and will be used in designing parachutes. In addition, the basic measuring scheme can be applied to non-rigid aerodynamic devices such as parawings and other airborne recovery systems.

Data Processing

Research supported by the Electronics Research Center demonstrated the feasibility of optical data storage techniques highly superior in reliability and capacity to magnetic tape recorders used on Nimbus and Mariner. In this system, interference patterns of light, created by intersecting laser beams, selectively bleach color centers in a photo-sensitive crystal to record data in the form of a holographic image. Recorded data is retrieved by illuminating the stored hologram with a single laser beam. Since the hologram technique diffuses each data bit throughout the crystal the entire message may be retrieved, with reduced resolution, even though a portion of the crystal is damaged. The technique may eliminate moving parts and electrical interconnections, thereby increasing reliability, and it could enable a thousand billion bits of data to be stored in one cubic centimeter of crystal volume.

In other work, the Electronic Research Center developed conceptual spacecraft computer organizations based on searching a memory data field according to data content rather than to storage location as in conventional computers. Such systems offer several advantages: the possibility of reducing by at least 1000 to 1 the number of processing operations required to identify and describe data (such as star position coordinates); the ability to simultaneously monitor and control a number of instruments aboard a spacecraft and select from the total measurements instantaneously those which are the most significant; and maximum efficiency and reduced ground processing of non-essential data through continuous optimum matching of collected data to transmitter channel-capability.

Electronic Techniques and Components

Goddard Space Flight Center developed a self-healing fuse that will "blow" to interrupt overloaded circuits aboard spacecraft, and then, after a preselected period of time, will heal itself and restore power to the circuit. The device employs metal particles in a dielectric material with a greater coefficient of thermal expansion than the metal. Heat produced by excessive current flow produces strains in the material thus separating the metal particles, increasing the resistance, and lowering the current flow. Recovery time is determined by the rate at which the device cools. The new fuse, a no-moving-part replacement for present electromechanical circuit breakers, has the potential of improving reliability for spacecraft applications.

AERONAUTICAL RESEARCH

Aircraft Aerodynamics

Because of the lack of research on the turbulent boundary layer for bodies of revolution, NASA began an experimental study of the turbulent boundary layer characteristics of several pointed bodies of revolution at supersonic Mach numbers. The boundary layers on slender cones, parabolic-arc bodies with conical noses, and parabolic-arc bodies with boattailing were surveyed at zero angle of attack and under conditions of zero heat transfer by means of static and pitot pressure probes. The results indicated that body profile shape had a strong influence on turbulent-boundary-layer thickness and skin friction. In addition, it was found that shape effects on slender bodies can be estimated fairly accurately by combining axisymmetric flow theories with flat-plate theory.

Conventional elevon controls on delta wings lose effectiveness at hypersonic speeds when they come within the hypersonic shadow region, while canard controls, which are not subject to this blanketing effect because of their forward location, create adverse disturbances in the flow field in their wake. An investigation was undertaken to determine the magnitude of this canard-induced interference at Mach 10. Variations in canard size and shape, body length, wing planform, and wing vertical position were studied on generalized hypersonic aircraft configurations. The results indicated that the canard control induced a broad pattern of interference flow in which the average angle over the wing and body surfaces downstream of the canard varied significantly from the free-stream value. In general, the magnitude of the interference increased with increasing canard deflection and angle of attack. For high wing configurations the induced flow angularity generally caused a decrease in lift and drag and an increase in pitching moment. For low wing configurations the corresponding effects varied between positive and negative. The effects of wing position for the delta wing differed considerably from those for the trapezoidal wing.

Aircraft Loads and Structures

An idealized model of a pneumatic tire was developed as part of a study of tire behavior. The model affords a means for calculating tire fore-and-aft stiffness, an important element in the behavior of tires under tractive and braking conditions. This development is an important advance in efforts to devise acceptable methods for predicting tire behavior to replace the current empirical approach.

A wind tunnel study using a model which geometrically and dynamically scaled a large, multijet cargo airplane, was conducted to determine the flutter characteristics of a T-tail configuration at transonic speeds. The tests established the flutter margins for this specific configuration and also furnished information of general interest on the flutter behavior of T-tails in the transonic region.

Airbreathing Propulsion

Preliminary results of experimental research programs in the compressor and combustion area indicated that more compact compressor and combustion components may be feasible. Such components could significantly reduce the overall length and weight of a propulsion system and thereby increase payload and/or range of an aircraft. In the work on compressors, higher pressure rise per stage at high levels of efficiency was achieved with single compressor stages and should make it possible to develop short length compressors. In combustor sector tests, high heat release at combustion efficiencies of about 100 percent with satisfactory pressure losses was attained and should result in short length combustors. Additional research will be required to demonstrate that these improvements can be applied to multistage compressors and full scale combustors.

Noise Abatement

The study and development of aircraft engine turbofan nacelle modifications to minimize fan compressor noise radiation progressed under contract. Wind tunnel and full scale engine ground tests were run to evaluate inlet and fan exhaust duct configurations and the physical characteristics and sound attenuation effectiveness of candidate lining material. Mechanisms to vary inlet geometry were studied to determine an effective choked inlet design to block the forward propagation of noise from the engine throat, and acoustically treated concentric ring inlet designs were tested. Flight tests will be conducted following completion of ground tests of nacelle designs with optimum acoustical characteristics.

General Aviation Aircraft

Preliminary results have been obtained from a six-year data collection program to assess the flight loading and operational practices to which general aviation aircraft are typically subjected. It was found that the margin between actual gust and maneuver limit load factor was less for the general aviation aircraft than for commercial transport aircraft and also that the light airplane was subjected to more severe service, with respect to design specifications, than the commercial transport.

V/STOL Aircraft

NASA continued studies of V/STOL transport configurations with lift fans, cruise fans, or combinations of the two. Low speed aerodynamic characteristics were investigated in the Ames 40- by 80-foot wind tunnel, using a large scale model with six lift fans in the wing and two lift-cruise engines mounted forward of the wing in the fuselage. Fan performance and longitudinal aerodynamic characteristics of the model were studied for various configurations with two, four, and six fans in operation; tests were also made with the fans located at two different chordwise positions in the wing. Longitudinal aerodynamic characteristics for the model were obtained with simulated lift cruise engines operating in conjunction with the six lift fans, and limited lateral-directional characteristics were obtained for the fan-only configuration as well as for the lift cruise engine and fan combination. The complete configuration with six fans operating and with the fans and lift cruise engines operating had generally acceptable aerodynamic characteristics.

As the first step of a program to provide basic detailed information on the dynamic stability characteristics of tilt-wing V/STOL aircraft configurations, static and dynamic longitudinal stability derivatives were determined for a powered 1/9-scale model of a four-propeller tilt-wing V/STOL transport. The model was flown in free-flight tests while qualitative measurements were made of the control-fixed longitudinal motions at several speeds in the transition range. The experimentally determined values of the stability derivatives were used as inputs for an analytical investigation of dynamic stability, and the model flight tests provided data for correlation and validation. An investigation was then undertaken (1) to determine appropriate methods with which to analyze the longitudinal dynamics of tilt-wing vehicles, (2) to calculate the dynamic stability of a typical tilt-wing aircraft over the transition flight range, (3) to correlate the results of the calculations with those of the model free-flight tests, and (4) to determine the effects of the various static and dynamic stability derivatives on control-fixed dynamic stability.

The results indicated that the control-fixed motions of the aircraft without artificial stabilization in hovering flight would be dominated by an unstable oscillation similar to that displayed by most helicopters. As the transition to conventional forward flight progressed, stability characteristics were encountered in which there were aperiodic divergent modes of motion as well as unstable oscillations. The conventional-aircraft short-period and phugoid (long-period longitudinal) oscillations began to appear at the high-speed end of the transition. In general, the analytical results agreed with the motions observed during the free-flight model tests. The results also indicated that the unstable oscillation occurring in the hovering and low-speed flight regions can be overcome by adding a combination of pitch-rate and pitch-attitude stabilization, but that angle-of-attack stability must be increased if the aperiodic divergent modes of motion are to be made stable.

An investigation, employing a variable-stability helicopter, was undertaken to expand available data on the longitudinal axis to include the effects of angle-of-attack stability and speed stability upon the low speed instrument-flight-rules (IFR) task. Various combinations of angle-of-attack stability, speed stability, pitch-rate damping, and longitudinal control sensitivity were evaluated by means of a simulated instrument task selected to bring out problems which would be representative of low speed instrument flight.

Neutral to slightly stable angle-of-attack stability was found to be most satisfactory, regardless of the level of pitch-rate damping. Low unstable values of angle-of-attack stability were tolerable with sufficient pitch-rate damping. Combinations of angle-of-attack stability and pitch-rate damping which provided minimum satisfactory handling qualities were in general agreement with current specifications for low values of angle-of-attack stability. Variations in the longitudinal control sensitivity had little effect on pilot rating over a wide range of values centered about the optimum tested.

In wind-tunnel investigations of ground effects, the ground is normally simulated by placing a board in the airstream immediately below the model. However, a boundary layer develops between the airstream and the ground board and creates problems in testing STOL and VTOL aircraft with very high-lift devices, such as blowing and jet flaps. Tests showed that the apparent lift loss due to ground proximity, for high-lift configurations, was much too large when a conventional wind-tunnel ground board was used and indicated the need for a better method of simulating the ground in wind-tunnel testing. To satisfy this need, a moving-belt ground plane was developed and installed in a 17-foot wind-tunnel test section at the Langley Research Center. Studies of the effects of ground proximity on the characteristics of a swept and an unswept full-span blowing-flap configuration indicated that the moving belt satisfactorily removes the boundary layer on the ground plane. The lift loss of high lift models at small distances from the ground was considerably less with the belt moving at stream velocity (boundary layer removed) than with the belt at zero velocity. For configurations with full-span lift devices, the data indicated that the moving-belt ground plane is not needed for ratios of wing height (in spans) to lift coefficient greater than about 0.050, but is desirable for smaller ratios.

XB–70 Flight Research Program

The NASA–USAF XB–70 flight program continued to provide data related to the design and operation of large supersonic aircraft; topics emphasized were stability, control, and handling qualities; ground-based and airborne simulator validation; dynamic loads; and aircraft and propulsion system performance.

Airplane response to clear air turbulence was measured during supersonic flights of the XB–70 airplanes to an altitude of 74,000 feet. Preliminary evaluation of the data obtained at altitudes above 40,000 feet indicated that large supersonic aircraft would encounter turbulence at high altitudes more often than predicted by data obtained earlier from small subsonic aircraft. The XB–70 encountered turbulence on an average of 7.2 percent of the miles flown between 40,000 feet and 65,000 feet and 3.3 percent of the miles above 65,000 feet whereas for the subsonic aircraft the comparable figures averaged less than 2 percent and 1 percent of the miles flown.

Flight tests to validate the NASA General Purpose Airborne Simulator (GPAS) as a simulator of large supersonic transports in cruise were conducted at the Flight Research Center (Fig.

4–1). The GPAS is a small jet transport with a NASA-installed variable stability and control system so that flying characteristics can be changed at will. The XM–70 flight conditions were programmed into the GPAS, and it was flown by XB–70 pilots within one to two days of the XB–70 flights. Pilot comments and a comparison of XB–70 and GPAS motions clearly indicated the excellence of the GPAS as a simulator for large supersonic aircraft configurations.

A supplemental agreement to the basic contract for the maintenance of the XB–70, signed by NASA on November 14, provides for the design, fabrication, and installation (in 1968) of a modal control (elastic mode control) system in the XB–70, the cost to be shared equally by NASA and the Air Force. The system is designed to reduce the structural dynamic gust response of flexible airplanes typified by the XB–70 and the supersonic transport, thereby improving the "ride" comfort of passengers and crew. Flight tests of the system and an aerodynamic shaker designed to excite the airplane at its various natural frequencies, following their installation and the installation of several safety-of-flight modifications to the pilot escape system, were scheduled for early June 1968.

Five flights were made during the last half of 1967, bringing the total for the year to 14 and the grand total to 115 XB–70 flights.

X–15 Research Aircraft Program

The three X–15 aircraft made seven flights during the period, and a total of 15 flights during the year. Flight objectives were to obtain data relating to the following experiments and aircraft systems: hypersonic research engine (HRE) flow fields; struc-

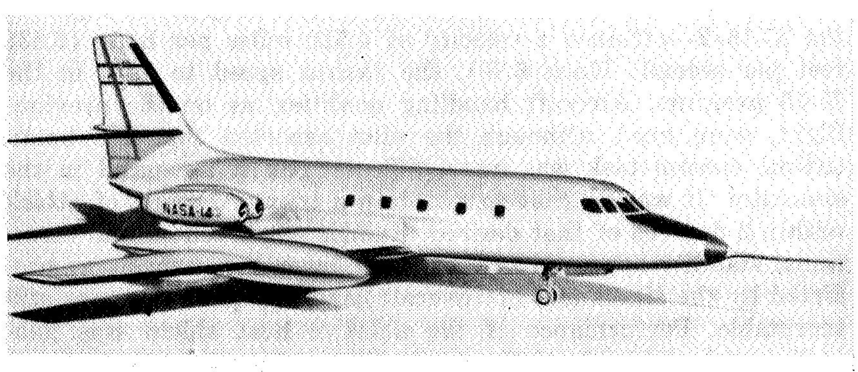


Figure 4–1. The general purpose airborne simulator.

tural heat transfer to cold-wall and wavy panels at hypersonic speeds; development of techniques and instrumentation to measure aerodynamic and structural loads under high aerodynamic heating; human pilot capabilities to provide guidance to launch vehicles during the boost-phase of flight; boundary-layer noise and flow-field characteristics; development of a fluidic probe for measurement of total temperature at hypersonic velocities; X–15–2 stability, control, and handling qualities with the external tanks installed and with a complete coating of ablative thermal protection material; X–15–2 external tank separation characteristics; measurement of wing tip deflections and accelerations and of nose-gear loads during landing; and flight test of the Apollo Saturn S–II ablative material at high Mach numbers.

In addition, data were obtained for the following test-bed program experiments: micrometeorite collection at high altitudes; measurement of the LR–99 rocket engine exhaust plume characteristics at high altitudes; measurement of the solar spectrum at altitudes above the sensible atmosphere; and development of instrumentation for determining atmospheric density at very high altitudes.

The first flight of the X–15–2 with the entire airplane coated with ablative material and with the HRE shape and the external tanks installed indicated that the overall performance of the coating was very good. (Fig. 4–2) No major differences in aircraft handling qualities which might be attributed to the ablative material were apparent to the pilot. Maximum mach number on this flight was 4.94.

Another X–15–2 flight with the ablative material, external tanks, and the HRE shape was made on October 3, by Air Force Major William J. Knight. This flight—the fifty-third flight of the X–15–2—attained a velocity of 4,520 miles per hour (6,630 feet per second; Mach 6.70), the fastest speed to date in the X–15 program. Aircraft handling qualities, as on the previous flight, were good, although the pilot reported that the longitudinal control task was more difficult than it appeared in the simulator. It was difficult to maintain a trimmed angle of attack within 2 degrees of that desired. Rudder effectiveness and directional stability appeared to be a little lower than what was predicted by the simulator, but overall handling qualities were still acceptable. Performance of the ablative heat shield was generally good, although a strong shock-wave/boundary-layer interaction on the HRE pylon caused a total failure of the ablator

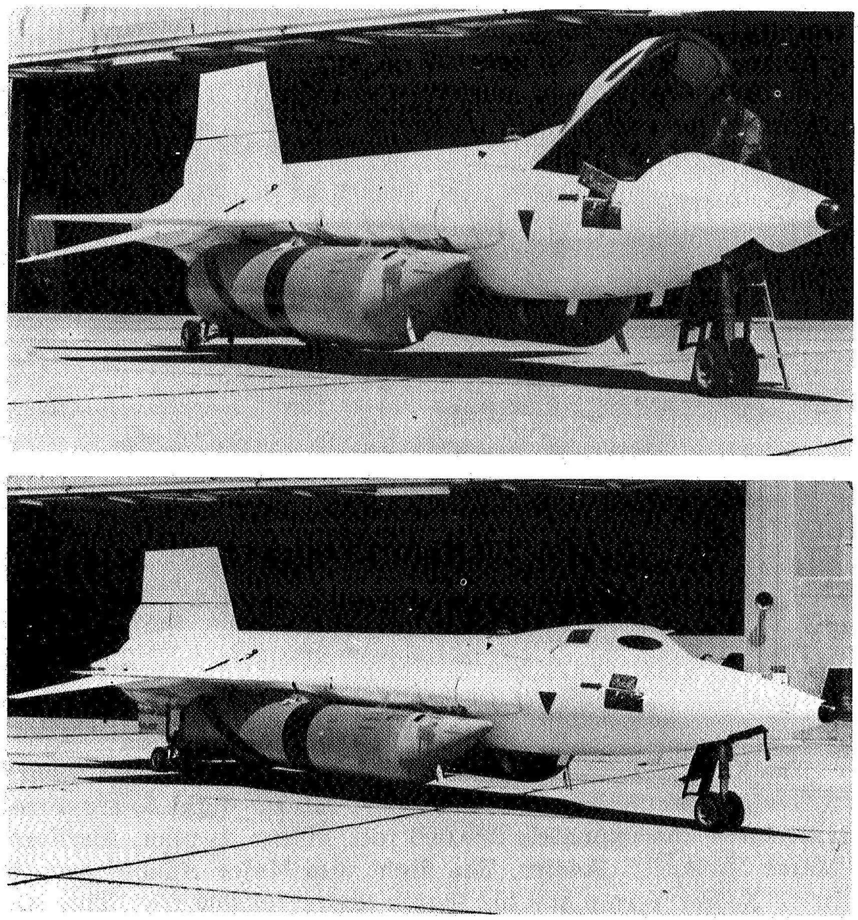


Figure 4–2. The X–15 with ablative coating and external tanks.

and melting of a considerable portion of the pylon leading-edge skin and substructure. Maximum skin temperature during the flight exceeded 2,700° F. Following this flight, the airplane was returned to the manufacturer's plant for structural inspection and repairs. (Fig. 4–3)

The X–15–2 made 2 flights in the last half of 1967, and only three during the year.

The five X–15–3 flights during this period and the three during the preceding period accounted for over half of the X–15 flights flown in 1967. The last 5 flights obtained heating and loading data and data for several of the test-bed experiments already listed.

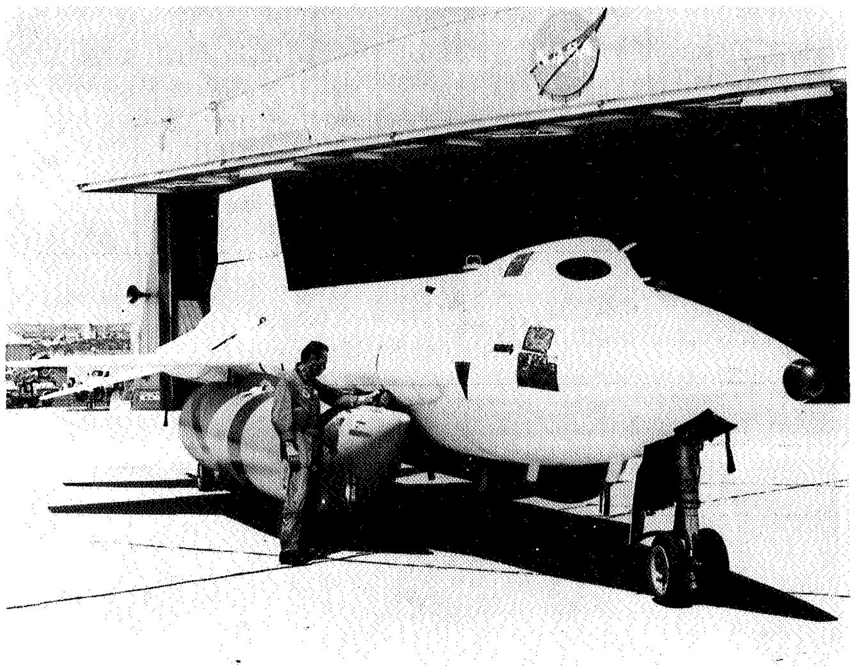


Figure 4-3. Major Knight checks tank connection.

The X-15-3 aircraft crashed on November 15, (its 65th flight), following reentry into the atmosphere after a flight to a planned altitude of approximately 250,000 feet, killing its pilot, Air Force Major Michael J. Adams. The flight was Major Adams' seventh in an X-15 aircraft and his fourth above 100,000 feet. This was the first fatal accident in the X-15 flight program since it began in June 1959. A NASA-USAF Aircraft Accident Investigation Board was appointed immediately after the accident. The Board reviewed all available data and was preparing a report of its findings.

By the end of 1967, the three X-15 aircraft completed a total of 191 flights including 146 at Mach 4 or greater, 103 at Mach 5 or above, and 4 at Mach numbers greater than 6. Twelve flights, by eight differrent pilots, exceeded an altitude of 50 statute miles. And twelve pilots had flown the X-15 aircraft, including 5 Air Force, 5 NASA, 1 Navy, and 1 contractor pilot.

BIOTECHNOLOGY AND HUMAN RESEARCH

Advanced Concepts

In efforts to develop new and improved bioinstruments for measuring man's physiological and performance status, an investigator, under contract to the Electronics Research Center, developed a device that measures blood flow by an ultrasonic technique. Called a doppler ultrasonic blood velocity meter, the device can make measurements noninvasively, in some cases even without contact between the probe and the subject. (Fig. 4–4)

Life Support Systems

The advanced life support subsystem technology program emphasized work on new processes, components, and materials. The Langley Research Center continued research on two-gas sensors for control of the space cabin atmosphere. A test instrument, developed by a contractor, measures continuously oxygen, carbon

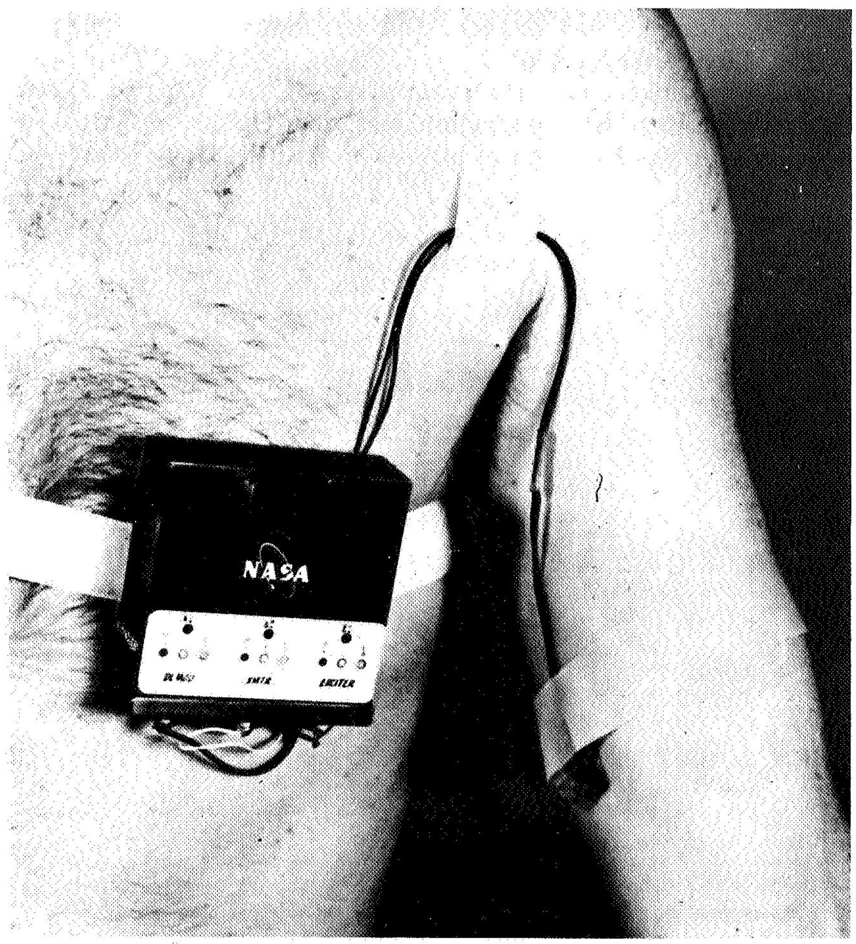


Figure 4–4. The Doppler ultrasonic blood flowmeter.

dioxide, water vapor, and inert gas using a mass spectrometer technique (ionized gases are deflected by a magnet according to their mass into a collector which indicates their concentrations). Instruments were integrated with life support systems and tested in space cabin simulators. (Fig. 4–5.)

An advanced method of oxygen regeneration, which eliminates one step (water formation) and a number of supporting components, was developed. In the new process, oxygen is separated directly from carbon dioxide by an electrochemical reaction using a solid electrolyte, carbon dioxide is converted to oxygen and carbon monoxide in the solid electrolyte reactor, and the oxygen is returned to the cabin. The carbon monoxide is cycled repeatedly through a catalytic reactor where most of it is broken down into carbon and oxygen, and the rest is reconverted to carbon dioxide. (Fig. 4–6)

NASA scientists and representatives of the Federal Water Pollution Control Administration met to exchange research information on the handling of wastes to prevent water pollution.

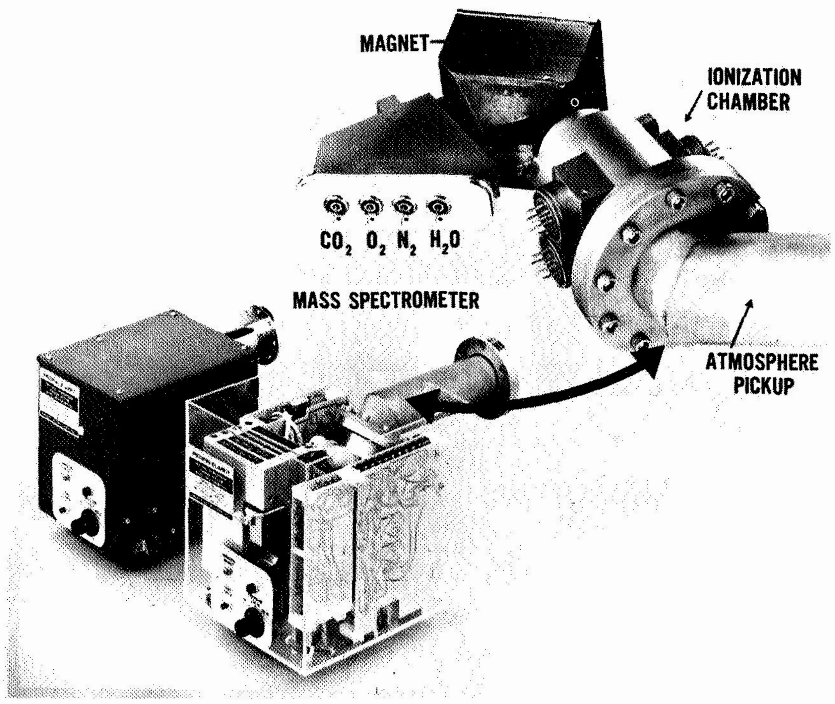


Figure 4–5. Two-gas sensor.

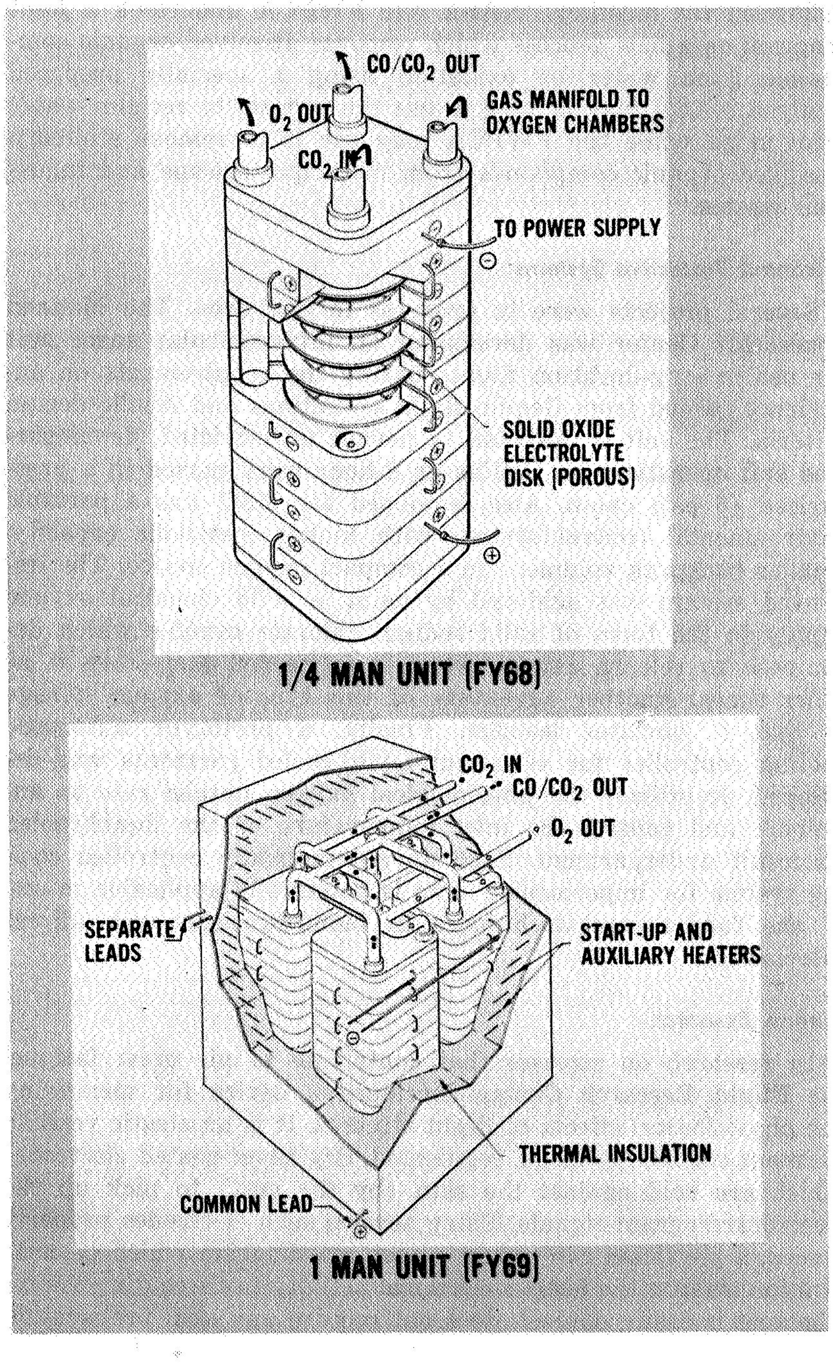


Figure 4–6. Solid electrolyte laboratory model.

Following the meetings, NASA and FWPCA undertook a joint program on a new process which removes dissolved organic compounds from water by oxidation using a specially prepared catalyst. NASA may be able to use the process to reclaim water from urine while the FWPCA may use it to remove stubborn dissolved organic compounds from municipal sewage and industrial wastes.

Astronaut Protective Systems

Several projects were in progress in this area. The Manned Spacecraft Center was developing an intravehicular space suit for use in long-duration flights basing the requirements on experience gained from Gemini flight operations and Apollo design criteria. The suit is designed to permit unrestricted, depressurized suit operations as well as an 8-hour work period in a pressurized (5 psi) cabin. Also developed for MSC was a portable environmental control system with higher metabolic capacity, smaller backpack volume, and a compact oxygen source. The improved system was achieved by using a solid chemical oxygen supply in the form of solid sodium chlorate candles which decompose to release oxygen when it is needed and store it at other times. Another advantage of this type of oxygen storage is that it obviates leakage. Finally, a prototype automatic cooling controller for astronaut liquid-cooled garments was developed. It utilizes the physiological oxygen uptake rate to anticipate and control the inlet temperature of the liquid-cooled spacesuit undergarment. Such an automatically controlled cooling system for impermeable suits is potentially applicable to one of the fundamental techniques in biomedical research—direct calorimetry.

Human Research

In research on stresses that contribute to air crew fatigue, the Flight Research Center developed a device for measuring the physiological effects of flight stresses. It is an elastic vestlike garment containing large, segmented, dry silver-coated electrodes which are held against the skin (by the vest) to pick up the electrocardiogram signals. Using several such electrodes properly placed, a physician can obtain a vectorcardiogram which permits him to visualize the heart's electrical activity in three dimensions. The vest is easily donned, does not require any skin preparation or paste, and may be worn for long periods without discomfort. (Fig. 4–7)

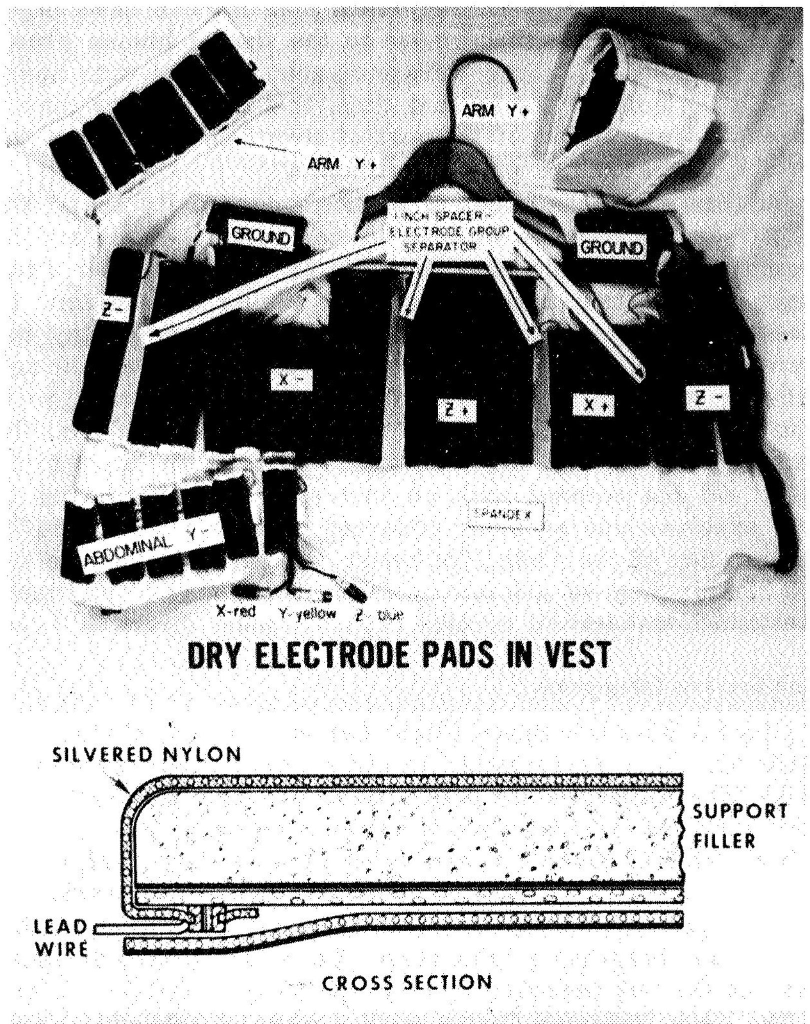


Figure 4–7. Vest used in stress measurements.

In other Ames work on the body's ability to adapt to stress, studies were made of the endocrine system and its hormone secretions. Two of the glands in this system—the pituitary and the adrenal cortex—are most directly tied to the impact of stress in the body. Investigators at Ames discovered and studied the activity of nine pituitary enzymes which break down the extremely active pituitary hormones and prevent their excess accumulation. During the course of this research, an enzyme called arylamidase IV was discovered which breaks down molecules of bovine pituitary growth hormone to the size of human growth hormone molecules. Since we are unable to synthesize human growth hormone at the present time, this new enzyme may be the key to prevention of the sort of dwarfism in humans that results from a lack of growth hormone.

Another Ames investigation of hormone activity found that aldosterone, a hormone secreted by the adrenal cortex and apparently needed in increased amounts for survival under stress, plays an important part in the body's ability to withstand the stress of extreme cold. In the study, 14 vigorous, healthy men were exposed to the arctic cold at Fairbanks, Alaska, during a 110-mile walk lasting 10 days. After the test, an increased secretion of aldosterone was found in the urine of most subjects, but two subjects who had low aldosterone levels at the start of the study did not respond with an increased secretion during the cold exposure and suddenly collapsed without warning on the seventh day of the study. The results of the study indicate that the measurement of aldosterone in the urine may be an important functional test of adrenal capacity under stress.

Man-Systems Integration

Under a Marshall Space Flight Center contract, studies were made of human performance in eight typical lunar exploration tasks. The subjects wore pressurized spacesuits and performed such tasks as collecting soil samples, measuring local gravity, driving and navigating a simulated lunar-surface vehicle, and setting up an antenna. When the schedule included a programmed rest, fatigue was reduced and average heart rates were lowered (100 to 110 beats per minute versus 125 to 135 beats per minute without the rest period).

The Ames Research Center studied ways of achieving an optimum aircrew workload in order to reduce stress and fatigue and increase safety. The work focused on reducing workload in one of the most demanding flight situations—a landing in which there is a minimum ceiling of 100 feet and a runway visual slant range of about 1,250 feet—a Category II condition. At normal approach speeds and glide angles, the crew has about 10 seconds after visual contact to judge whether it is safe to land and to make the landing or elect to go around again. Ames adapted a piloted flight simulator (a fixed cockpit setup with a TV display attached for use by a two-man crew) for its studies. The degree of physiological stress experienced by pilots in such situations will be determined by measuring the amount of stress hormones in their blood and urine. (Fig. 4–8)

Another flight simulation device, the two-axis Nike mount cockpit, was used by the Langley Research Center to determine how many simulated motion cues the pilot needs and how frequently he needs them to perform as if he were receiving actual aircraft visual and motion cues. Such cues can then be incorporated into other maneuvering simulators. (Fig. 4–9)

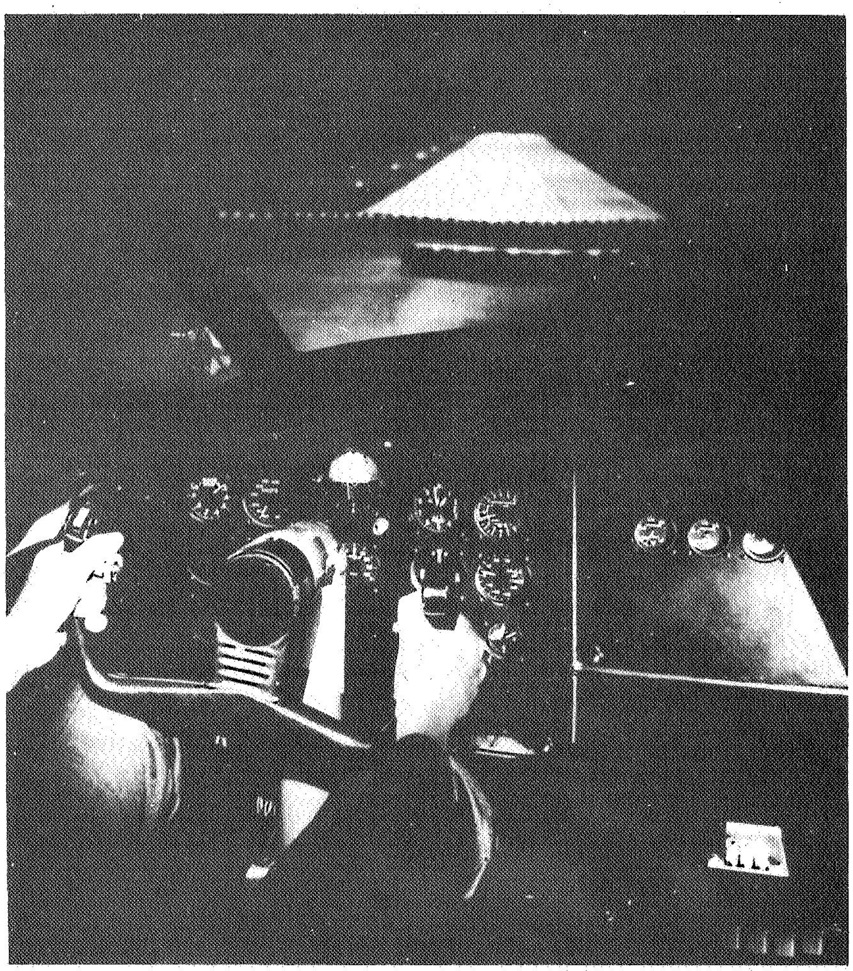


Figure 4–8. Piloted flight simulator.

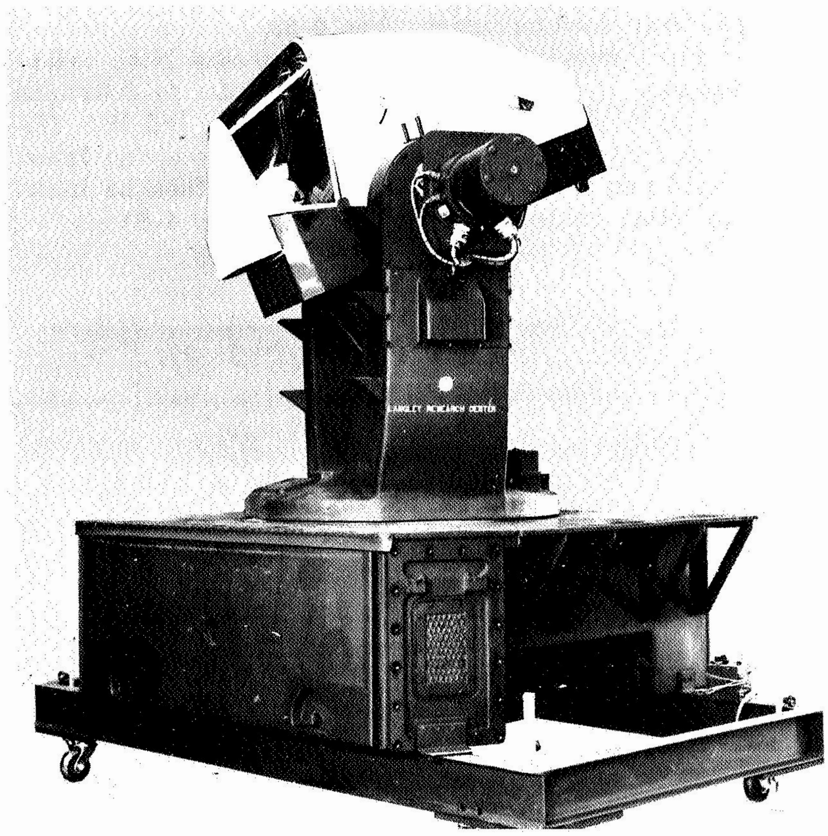


Figure 4–9. Two-axis cockpit simulator.

ADVANCED PROPULSION SYSTEMS

Liquid Propulsion Systems

The liquid propulsion program was modified to emphasize areas of advanced technology and improved system operating characteristics which offer advantages in overall performance and cost. Extensive work was being done on the technology of deep cryogenic and space storable propellants which have a demonstrated specific impulse advantage over the current earth storable propellants; performance of the cryogenic systems is higher than that of the space storables.

Research on problems related to storing liquid hydrogen in the space environment progressed with the accumulation of data on superinsulation, minimum heat leak tank supports, propellant line connections, and thermal conditioning systems. Tests of a near-flight-configuration liquid hydrogen tank in a simulated space vacuum chamber indicated that liquid hydrogen can be stored in the space environment for extended periods. For example, a hydrogen tank, built on the basis of present multilayer insulation and fiberglass tank support technology, containing 1165 lbs. of saturated liquid hydrogen could be stored longer than six weeks in earth orbit without venting. (Fig. 4–10.)

In addition, thermal effects of subsystems, flight experiment equipment, life support equipment, and trajectory and design techniques for both the cryogenic and space storable systems were compared on a common baseline. Finally, missions were analyzed based on design point vehicles for various propellants.

Extensive research on material compatibility problems associated with storage and combustion of fluorine-containing oxidizers included studies of tank corrosion, expulsion bladders, and chamber materials of construction. Work on propellants in-

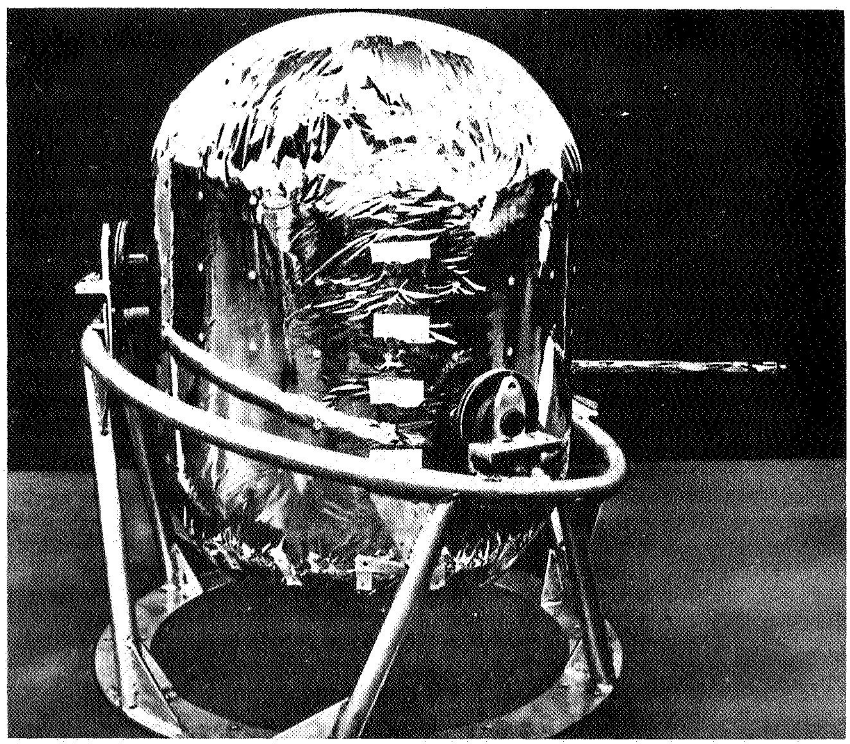


Figure 4–10. Test tank with multilayer insulation.

cluded progress in the liquid/solid hydrogen (slush) program and the gellation of oxygen difluoride (OF_2) by frozen chlorine trifluoride (ClF_3).

Combustion experiments on a rocket utilizing lithium, fluorine, and hydrogen indicated that this tripropellant combination may offer performance advantages in operations requiring high velocity increments. In the tests a specific impulse in excess of 500 lb. force sec/lb. propellant was achieved.

In related research, the combustion instability program provided acoustic absorber data that was used by a contractor in a series of experiments to develop stable operation of a baffled injector. In university research on the altitude starting problem associated with operational nitrogen tetroxide-hydrazine 50/50 engines, certain explosive constituents were identified. Known as azides, they may be generated as an intermediate product during ignition. Work continued in the hydrodynamics associated with fluid flow and turbo-pumping in large booster propulsion and fluid transfer systems. Reducing costs involved in the fabrication and test of rockets was a major objective.

Launch Vehicle Propulsion.—Testing of 250,000 pound thrust liquid oxygen, liquid hydrogen aerospike thrust chambers was initiated. These chambers, consisting of an annular combustion chamber arranged around a plug, or "spike," nozzle resulted from several years of experimental work on segments of the full thrust chamber and small scale aerospike configurations, jointly supported by NASA and the Air Force under the auspices of the Astronautics and Aeronautics Coordinating Board. NASA continued support of the aerospike concept with an eventual goal of a breadboard engine demonstration; the Air Force decided on an advanced development program with the high-pressure topping-cycle engine. Both efforts will continue to be coordinated, with NASA and the Air Force assisting each other and conducting joint technical reviews.

Studies of large launch vehicles for payloads beyond the capability of Saturn V indicated several competitive chemical propulsion possibilities. The high-performance cryogenic engine concepts previously discussed could be scaled up for use in upper stages. The large solid rocket could be used as a strap-on or in first stage applications.

Spacecraft Propulsion.—Evaluation of the internal-conduction cooled beryllium thrust chamber with earth storable propellants at the 1000 lb. thrust level was completed, and the feasibility of this cooling technique was demonstrated for low thrust, low chamber pressure application, including throttling. In addition, sufficient design criteria were generated to begin work on flightweight design configurations.

Testing of the RL–10 A–3–3 thrust chamber with fluorine-hydrogen was completed; performance and cooling characteristics were excellent. All component testing was completed, and engine assembly was underway in preparation for integrated engine system testing which will take place in the near future.

Based on the technology work with fluorine, criteria covering the design, fabrication, inspection, servicing, and operation of liquid fluorine feed system components were being published and distributed to government agencies and industry. As a result of the work on liquid hydrogen storage previously discussed and the two liquid fluorine efforts, it appears that the fluorine-hydrogen propellant combination can be considered for development in the 1970's.

Work on the space-storable propellants advanced as test hardware was fabricated to demonstrate regenerative cooling with liquefied petroleum gases (LPG's) at chamber pressures between 500 to 1000 psia. Several economical regenerative thrust chamber construction methods were devised and were used to fabricate thrust chambers which will be tested under actual firing conditions. Pump technology for the smaller spacecraft engines is planned for higher chamber pressure operation with the fluorinated oxidizers, either flox or oxygen difluoride in conjunction with liquefied petroleum gases.

The highest performing space storable propellant combination studied is oxygen-difluoride with the boron based fuel, diborane. However, its operation is limited to low chamber pressures since regenerative cooling cannot be effected with either propellant. Passive cooling techniques, such as ablative or radiative, which must be utilized are compatible only with the heat transfer rates associated with the lower chamber pressures. Carbon based materials were found most suitable for this application and thrust chamber tests conducted to date indicated that carbon chamber design technology can meet the requirements dictated by the highly reactive, 8000° F. products of combustion. (Fig. 4–11) These two space storable propellant combinations were emphasized in research and technology efforts for space propulsion and were progressing toward acceptance for consideration in development planning.

Auxiliary Propulsion.—Work on small thrusters utilizing space storable propellants reached the injector demonstration stage,

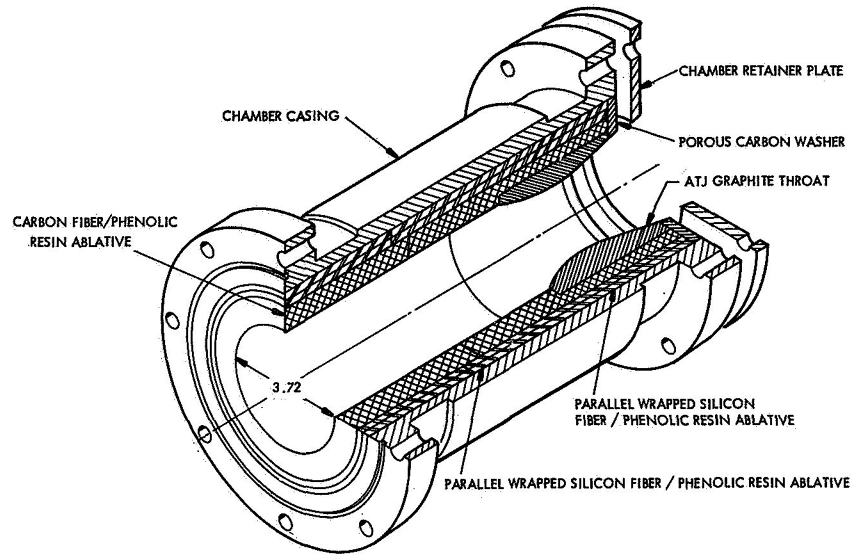


Figure 4–11. Oxygen difluoride-diborane thrust chamber cross-section.

and an investigation of auxiliary systems using these propellants was initiated; the objective of the latter effort is to provide a capability for thermal integration of advanced spacecraft main and auxiliary propulsion systems.

Several chemically-fueled very low thrust concepts were under investigation. These concepts generally call for liquid propellant storage systems, a means of converting the liquid to a gas at moderate temperatures, and a system to distribute the gas to very small nozzles for attitude control of space vehicles. The systems under investigation are better than stored-gas or all-liquid systems in that they provide the accuracy of gas for controls without drawback of heavy tanks required for gas storage. A typical low thrust system uses a single liquid propellant, hydrazine, which is decomposed by a catalyst to form a gaseous mixture of ammonia, hydrogen, and nitrogen. The gas mixture is held in a plenum or manifold until required by one of the small thrusters which consist only of a valve and nozzle. Thrust levels as low as five millipounds are practical with this system.

Solid Propulsion

NASA successfully tested two prototype high energy solid fuel motors of a type which may be useful for spacecraft propulsion in future missions. The motors were Surveyor landing-motor-size, and hardware from that program was utilized. The solid fuel contained beryllium powder, a highly effective propellant fuel additive whose use, it has been calculated, would make it possible to increase a Surveyor type lunar payload by almost 50 percent. Both motors were tested in the open at sea level pressure; a third motor was ready for test in the simulated altitude motor test facility at Tullahoma, Tennessee.

Three contractors were selected for a design competition for a new 2500 pound high energy motor which will have an optional quench and restart capability, to be used when the mission calls for a coast period between two propulsive maneuvers.

In recent mission analyses, hybrid motors (liquid oxidizer and solid fuel) also showed potential as spacecraft motors. They offer high energy (400 sec Specific Impulse (I_{sp})) and controllability with costs potentially between those of solid motors and liquid motors. Planning of a hybrid motor demonstration program was completed.

The large solid motor demonstration program has been inactive since completion of the contract for the third firing in June, 1967. Work on large motor technology continued with efforts in ablative nozzles, new case materials, and propellant processing improvements.

Solid Propulsion Technology.—In-house and contract research work in solid propulsion at Langley Research Center and the Jet Propulsion Laboratory made significant advances. Polymers of improved characteristics for propellant binders applicable to solid motors were studied, and further work was planned to improve the physical characteristics of advanced solid propellant grains.

The energy content of modern composite propellants is determined primarily by the amount of metal fuel additive and the type of oxidizer used, while the mechanical properties are controlled primarily by the rubbery binders. One means of improving the overall thrust performance is by improving the mechanical properties. The JPL polymer mechanical behavior program developed the theory of stress softening. (*17th Semiannual Report,* p. 98). The theoretical work was confirmed in laboratory tests and was the basis for the development of methods for predicting the stress and distortion of systems undergoing cyclic stresses close to the material limits. This work is expected to have important applications in analysis and design of solid propellant grains and of plastic and rubber-like materials used as structural elements or components.

Tests were started on microwave nondestructive testing techniques applicable to a large block of solid propellant within a metal case. Figure 4–12 shows the experimental nondestructive testing set-up. A block of propellant about 52 inches deep is bonded on the back surface with a metal plate to simulate a case. A broadcasting and a receiving antenna are pressed against the propellant. The RF signal sent through the block reflects off the back surface and is picked up by the receiving antenna. The signal has a characteristic waveform which changes if the propellant is not properly bonded to the case, or if a void is encountered. When perfected, this method will make it possible to inspect large solid motors and other viscoelastic materials, such as aircraft tires, for voids, cracks, fissures, or bond separations. Advances were also made in understanding and controlling solid motor combustion instability.

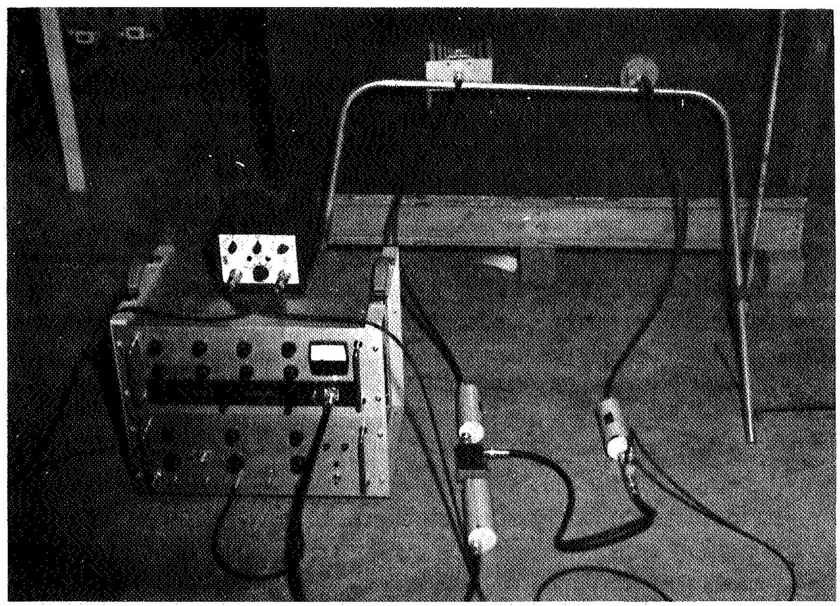


Figure 4–12. Microwave nondestructive testing set-up.

BASIC RESEARCH

Fluid Physics

Clear Air Turbulence.—These rather severe atmospheric disturbances, which occur under seemingly good weather conditions and can be dangerous to passengers and aircraft, were simulated in laboratory water experiments. (Fig. 4–13) The tests showed that the amplitude of a low turbulence level produced by a small disturbance in the simulated atmosphere grew tenfold under certain conditions. Applied to the atmosphere, the result would be a severe disturbance in the "clear air" far from the small disturbance. Some understanding of the physical parameters which determine whether the disturbance grows or diminishes was achieved, and it was concluded that a temperature inversion in the atmosphere (warm air above cool air) would tend to suppress the turbulence.

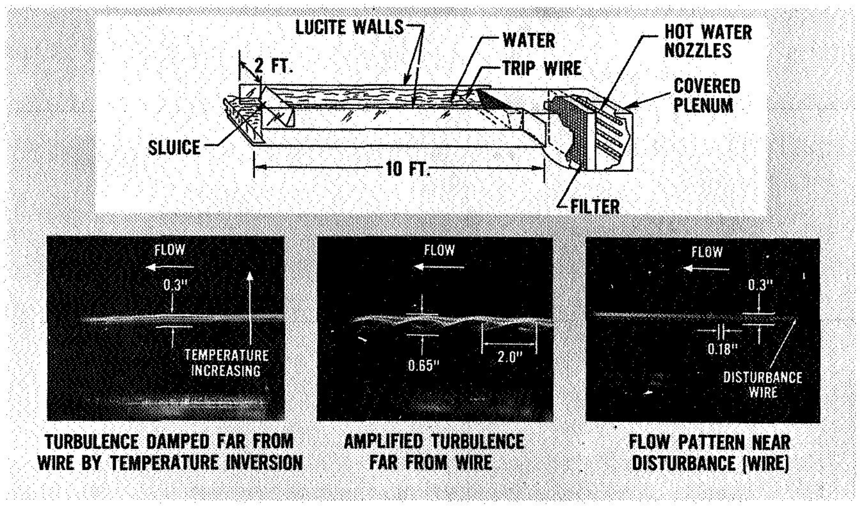


Figure 4–13. Water simulation of clear air turbulence.

Meteor Entry.—Small steel spheres were launched in a ballistic range to simulate natural meteor entry into the atmosphere. Instrumentation measured the luminosity of the hot gas cap of the "meteor" and observed the mass loss from its eroding surface. Flight photographs showed that the forward face of the meteor melted and that the molten material ran back to the periphery where it refroze, forming a flange. This phenomenon explains observed variations in atmospheric deceleration of actual meteors. The experiments also verified the theoretical prediction of a sharp reduction in gas-cap luminous efficiency as velocity falls below about 10 kilometers per second.

Reentry Heating Shielding.—The vaporization of heat shield materials during entry into the atmosphere was simulated by injecting various gases through the porous forward surfaces of model vehicles. (Fig. 4–14) Tests showed that these gases can very effectively shield the vehicle from the high convective heat-

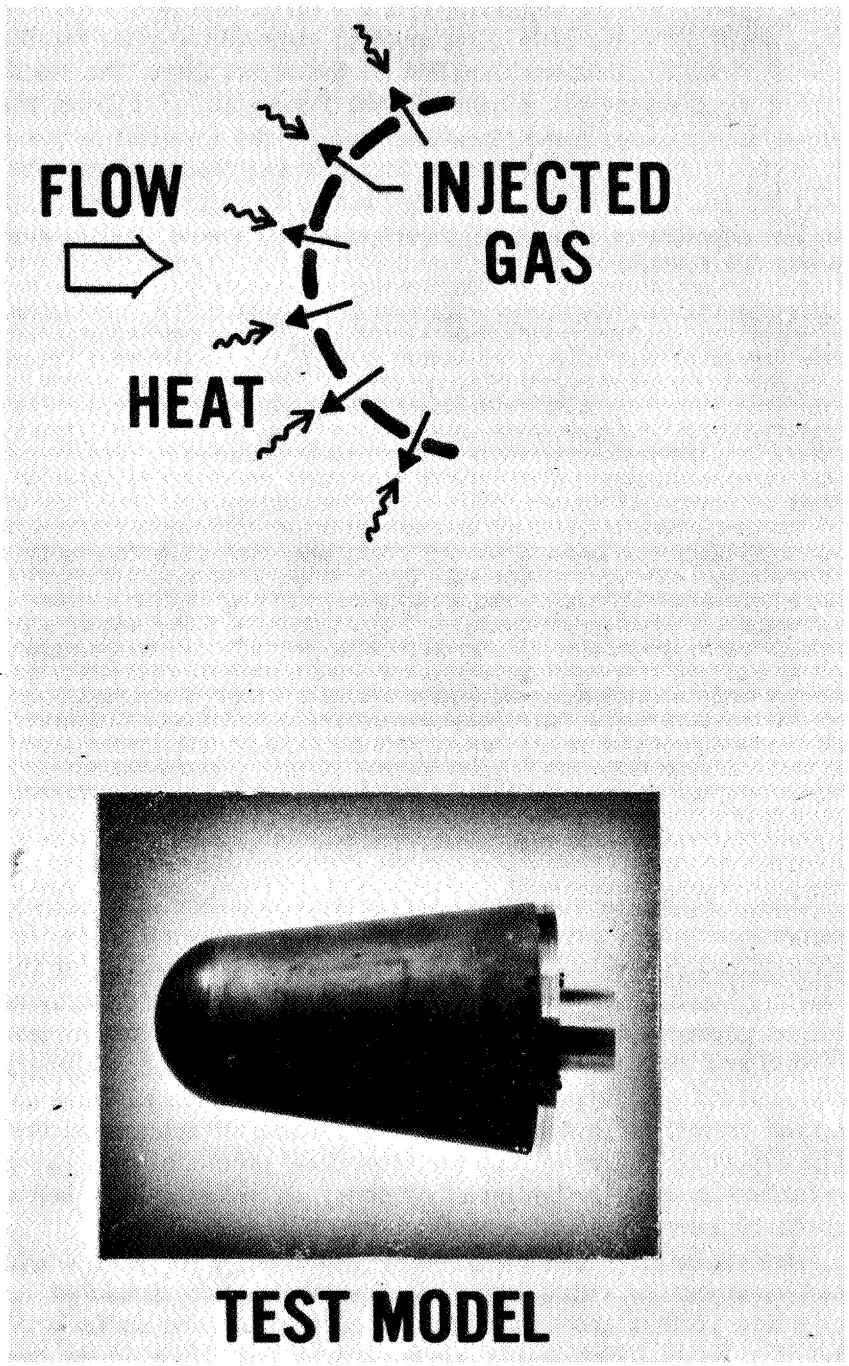


Figure 4–14. Shielding by gas injection.

ing rates of reentry. The other major source of heating, gaseous radiation, can be reduced by use of small nose radii. These experiments suggest that a slightly blunted cone is an advantageous shape for vehicles which enter the atmosphere at velocity higher than earth-escape speed (7 miles/sec). (Fig. 4–15.)

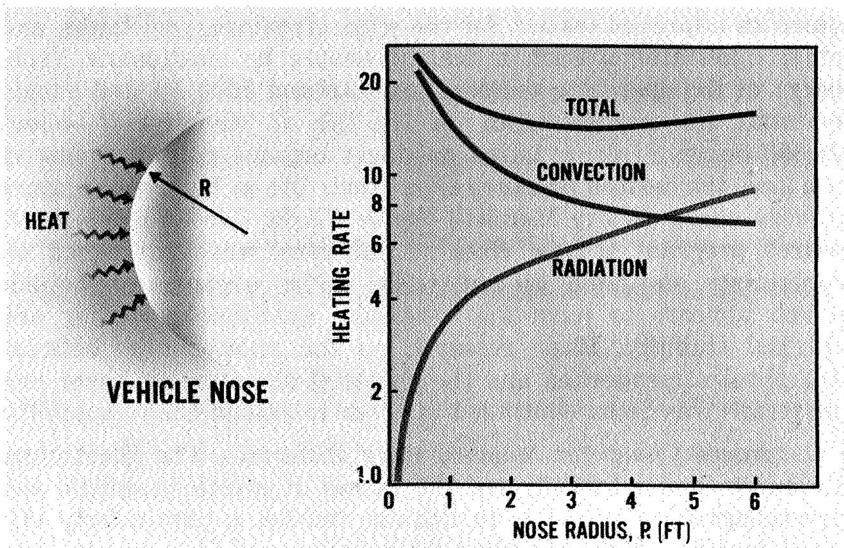


Figure 4–15. Effect of nose radius on heating.

Applied Mathematics

To calculate long-distance trajectories, like that of Mariner V to Venus, with great accuracy, the mathematical theory must include many non-gravitational disturbing forces, such as the solar radiation pressure on the space vehicle, the pressure due to reflected radiation from a nearby planetary surface, and reactionary forces caused by spacecraft characteristics (unsymmetrical heat radiation from the skin, unbalanced attitude control devices, radio energy from antennas). Although such perturbational forces amount to less than that exerted by the weight of a small scrap of paper, they can, after many days, produce errors of hundreds or even thousands of kilometers. Mathematicians at the Jet Propulsion Laboratory worked out precise mathematical terms which included the many complexities of geometrical direction and amount of the non-gravitational forces. These terms were included in the equations of motion of Mariner V, and, as a result, its approach to Venus was predicted within a very few kilometers, a significant advance over the calculations for the Mariner IV Mars mission where the non-gravitational forces could only be approximated.

Materials

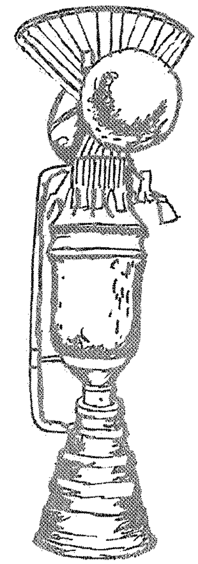
Elastomeric Materials.—Future high speed aircraft will require an improved sealant for the wing structure, fuel tanks, and other applications. Such a sealant should be elastomeric (rubbery) at the operating temperature (around 500° F) and should maintain its characteristics for the life of the aircraft—about 25,000 hours. Sealants based on linear organic polymers now in use have the desired properties, but their life at high temperature is very short. In the Marshall Space Flight Center polymer research program, a new class of polymers was synthesized by combining inorganic silicon with cyclic organic compounds which appears to have the necessary qualities—elasticity and thermal stability. Basic research on the relationships between the physical properties and the chemical structure of these new materials was being continued in order to extend their capability.

Improved Computer Memory Core Material.—The Electronics Research Center investigated the causes of erratic magnetic and crystallographic behavior in lithium ferrite, a particularly efficient member of the ferrites extensively used in memory core-elements for computers in spacecraft. The research revealed that the erratic behavior was due to a loss of lithium and a change in state of iron during production. It also made it possible to define the processing variables which required control and the degree of precision required for the control; as a result, reproducible values were established for the physical properties of this material. In a corollary research effort, the composition of the ferrite was slightly modified, and the operational power requirements for lithium ferrite were reduced substantially. The ERC research on lithium ferrite increased its reliability and efficiency.

Electrophysics

Ion-Atom Impact Excitation.—One factor that determines the amount of radiation from a hot gas or plasma is the collisional excitation of the gas particles. It was thought that excitation would occur predominantly through the impact of electrons and atoms, and that the collisions of ions and atoms would contribute very little to excitation below energies equivalent to a billion degree temperature. New research showed, however, that for the impact of helium ions and helium atoms, the excitation remains large down to energies equivalent to less than 100,000 degrees, and it is expected that other gases will behave similarly. This finding is important to research on MHD generators involving non-equilibrium ionization since it suggests that radiative heat losses can be significantly larger than previous calculations indicated. Also, atmospheric ion-molecule collisions at high speed reentry may be producing radiation at a higher rate than previously calculated.

Compact High Density Computer Memory.—Research on advanced computers at the Jet Propulsion Laboratory indicated that it may be possible to store as many as ten million bits of information in an area one inch square. Computers of present design would need about 10 cubic feet for equivalent storage capacity. The new memory unit studied was a ferromagnetic thin film, manganese bismuth, on which magnetization was impressed by an external magnetic field using a laser beam pulse as a tripping device. The magnetized dot stored in the memory unit can correspond with "one" in computer terminology. For a "zero," the direction of the applied magnetic field is reversed so that magnetization of the dot is opposite. The memory unit will consist of a mosaic of closely spaced dots each carrying the information "one" or "zero" depending on its direction of magnetization. A 1 micron diameter laser beam can produce information dots on the memory unit with a 5 micron separation. With this dot spacing in a one-inch square film of about 500 Angstroms (2 millionths of an inch) thickness, the 10 million bits can be accommodated.



5 NUCLEAR SYSTEMS AND SPACE POWER

The nuclear rocket program continued to provide the technology needed for nuclear propulsion systems, though shifting stress on the NERVA engine to a system that would produce a thrust level of 75,000 pounds. Meanwhile, the SNAP–8 project emphasized the testing of an improved turbine, the nuclear electric power and research efforts stressed broadening the technological base for electric power systems, thruster systems received increasing attention in the electric propulsion program, and non-nuclear space power technology activities continued to concentrate on more advanced space electric power systems.

NUCLEAR ROCKET PROGRAM

The joint NASA/AEC nuclear rocket program activities continued the work necessary to provide the basic technology for nuclear propulsion systems, to develop a NERVA engine of approximately 75,000 pounds thrust for flight applications, to extend the technology of graphite reactors and engine systems components, and to investigate advanced concepts.

Progress made during the last six months particularly stressed the work of providing the basic technology for nuclear propulsion systems. This work included cold-flow tests of the larger diameter Phoebus-2CF reactor; a one-hour test at full power of the NERVA NRX–A6 technology reactor; and the remote installation and testing of the first down-firing, ground-experimental engine, the XE cold-flow (still in progress at period's end). The description of these events and their significance in terms of overall objectives is described later in this report.

While this work was taking place, the future of the space program was being reassessed as a result of fiscal year 1968 budget constraints. Part of this reassessment was the re-examination of the goals of the nuclear rocket program for flight engine development. This re-examination led to the decision to reduce the thrust level of the NERVA engine from the 200,000 pounds originally proposed to 75,000 pounds. The 75,000 pound thrust engine would be quite suitable for all missions for which the nuclear rocket is significantly advantageous, with the possible exception of manned planetary missions.

Once the scaled-down engine was decided upon, the preliminary phases of engine design and the preliminary planning in preparation for its development were initiated. This work, completed during the period, indicates that preliminary flight rating tests for such an engine, based on current NERVA technology, could be accomplished in seven or eight years.

Reactor Technology Progress

The tests of the larger diameter Phoebus-2CF reactor and NRX–A6 reactor were important steps toward completing the reactor technology program. The description and results of these experiments follow.

Phoebus–2 Cold-Flow.—In July and August, a series of cold-flow tests on the Phoebus–2CF reactor and checkout runs of the Test Cell "C" facility were conducted. (Fig. 5–1). These tests and runs were to determine the behavior of the reactor and facility under conditions of high flow and high pressure, and to search for and eliminate experimental difficulties which might occur during the test of the Phoebus–2A hot reactor. The Phoebus–2A reactor, rated at 5,000 megawatts, is currently scheduled for testing in June 1968. Other major objectives of the cold-flow experiments were to demonstrate the mechanical and structural integrity of the reactor system, to measure pressure and flow distributions, to verify that none of the reactor components show tendencies to vibrate in any unstable manner, and to determine the best procedures for starting up the Phoebus–2A.

Over a five-week period, more than a dozen runs were made. The performance of the instrumentation and control system was excellent, with reactor pressure and flow distributions generally in agreement with predicted values. A number of changes in

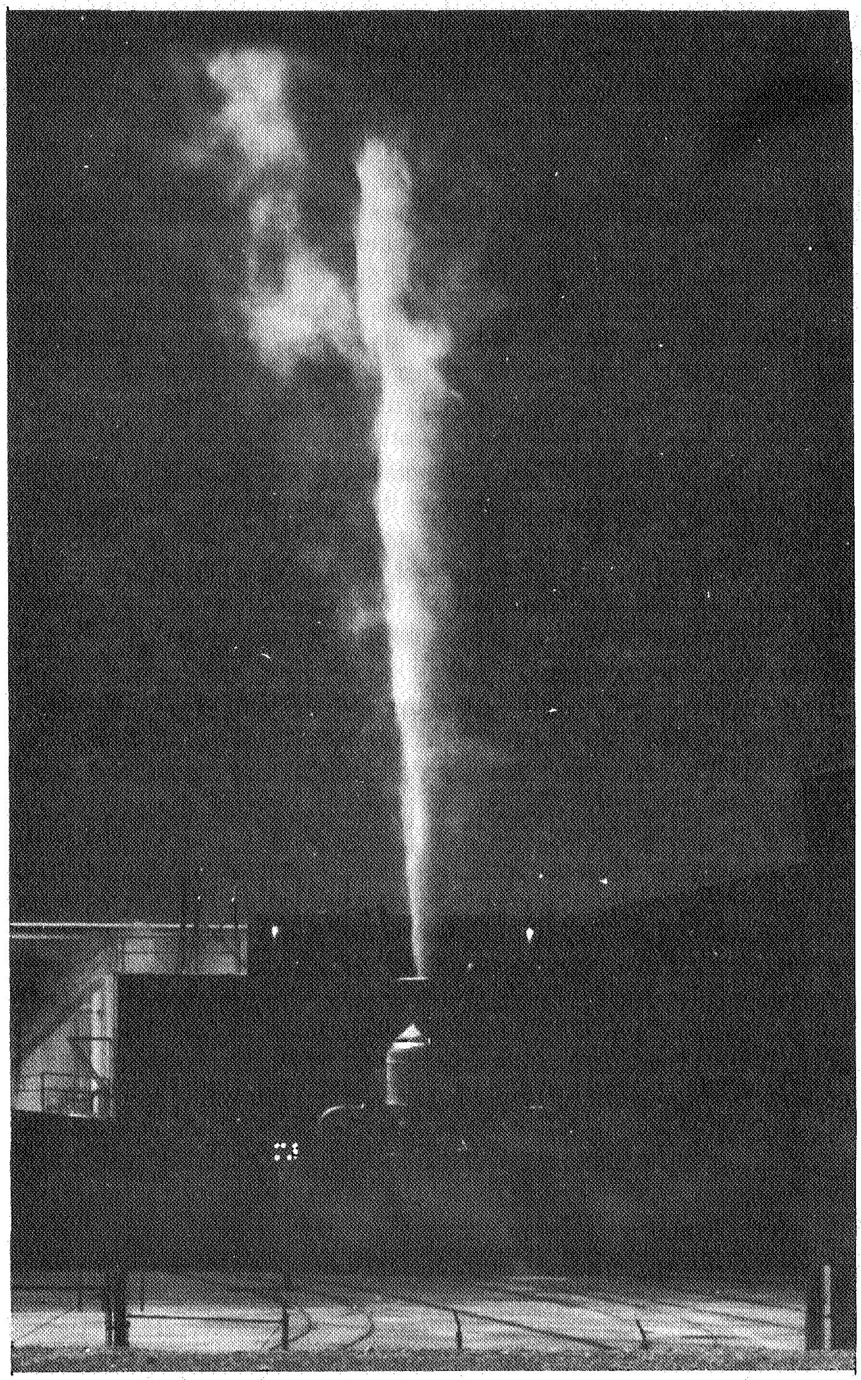


Figure 5–1. Phoebus-2 Cold Flow Reactor.

valve programs and orifice sizes were made to obtain more stable and reproducible start profiles for the Phoebus–2A. No mechanical or structural stability problems were found.

NRX–A6 Reactor.—The NRX–A6 reactor test was run on December 15, 1967 (Fig. 5–2). This was the last and by far the most ambitious test in the series of experiments conducted in the NERVA technology program using the NRX–A reactor design. The principal objective of the run was to demonstrate how long all reactor components could operate under closely-controlled, full-power (nominal 1100 MW) conditions.

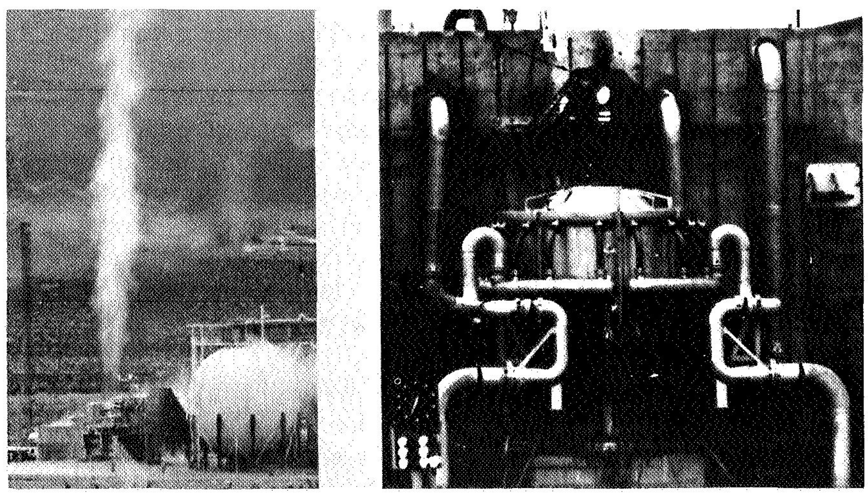


Figure 5–2. NRX-A6 Reactor full power test.

The test began with a checkout of the test article and the Test Cell "C" facility. The checkout was followed by reactor startup to a partial power hold (291 MW), an increase in power to a second partial power, and finally, an increase to full power conditions (about 1120 MW). After operating for sixty minutes at full power, the reactor was shut down and the test was ended. Total operating time at significant power levels (above one megawatt) was about 70 minutes.

The preliminary analysis of the NRX–A6 test data indicated that the reactor operated close to the planned test conditions. At the period's end, these data were being analyzed to define, in detail, the reactor operating conditions. Initial indications were that corrosion was markedly reduced in the improved fuel elements which comprised the NRX–A6 reactor core.

The early data also indicated that fuel element corrosion behavior in laboratory hot-gas tests was representative of the corrosion behavior of fuel-elements in full-scale reactor tests. The average weight loss of the NRX–A6 elements appeared to be close to that predicted from laboratory tests. An exact correlation of the detailed corrosion of the NRX–A6 elements and the corrosion data obtained from hot-gas tests must await the results of the postmortem examination of the NRX–A6 elements.

Test Cell "C", in which the NRX–A6 test was conducted, performed very well. Operation of the liquid-hydrogen feed system was excellent. No significant anomalies were noted in the operation of the reactor control system, and all associated lines and valves performed satisfactorily.

Fuel Element Materials Research.—The major gains made in fuel-element technology have resulted from increased knowledge of the mechanism of corrosion, improvements in the application of corrosion resistant coatings, and extensions of quality control needs. Over the past year, the progress made in these areas was substantial. The Phoebus–1B reactor's resistance to corrosion was about twice that of the NRX–A5 reactor previously tested. Less than one year later, the NRX–A6 reactor's endurance was double that of the Phoebus–1B. Laboratory tests being made on fuel elements show promise of performance substantially beyond that exhibited by the NRX-A6 reactor.

Studies at Los Alamos aimed at finding a more economical method for testing fuel elements under actual reactor operating conditions resulted in the design of a small test reactor, termed Pewee. The Pewee assembly will contain only about one-fourth as many fuel elements as the NRX–A6 reactor, yet it will operate with a number of elements at power densities as high as those expected in the Phoebus–2A. The first Pewee reactor is scheduled for testing late in 1968. Additional reactors will be fabricated and tested as required to test promising advanced fuel materials and design concepts.

Engine System Technology Progress

The full-power run of the NRX-A6 reactor completed the reactor technology effort in the NERVA technology program. The emphasis in the technology programs then shifted to ground-experimental engine (XE) investigations in Engine Test Stand No. 1 (ETS–1) (Fig. 5–3). The three primary objectives of these investigations are to obtain additional data on engine operating characteristics, to test candidate control concepts for the NERVA flight engine control system, and to gain experience in the operating characteristics of ETS–1 (Fig. 5–4).

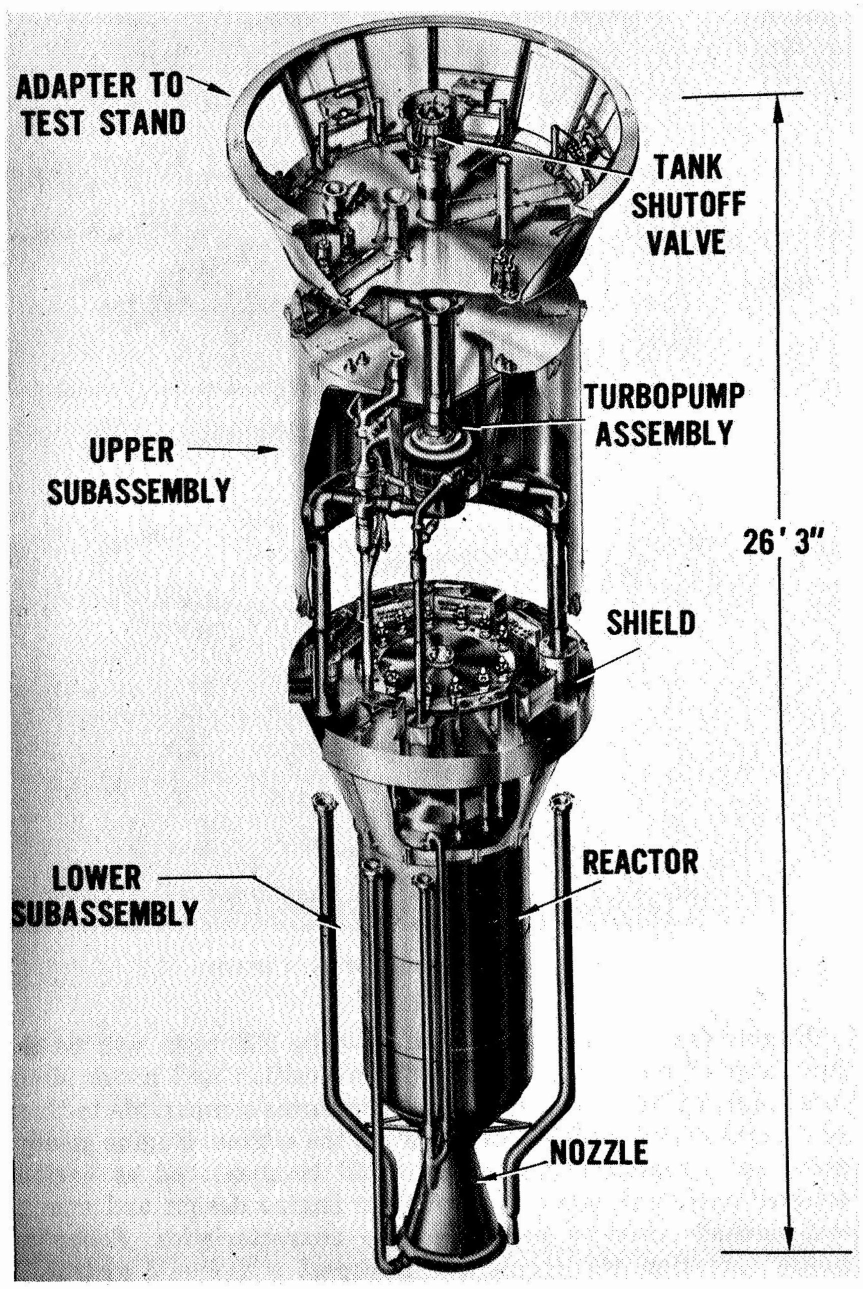


Figure 5–3. Ground Experimental Engine (XE)

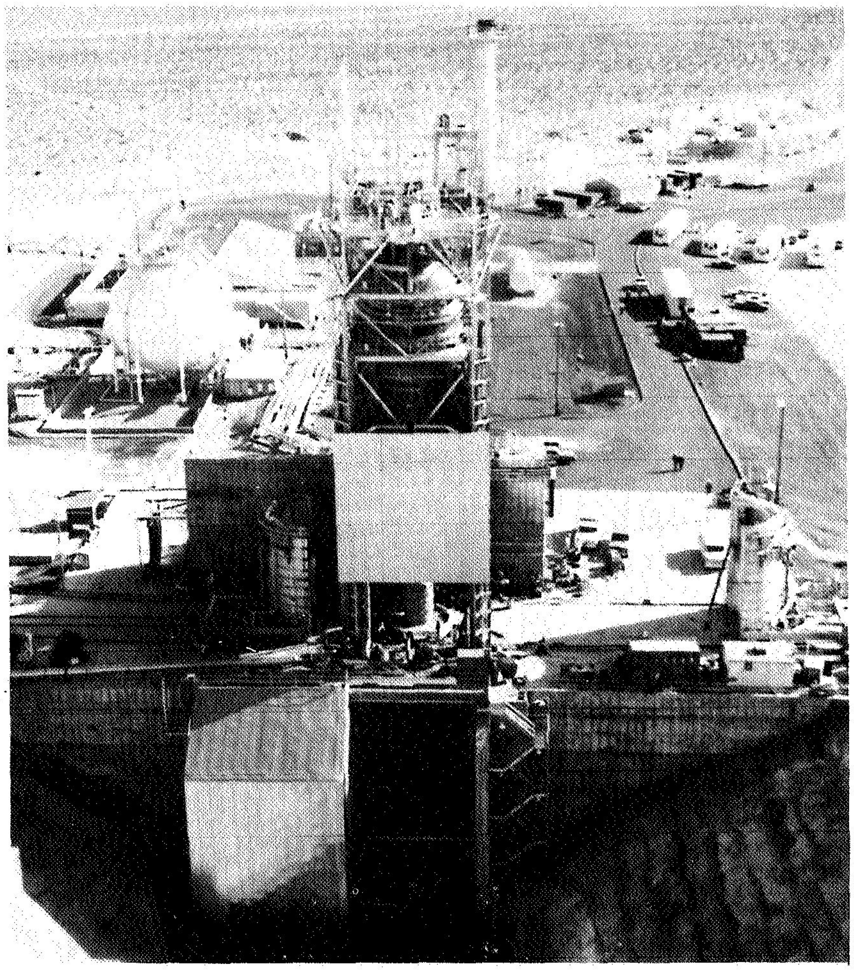


Figure 5–4. Engine Test Stand No. 1 (ETS–1)

Engine Operating Characteristics.—The XE tests will be the first tests of engines in a down-firing position and under simulated high-altitude conditions. Tank pressures comparable to those of a flight module will be used to start the engine. Engine steady-state and dynamic characteristics will be measured at various selected operating points to prove the engine design and analytical methods used to predict engine characteristics. Following power operation, the engine will be cooled with liquid hydrogen, comparable to the way flight engines will be cooled.

Control System Evaluation.—The control system for the XE engine will be simpler than that used for the breadboard engine system tests (NRX–EST) conducted in 1965/66. It will use temperature sensors for the primary control of the reactor instead of a combination of power and temperature sensors. In addition, tests will be conducted to start the reactor without using power feedback as was employed in the NRX/EST.

Checkout of Engine Test Stand No. 1.—All ground-experimental engine tests will be conducted in ETS–1 at the Nuclear Rocket Development Station (NRDS). The stand is designed so that the complete engine assembly can be remotely installed and removed by a specially designed mobile installation vehicle.

ETS–1 is a necessarily complex facility because of the intricacies imposed by the operational characteristics of nuclear rocket engines. It is the first known stand of its kind anywhere, and the technology and engineering which have gone into its development and construction is comparable to that of the XE engine.

During the report period, efforts continued toward making certain that ETS–1 would be ready to receive the first XE test article. The final check of the stand is to use a cold-flow version of the XE engine called the XE–CF. This engine was first installed in the stand in November. Later, as planned, the specially designed mobile installation vehicle removed and reinstalled it to demonstrate remote installation into the stand.

Ground Experimental Engine Test Program.—The ground experimental engine test program involves development testing of three XE engines. The XE–CF, now installed in ETS–1, is being used to determine the initial start characteristics of the engine in the stand, to investigate the characteristics of the test stand emergency shutdown system, and to provide training for the test crew.

The first engine to be tested under power conditions in ETS–1 will be the XE–1. This test series is to begin in the Fall of 1968. Following the XE–1 test program, the XE–2 will be installed and tested in ETS–1. An ambitious series of tests is being planned for these two engines involving some 11 intermediate power tests and 5 full-power tests.

Engine Maintenance, Assembly, and Disassembly.—The maintenance, assembly, and disassembly of ground experimental engines will be conducted in the E–MAD (Engine Maintenance Assembly and Disassembly) building at NRDS (Fig. 5–5). This building was largely completed during this report period, with the activation of the Cold Area in September and the Hot Area in December. The Disassembly Area will be activated in the Spring of 1968. The first use of the entire E-MAD facility will be for the XE-1 engine.

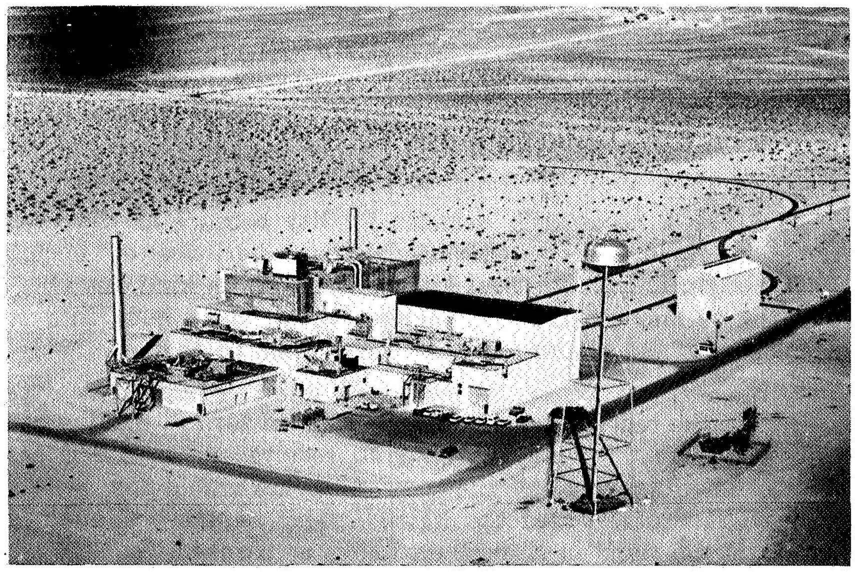


Figure 5–5. Engine Maintenance, Assembly and Disassembly Building (E-MAD)

NERVA Development

The performance characteristics established for the NERVA engine are a thrust of approximately 75,000 pounds, a specific impulse of 825 seconds, an endurance capability of about one hour, the capability for multiple restarts in space, and the highest reliability possible. When fully developed, this engine will differ substantially from the ground experimental engines now being tested.

A large nozzle extension will be used to achieve the desired specific impulse. The engine will be made smaller and lighter, and a new turbopump will be used to provide for more efficient flight operations. While the dimensions and design of the reactor nozzle, pressure vessel, and lines of the NERVA and XE engines will be similar, very little else will be.

The NERVA engine development will be based on the total available technology. The best features from the NERVA and Phoebus technology programs and from chemical rocket technology will be applied. In addition, available facilities and test equipment will be used for development and qualification of engine components and subsystems. Major system testing will be conducted at the NRDS, using existing facilities, reactor testing will be conducted in Test Cell "C", and engine system testing will take place in ETS–1.

Engine Test Stand No. 1 requires operational modifications to support flight readiness testing. More propellant storage is needed to provide increased propellant flow rate and operating duration. The exhaust system will be modified to meet the design specifications of the NERVA engine, which will operate at a higher flow-rate than the XE. In addition, the exhaust duct diameter will be increased to accommodate the nozzle skirt extension and to permit tests of engine gimballing for thrust-vector control.

During the first two years of the reoriented program, intensive reactor and non-nuclear component development is expected. Four reactors and seven or eight complete engines are to be tested under various operating and environmental conditions in the following years. The first fully flight-configured engine is to be tested in 1972, with flight rating testing expected in 1975 or 1976.

The best judgment today is that an operational system can be defined, based on a nuclear third stage for the Saturn V Launch. Such a stage would be useful for a variety of missions. A stage development program would be based on this type of operational system definition, and flight testing would be an integral part of the development of a complete operational capability.

Advanced Nuclear Rocket Propulsion Concepts

The nuclear rocket program advanced concepts work seeks to assess the feasibility and performance potential of nuclear rocket concepts which would theoretically out-perform the solid-core nuclear rocket.

During this period, the major portion of this work was directed toward the nuclear light-bulb concept in which the fissioning nuclear fuel is contained by a transparent wall. This concept is favored because of the potential of complete fuel containment. Even though there are some extremely complex problems associated with this concept, the problems lend themselves to definitive experiments which could prove or disprove basic feasibility.

Tests were initiated to provide data on certain of these problems, primarily on the thermal radiation environment in such an engine. The environmental tests were being conducted in a radio-frequency induction heater which provides energy directly to the simulated fuel gas. Other radio-frequency experiments are being conducted to obtain information on the spectral characteristics of test gases at high temperatures.

Experimental work supplemented by theoretical analysis continued on the second advanced concept, coaxial flow. This work was conducted to determine the effects of inlet flow geometries and velocity, and density ratios on the fuel containment characteristics in this open cycle concept. Critical experiments on cavity reactors conducted at the National Reactor Testing Station (NRTS) in Idaho have provided much basic information pertaining to the nuclear design of gas-core reactor concepts.

SNAP-8 DEVELOPMENT PROJECT

During this period, NASA and the AEC emphasized the testing of an improved turbine designed during the previous year. The Agencies also tested a new refractory metal boiler aimed at correcting major life-limiting deficiencies noted from previous development testing. Investigators inspected the modified turbine after 2,122 hours of operation. Finding that it successfully avoided the cracking noted with earlier designs, they planned to continue life development of this unit.

The thermal performance of the new boiler was evaluated; this boiler uses a refractory metal, tantalum, to correct the corrosion problems observed with the previous iron-based boiler tube. Initial results indicated that the boiler thermal design is satisfactory but that contaminants such as oxygen or oil caused degradation of thermal performance with time. A new full-scale boiler test facility was brought to operational status. This facility will permit acceleration of boiler endurance testing and better control of contaminants.

Investigators also continued the endurance testing of other major components of the SNAP–8 power conversion system which previously met their design requirements. The lube/coolant pump passed 10,000 hours of demonstrated endurance. This is the first major component to achieve this goal.

Finally, operation of the first breadboarded power conversion system was continued. This work was necessary to test the modified turbine and to continue obtaining overall power conversion system performance information needed for evaluation of the mercury Rankine system as a space power source.

NUCLEAR ELECTRIC POWER RESEARCH AND TECHNOLOGY

Research programs intended to establish the technological base required for future nuclear electric power systems continued to yield important results.

Rankine Turbo-Generator Technology

Progress continued in the fabrication of major test components of pioneering design. Assembly of the three-stage potassium vapor turbine containing refractory components was nearly complete, and the stator subassembly was undergoing aerodynamic testing with air (Fig. 5-6). Fabrication was completed on the advanced potassium corrosion loop and installation of instruments was started. This loop is capable of operation in vacuum at temperatures as high as 2100° F.

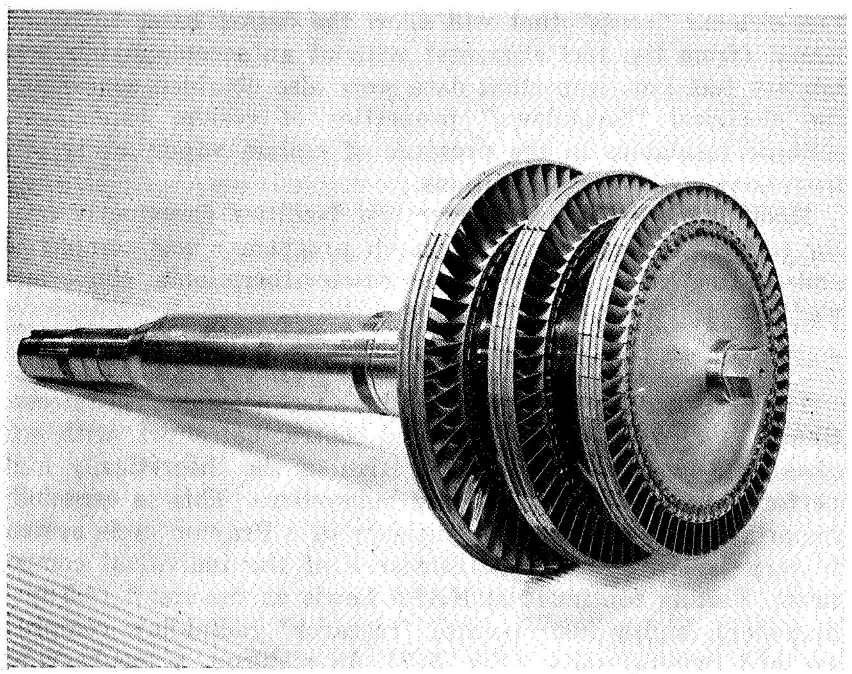


Figure 5–6. Advanced Rankine potassium turbine.

A 300° F increase in temperature capability appears feasible in the stator of the electromagnetic potassium boiler feed pump on the basis of design and test work. A high temperature braze material being incorporated into the potassium boiler feed pump stator fabrication may make this increase possible.

Thermionic Conversion Technology

Research programs investigating thermionic reactor-electric power system technology were continued under contract, at JPL, and at NASA-Lewis. Typical of these programs are in-pile and out-of-pile insulator evaluation test programs, long-term fuel-emitter materials fuel diffusion testing, performance evaluations of advanced thermionic converters (e.g., converters with rhenium emitters), and analog studies of thermionic reactor system stability and control. These programs are aimed at solving key performance and life-limiting problems.

Encouraging test results were obtained in efforts to solve the fission gas "venting" problem common to all thermionic reactor concepts presently proposed for lightweight power system applications. Preliminary data indicated that it is possible to design fuel element "vents" that will allow the fission gases to be released (from the fuel elements) without an accompanying prohibitive fuel loss. Important data were also obtained concerning the electrical "breakdown" properties of cesium vapor, and ceramic insulators in the presence of cesium vapor, at typical thermionic operating conditions.

Modification of JPL converter test facilities (previously used for solar-thermionic power research programs) was completed, and testing of contractor-built reactor-thermionic converters was begun.

Low Power Brayton Cycle Equipment

The Brayton cycle (turbogenerator) technology program continued as a combined in-house and contractual effort, with emphasis on experimental demonstration of the theoretically high performance of components and subsystems. This is especially important since the thermal efficiency of a Brayton cycle system is very sensitive to the performance of the individual components. Testing continued at NASA-Lewis on the small (4.5 inch diameter), highly instrumented "research" radial-flow compressor and turbine units. (Fig. 5–7). In addition, a gas-bearing-mounted radial turbocompressor package was operated for the first time at the rated design conditions of 1500° F turbine inlet temperature and 38,500 rpm shaft speed. A bearing pivot failure temporarily halted testing. A gas-bearing-mounted turboalternator, mate to the turbocompressor under test, was delivered to Lewis for testing.

Isotope Power

The SNAP-19 (isotope-thermoelectric) power system was flight approved as the power supply for the Nimbus B weather satellite to be launched in early 1968. Fabrication and flight qualification of the SNAP-27 (isotope-thermoelectric) ALSEP power system was also proceeding satisfactorily.

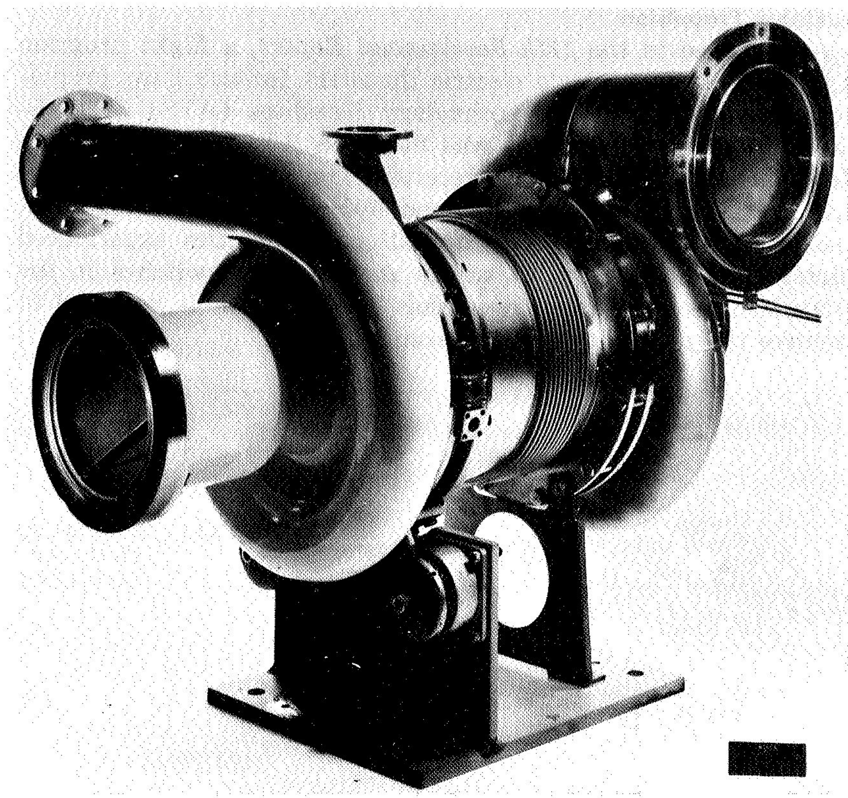


Figure 5–7. Radial flow–compressor.

The roles of AEC and NASA and of their in-house laboratories in the management and execution of the isotope-Brayton turbogenerator program were being established, with joint program planning to follow.

ELECTRIC PROPULSION PROGRAM

Electric thruster systems are of interest both for auxiliary propulsion functions (satellite position control, for example) and for prime propulsion of interplanetary spacecraft. In addition to being lighter than competitive chemical propulsion systems, electric propulsion systems offer certain unique features (electrical thrust vectoring for some applications). Recent studies showed that solar cell arrays providing power for electrically propelled spacecraft can perform interplanetary missions using smaller and less costly launch vehicles than equivalent missions using conventional chemical propulsion.

Auxiliary Propulsion

As reported in the *17th Semiannual Report,* a flight program is in progress to evaluate electric thrusters for auxiliary propulsion on the Applications Technology Satellites (ATS) (Fig. 5–8). A resistojet experiment was flown on ATS–III, launched in November. Telemetry data received from ATS–III indicated that thrust levels of about 40 and 400 micropounds were successfully produced. However, operational difficulties experienced during the flight test with valves and pressure switches in the propellant feed system showed that further work is required to improve the reliability of these components.

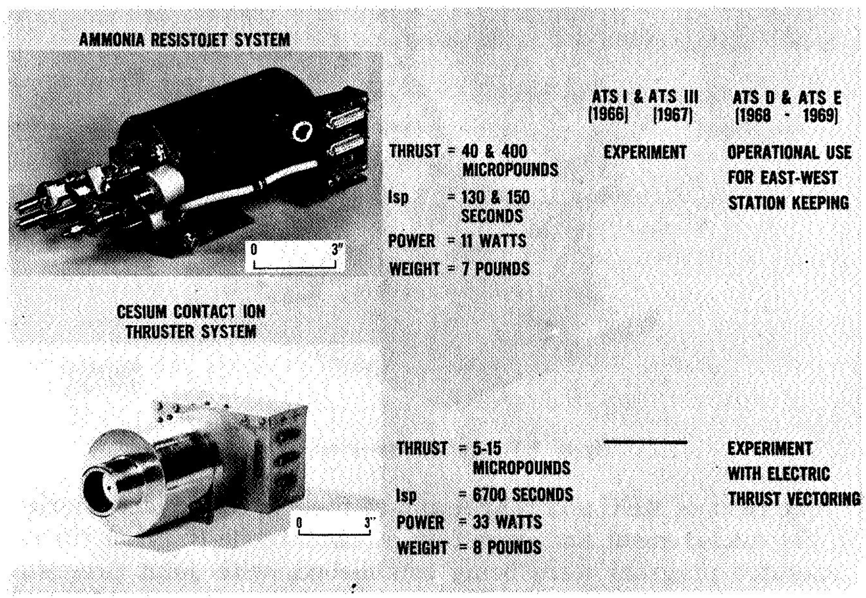


Figure 5–8. Auxiliary Propulsion Flight Technology Experiments.

Plans call for using a resistojet as the operational system to perform East-West station-keeping for the upcoming flights of the ATS–D&E spacecraft. Also, present planning calls for flight experiments of a cesium contact ion engine with a thrust vectoring capability on ATS–D&E. Development of this thruster was completed during the period, and one flight-qualified unit was delivered to the spacecraft contractor for integration into the ATS–D spacecraft.

Position control of a large manned orbiting vehicle calls for high specific impulse (300 to 700 seconds) to reduce propellant resupply requirements. High temperature resistojets, capable of achieving these levels of specific impulse, successfully completed preliminary testing with ammonia and hydrogen as propellants. Endurance testing is scheduled to follow.

Prime Propulsion

Two major efforts are continuing in the area of prime propulsion. The first is the development of flight hardware for the SERT II flight test scheduled for launch in 1969 (Fig. 5–9). This six-month orbital test of a 1-kilowatt mercury electron-bombardment thruster is primarily intended as a technology demonstration of the thruster in the space environment. Additional experiments are to be conducted to assess possible spacecraft interactions resulting from thruster operation. All major contracts in support of SERT II are in progress, and the prototype thruster was fabricated and tested to the required performance levels.

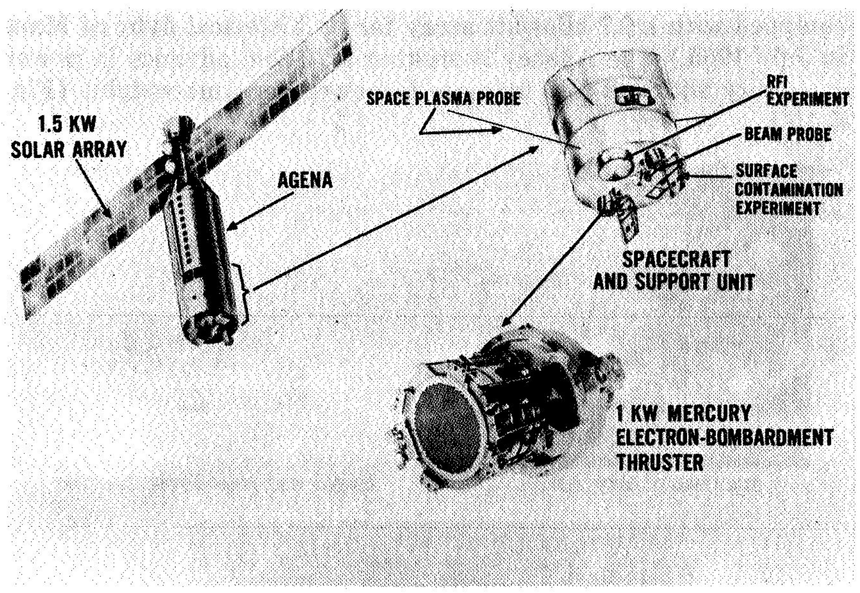


Figure 5–9. Space Electric Rocket Test (SERT-II).

The second major effort is directed toward a ground demonstration test of an ion thruster system to simulate the operational aspects of typical solar-electric missions. Preliminary performance tests of 2.5 kilowatt electron-bombardment thruster modules were conducted with an electrically isolated propellant feed system. Data obtained from these tests were used to prepare specifications for the power conditioning subsystem, to be procured under contract. Several concepts for spacecraft attitude control by proper positioning of the array of thruster modules were studied. Design of the selected concept for the system demonstration test was in progress.

SPACE POWER TECHNOLOGY

The Agency continued to emphasize research and technology directed toward more advanced space electric power systems using solar and chemical energy.

Solar Power Generation

NASA made progress toward developing the technology for large, lightweight solar cell arrays able to satisfy the power requirements on potential future spacecraft. The baseline model toward which the large solar cell array technology is aimed is a four-wing, 50-kilowatt array. (The Mariner IV spacecraft was equipped with a 0.7 kilowatt array for its historical flyby of Mars in July 1965.) The Agency is seeking a 70-fold advance in power capability with a 2-fold increase in power per unit weight. (Fig. 5-10.)

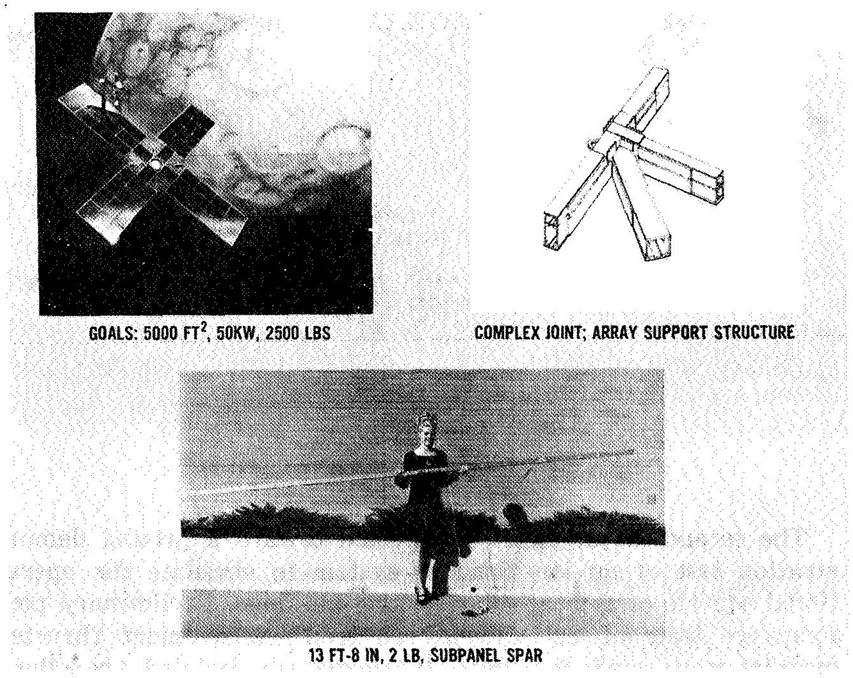


Figure 5–10. High Power Solar Cell Array.

A concept for supporting a new, lightweight type of silicon solar cell is being developed. Very lightweight and strong beryllium structures are under development for the array. These beryllium structures will support a mesh fiberglass substrate which, in turn, will provide a base for mounting up to one million thin silicon solar cells. The lightweight array technology should reduce the cost of transporting scientific instruments to the distant planets.

Chemical Power Generation

Among spacecraft batteries now in use, the silver oxide-zinc battery has the highest energy density. For discharges lasting ten hours or more, as much as 100 watt-hours per pound are obtained. The reason this battery is not always used in place of others, such as the silver oxide-cadmium and nickel oxide-cadmium batteries, is that it cannot be recharged very well. After a few hundred recharges, zinc is irretrievably lost from the anode and silver has migrated from the cathode into the separator and destroyed it.

To overcome this fault, a NASA contractor conceived of an inorganic battery separator as a replacement for the sausage casing normally used in silver oxide-zinc cells. During 3 years of development work, which included improvements in the zinc electrode and design of new cell construction and cases, the contractor produced a small (5 amp-hour) cell.

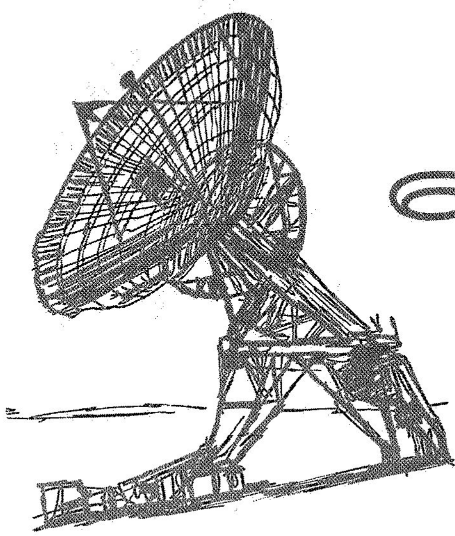
Samples of this cell have been cycled at room temperature more than 2,600 times to 20 percent depth of discharge, and more than 2,100 times to 30 percent depth. Even at the temperature of boiling water, some cells were cycled over 500 times to 30 percent depth. Others were taken through the sterilization cycle prescribed for spacecraft which will land on planetary surfaces and later performed satisfactorily. Though not quite ready for space use, such cells give promise of making rechargeable silver oxide-zinc batteries a reality.

Electrical Systems Technology

Design problems and operational failures in solid state power conditioning circuits have been a matter of concern to NASA for some time. One cause is the sharply rising currents which occur coincident with the (magnetic) saturation of the output transformer core and just before termination of the transistor switching cycle. These large "saturation currents" characteristically last only a short while and are generally referred to as "spikes," since they may be as high as five to ten times (or more) the normal or steady state current levels.

The energy represented by these current "spikes" is significant, and its dissipation within the circuit (principally in the power transistors) introduces undesirable power losses. More importantly, such spikes contribute to power transistor heating, to reduced life, and possibly to failure of the transistors.

Through recent research and development at the Electronics Research Center, techniques to solve this problem were devised and experimentally demonstrated. The ERC-devised technique makes it possible to detect the impending saturation of a transformer or inductor so the switching cycle can be ended before harmful saturation currents take place.



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TRACKING AND DATA ACQUISITION

The NASA tracking and data acquisition networks supported a very substantial workload during the report period. Support was provided to 74 flight missions, 18 of which were launched during the period. The major NASA missions launched included Apollo 4, Orbiting Geophysical Observatory IV, Lunar Orbiter V, and Surveyors IV, V, and VI.

Also during the period, Mariner V (launched in June 1967) successfully passed behind the planet Venus on October 19. During this encounter phase of the mission, the Deep Space Network stations received close-in measurements of the planet's atmospheric density.

Apollo 4 provided the first opportunity for the reconfigured Manned Space Flight Network to verify the operational capabilities of its new equipment, software, and personnel during an orbital Apollo-Saturn V mission. Much of the equipment and many of the techniques used during the mission represent significant advances in network capability. For example, this was the first time that satellite communications via Intelsat were used for high speed data communication in the mode required for Apollo. (Fig. 6–1.)

DEEP SPACE NETWORK

During the reporting period, the Deep Space Network (DSN) experienced its heaviest workload to date. Five new lunar and

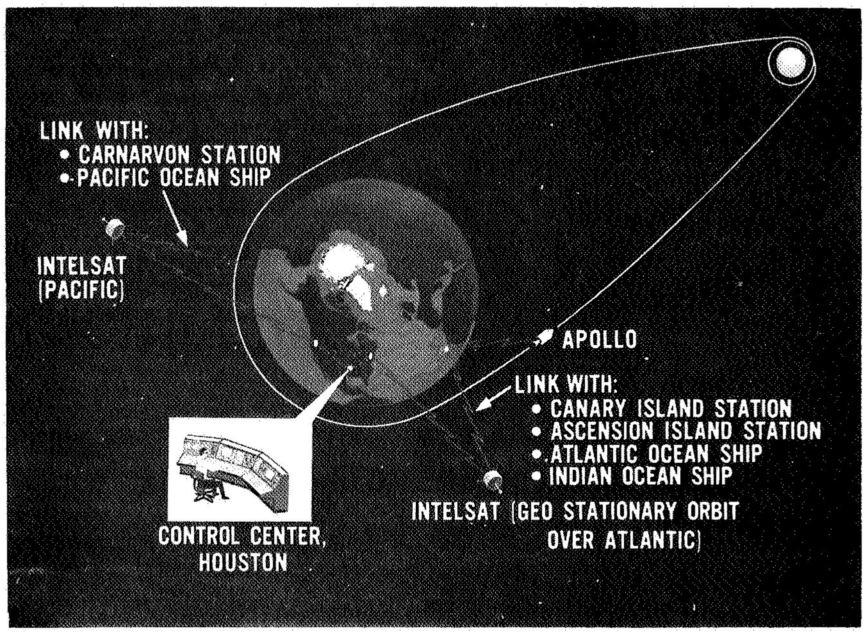


Figure 6–1. Use of Intelsat for communications.

planetary missions required extensive support from the facilities of the DSN. In addition, the Network continued to support eight missions launched before July 1, 1967. (Fig. 6–2.)

The five lunar and planetary missions launched this period were:

Mission	*Date Launched*
Surveyor IV	July 14
Lunar Orbiter V	August 1
Surveyor V	September 8
Surveyor VI	November 7
Pioneer VIII	December 13

In late August, the Network completed support of the primary objective of Lunar Orbiter V with the receipt of the 424th photograph at the tracking station in Madrid, Spain. On this final mission the network performed flawlessly, and the entire photographic mission was successfully completed. At period's end, the network stations were supporting Lunar Orbiter V in an extended mission phase and acquiring lunar environmental and gravitational data.

Another support highlight of the reporting period was related to the Mariner V mission. Launched June 14, 1967, the

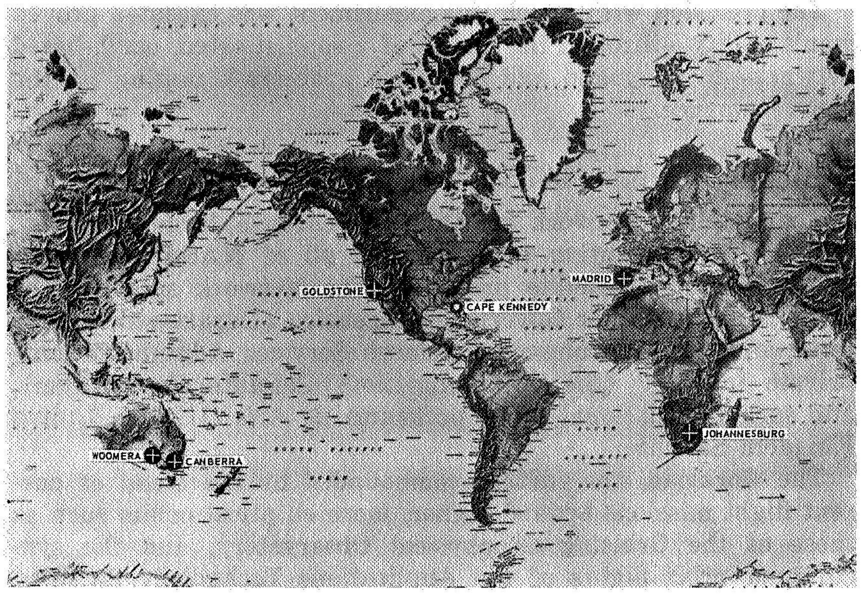


Figure 6–2. Deep Space Network.

Mariner V spacecraft successfully passed behind the planet Venus on October 19. The excellent support provided by the DSN permitted the spacecraft to pass within 2,500 miles of Venus, and to make close-in measurements of the planet's atmospheric density. After a flight of 217 million miles and an elapsed time of four months, the spacecraft deviated only 500 miles from the pre-launch projected flyby distance of 2,000 miles.

The Surveyor VI mission clearly demonstrated the effectiveness of the ground-based DSN facilities. On November 17, the Space Flight Operations Facility (control center for the DSN) sent commands to the spacecraft then resting on the surface of the moon, to restart the vernier engines. Responding to these commands, the spacecraft lifted off from its initial landing point and traveled a distance of about 13 feet to a new location.

Photographs received later at the Network stations from the spacecraft's cameras showed the footpad imprints in the original location and views of the path over which the spacecraft traveled. These photographs did not indicate any significant accumulation of lunar material on the footpads nor the spacecraft compartments, further adding to the Agency's confidence that the composition of the lunar surface is sufficient to support the Apollo Lunar Module.

The precision with which this experiment was executed proved man's ability—through the means of a sophisticated, earth-based network—to command and control a spacecraft resting on the moon's surface.

SATELLITE NETWORK

The Satellite Network continued to carry a large workload. (Fig. 6–3) In addition to supporting all of NASA's scientific and applications satellite programs, the Network supports the space efforts of other Government agencies (Department of Defense and the Environmental Science Services Administration), private industry (the Communications Satellite Corporation), and such international space programs as Ariel III, the United Kingdom Satellite.

The workload was further compounded by the trend of current flight missions toward higher, more elliptical orbits such as those of the Orbiting Geophysical Observatory, and the synchronous orbit flights of the Applications Technology Satellite. Missions such as these greatly increase the time a ground station views the satellite and receives data.

The electronic facilities of the Space Tracking and Data Acquisition Network (STADAN), operated under the management of the Goddard Space Flight Center, Greenbelt, Maryland pro-

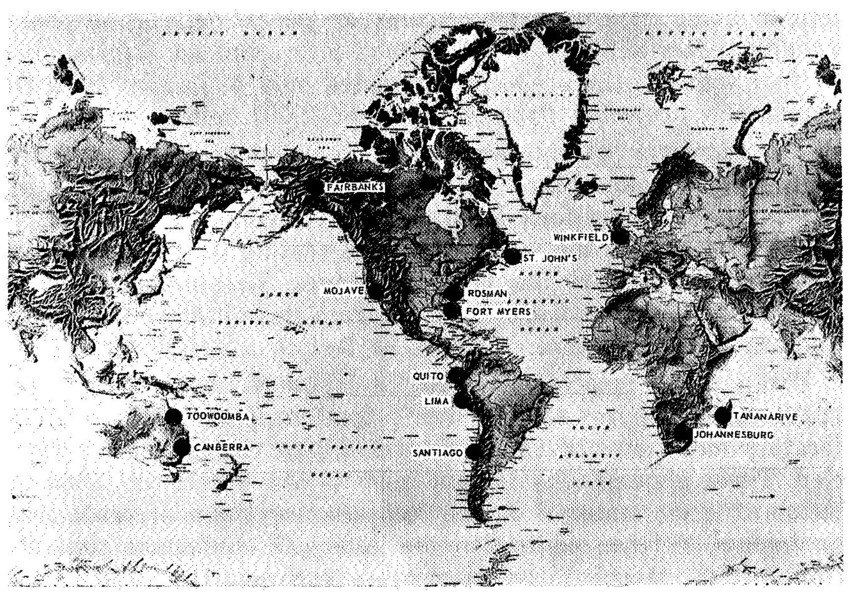


Figure 6–3. Sattellite Network.

vide this support. The STADAN stations are aided by a world-wide optical network of precision camera stations operated by the Smithsonian Astrophysical Observatory.

During the reporting period, the STADAN facilities supported sixty satellites, twelve of which were launched from July 1 through December 31, 1967:

Mission	*Date Launched*
*Dodge	July 1
Explorer XXXV	July 19
*OV1–86	July 27
*OV1–11	July 27
*OV1–12	July 27
*OGO–IV	July 28
Biosatellite II	September 7
**Intelsat II–D	September 27
OSO–IV	October 18
ATS–III	November 5
*ESSA–VI	November 10
*OV3–6	December 5

* Scientific satellites of other Government agencies.
** Communications Satellite Corporation (COMSAT).

The 45-hour flight of Biosatellite II produced new knowledge concerning the development of life forms in space, and the combined effects of radiation and weightlessness. The spacecraft, carrying wheat seedlings, pepper plants, frog eggs, amoeba and similar items, was successfully launched September 7 and planned as a three-day mission. During the second day of flight, however, a combination of circumstances—continuing problems in getting the spacecraft to accept ground commands, plus the fact that tropical storm Sarah was rapidly moving into the recovery area—led project officials to terminate the mission a day early.

Responding to this sudden change in the mission plan, network controllers, working with Biosatellite project personnel, began to compute a new Pacific Ocean recovery point, ahead of the westward moving storm. Recovery aircraft, based at Hawaii, were alerted to the early reentry plans.

On the satellite's next pass over the NASA station at Carnarvon, Australia, commands were transmitted to the spacecraft to start its deorbit sequences. Midair recovery was achieved approximately 15 miles from the recomputed impact point, permitting the samples to be returned to a laboratory within four hours of leaving the space environment.

MANNED SPACE FLIGHT NETWORK

NASA achieved significant progress in assuring readiness of the Manned Space Flight Network (fig. 6–4) to support the Apollo lunar landing mission. The remainder of the land stations required for Apollo support became operational and the construction work on the five instrumentation ships was completed. The modification of eight Apollo/Range Instrumentation Aircraft, shown in fig. 6–5, was completed, with the eight aircraft delivered to the Government on December 27. At the end of the period, the ships and aircraft were undergoing tests conducted by the Air Force and NASA. All are scheduled to become fully operational during the first half of 1968.

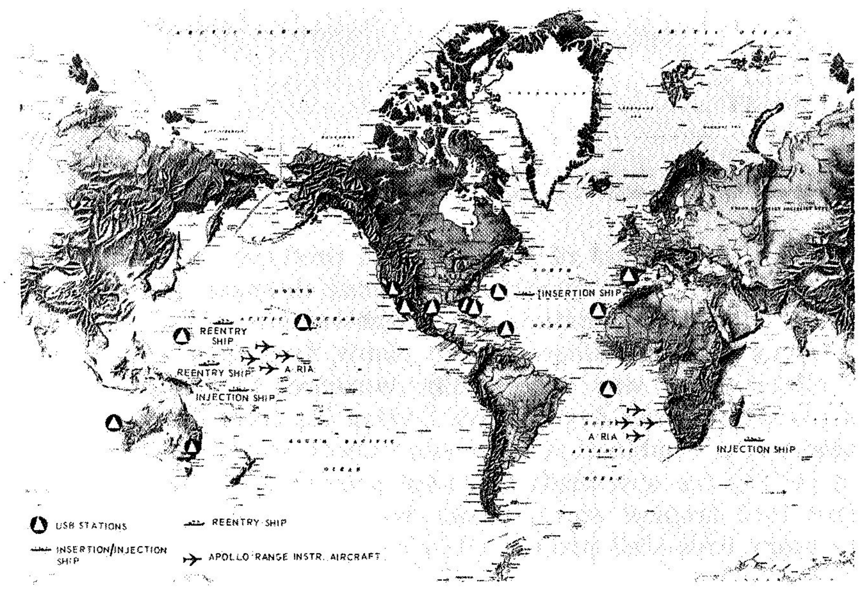


Figure 6–4. Manned Space Flight Network.

The first orbital Apollo mission was successfully launched November 9. With the exception of Madrid and Canberra (which were not required for this mission), all the land stations, five of the aircraft, and one ship—the Vanguard—participated in the mission. Apollo 4 enabled the Network to fully verify the operational capabilities of its new Apollo equipment, software, and personnel.

The Unified S-Band (USB) System, used for all communications between the earth and the Apollo spacecraft, performed

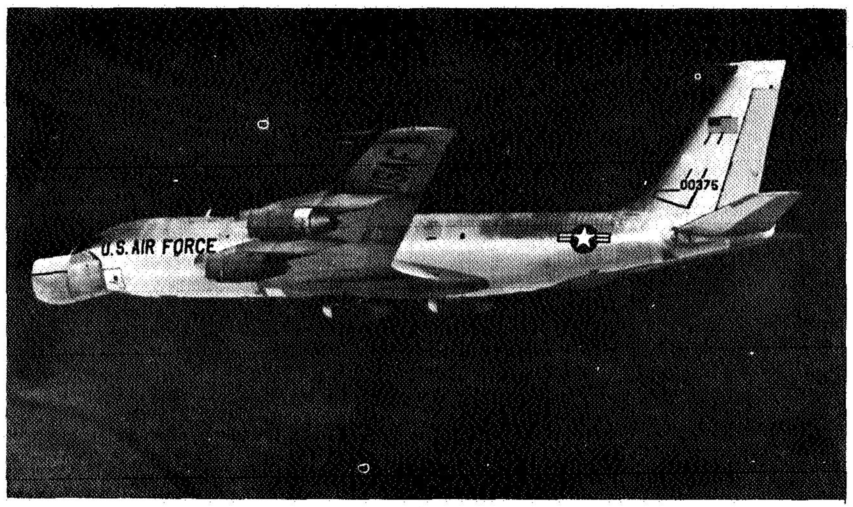


Figure 6–5. Apollo/Range Instrumentation Aircraft.

very well. The USB and other electronic systems aboard the Vanguard, positioned some 800 miles east of Bermuda, furnished data to verify the orbital insertion of the spacecraft. The five aircraft participated in the mission by providing engineering test support data to determine their operational capability.

Although this flight was the first major Apollo mission supported by the network's new capabilities, both the facilities and personnel performed in an excellent manner. The extensive preflight check-out and numerous mission simulations were evident in this performance.

The postmission evaluation of the network's performance showed that there were no system technical deficiencies nor any network-wide problems. The results of the evaluation clearly demonstrated the network's ability to perform the intricate functions required for successful Apollo lunar mission support.

Also during the reporting period, a Manned Space Flight Network Test and Training Satellite (TTS–1) was successfully launched piggyback from a Delta vehicle which injected the Pioneer VIII spacecraft into a solar orbit. At the end of the period, TTS–1, (fig. 6–6), was circling the earth in an elliptical earth orbit, was functioning well, and had an estimated lifetime of five months. TTS-1 provides the means for realistic simulation of network and control center operations for Apollo orbital missions. NASA will use it extensively before each Apollo launch in tests to assure the readiness of the Network. A second Test and Training Satellite was being fabricated for piggyback launch in 1968.

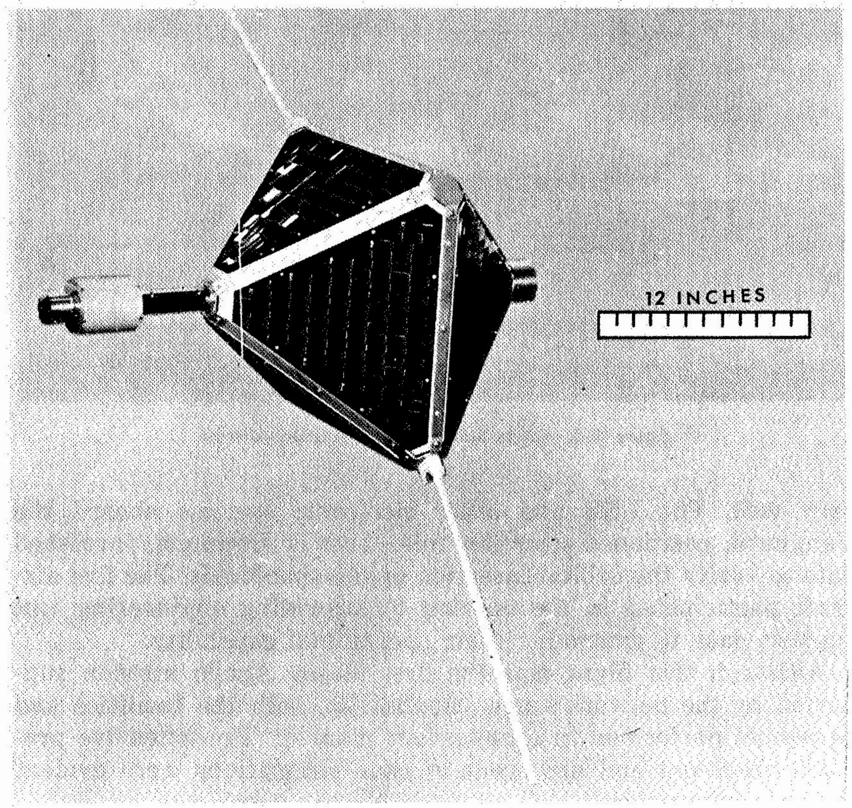
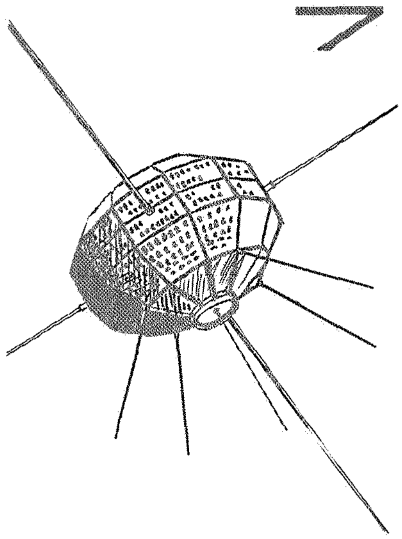


Figure 6–6. Manned Space Flight Network Test and Training Satellite.



7 INTERNATIONAL AFFAIRS

The number of international cooperative projects and support activities continued to increase during the period. The activities became broader, and the participating countries became more deeply involved. NASA made special efforts to engage developing countries in joint activity in space applications.

COOPERATIVE PROJECTS

During the second half of 1967, NASA cooperation with foreign governments continued to grow. Although no new cooperative satellite launchings took place (all 1967 launchings occurred in the first half of the year), several new projects demonstrated the versatility of the cooperative project approach and its susceptibility to innovation.

A new agreement was reached with the Italian Space Commission to extend the scientifically exciting and significant San Marco satellite project. Cooperative relations with India received new emphasis through an agreement to study possible use of future NASA space communications experiments to demonstrate the value of instructional television in the subcontinent. Agreement was also reached for launching NASA ionospheric payloads from the Thumba Equatorial Rocket Launching Station. The importance of access to foreign ranges was pointed up by a new agreement, reaching signature stage at year's end, to launch payloads from the Natal range in Brazil to sample radiation dosage in the Van Allen belts before and during Apollo flights. Finally, a new understanding with Brazil and Mexico was nearing signature; it provides for cooperation in the testing and use of remote sensors for earth resources survey from aircraft.

In all, eight new agreements were completed: two with the Brazilian Space Commission, two with the Indian National Committee for Space Research, and one each with Italy, Norway, Canada and Germany.

Australia

On November 29, 1967, Australia launched from the Woomera range a small scientific satellite prepared by the Australian Department of Supply. The launch vehicle was a modified U.S. Redstone rocket. NASA provided tracking and telemetry support and advised the Australian Department of Supply and the University of Adelaide on satellite design, construction, component procurement, and testing. The satellite successfully provided data during its nominal lifetime of about ten days.

Brazil

The Barreira do Inferno Range at Natai continued to be active, with 13 cooperative U.S./Brazil launchings during the reporting period. In November, an Aerobee 150 was launched to an altitude of approximately 130 miles to investigate day airglow emissions in an equatorial region. The launching of 10 Nike Cajun rockets from Natal continued the study begun in 1965 of winds, temperatures, and density changes in the equatorial mesosphere at different periods of the year.

The fist Nike Iroquois launch vehicles were used at the range in November when two were launched in engineering tests of a new system of payload recovery. Ultimately, this system will support a joint project to measure meteoroid flux in the upper atmosphere. The project, to be continued through 1968, will also train Brazilian recovery crews.

Canada

Two boosted Arcas rockets were launched in October from Resolute Bay, Canada, the northernmost launching station in Canada situated above the auroral zone. Access to this important site (through a National Research Council of Canada/NASA agreement) will enable NASA scientists to study polar cap absorption events and the D region ionosphere during the years of maximum solar activity. The program anticipates up to twelve sounding rockets through 1969.

European Space Research Organization (ESRO)

The European Space Research Organization (ESRO) was preparing the ESRO I and II satellites for 1968 launchings. Both satellites will be launched on Scout vehicles provided by NASA. The ESRO II satellite is a backup spacecraft which replaces the one lost in the unsuccessful launching attempt of May 1967.

As the period closed, NASA and ESRO staffs were exploring possible future areas of interest that might be suitable for cooperative projects.

Germany

NASA and the Max Planck Institute for Extraterrestrial Physics continued the highly successful barium cloud studies by launching a Nike Apache rocket from the European Space Research Organization site at Kiruna, Sweden (ESRANGE). At the same time, the Agency broadened its cooperation with Germany in sounding rocket work by including an agreement to launch from ESRANGE two payloads prepared by the Max Planck Institute for Nuclear Physics at Heidelberg. These payloads will investigate micrometeoroid flux and dust in the polar ionosphere and are to be launched in mid-1968.

The sounding rocket phase of the cooperative NASA/German radiation-belt research satellite project was completed early in December when a Nike Apache rocket was launched from the Kiruna Range. The purpose of this launch was to test proposed satellite instrumentation. Following completion of data analysis from this and previous sounding rocket firings, NASA expects a decision to proceed with preparation of the German satellite scheduled for launching late in 1969.

India

On October 2, NASA and the Indian Department of Atomic Energy agreed to form a Joint Study Group to consider using future NASA communications experiments, particularly the ATS F spacecraft, to demonstrate the transmission of instructional television into the villages of India. India will be completely responsible for the format and content of the instructional programs. NASA will help India study and define the technical requirements of the ground and space segments of the experiment.

NASA and the Indian National Committee on Space Research agreed to launch three boosted Arcas rockets from the Thumba Equatorial Rocket Launching Station (TERLS) in the spring of 1968. These launchings will investigate the electron density and collision frequency profile in the D region of the ionosphere, using a new low frequency transmission technique.

Italy

On October 14, San Marco II reentered the atmosphere as expected and was destroyed. During its 6 months of operation (launched May 1967), the satellite performed as designed and generated large quantities of data on variations in atmospheric density in the equatorial ionosphere. These new data are expected to be useful in equatorial aeronomy studies.

Efforts to continue the San Marco program were successfully concluded when NASA and the Italian Space Commission signed an agreement on November 18 to launch another Italian satellite. The spacecraft, designated San Marco C, will carry a more advanced version of the Italian air density experiment and will be launched from the San Marco platform off the coast of Kenya. The experimental payload will also include U.S. magneto sector and omegatron mass spectrometers to make more extensive and accurate investigations of density variation.

Netherlands

In October, a payload provided by the Netherlands Laboratory for Space Research (LRO) was launched from White Sands Range on a NASA Aerobee 150. The complex scientific mission successfully observed the spatial distribution of solar X-ray sources by means of zone plate telescopes.

Norway

In the August-September period, the Norwegian Council for Scientific and Industrial Research (NTNF) collaborated with NASA in launching from Andoya, Norway, three Sidewinder-Arcas rockets carrying experiments to investigate the quiet twilight ionosphere.

In September, NASA and NTNF reached an agreement to conduct a series of launchings on Nike-Tomahawk rockets from Andoya carrying barium cloud and direct measurement experiments. The scientific objectives were to compare the relatively new technique of measuring electric fields via barium ion clouds with proven methods of direct field measurement. These experiments were carried out successfully during late September.

Pakistan

NASA, the Pakistan Committee for Space and Upper Atmosphere Research (SUPARCO), and the British Science Research Council continued a tripartite cooperative project to measure wind temperature, pressure, and density by using the grenade technique. On November 29, a Nike-Apache was launched from the Sonmiani Beach launch area east of Karachi, Pakistan. Pakistan provided the launching services; the payload was constructed by the University College, London; and NASA provided the rocket and additional advisory and training services. It is expected that programs of this sort will be continued in 1968.

United Kingdom

Aeriel III, launched by NASA on May 5, 1967, as the third in a series of U.S.-UK cooperative satellite projects, continued to perform satisfactorily. Four experiments were returning scientific data as planned. A fifth experiment, to detect the amount of molecular oxygen present in the atmosphere, returned useful data during the planned instrument life. (NASA held a symposium in May, 1968, at NASA's Goddard Space Flight Center to formally present the scientific and engineering results of this project to the world community.)

Inter-American Experimental Meteorological Rocket Network (EXAMETNET)

The EXAMETNET operation continued active, with small meteorological rocket launchings from Argentina, Brazil, and Wallops Island coordinated for maximum scientific return. Argentina launched six and Brazil seven boosted Dart and Arcas rockets during this period.

UNITED NATIONS

The Assistant Administrator for International Affairs served as U.S. Representative to the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. The subcommittee met in New York from August 28 to September 6, 1967.

NASA's General Counsel attended the sixth session of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space; meetings were held in Geneva, Switzerland between June 19 and July 14, 1967. In addition, the General Counsel or his representative attended bilateral negotiation sessions between the U.S. and the U.S.S.R. (September through December) and a special 2-day session of the Legal Subcommittee (December 14–15). From these sessions came the draft of the Treaty on Rescue and Return of Astronauts which was ultimately approved by the General Assembly and signed by 40 countries including the U.S. and the U.S.S.R.

OPERATIONS SUPPORT

Other governments provided new or continued support for NASA activities abroad. Greece approved the stationing of a Smithsonian Astrophysical Observatory Baker-Nunn camera on its territory. In July, Iceland hosted a group of astronauts and geologists on an eight-day training expedition to the lunar-analog terrain in the interior regions of that country.

The intergovernmental agreement for a space vehicle tracking and communications station on Madagascar was extended through 1970. NASA made arrangements with the United Kingdon and South Africa for temporarily locating observation equipment within their territories in support of the National Geodetic Satellite Program (NGSP). Construction was completed for the telemetry and command station of ESRO near Fairbanks, Alaska.

As a part of the reconfiguration of the manned flight network for support of Project Apollo, the tracking and communication station on Canton Island was discontinued.

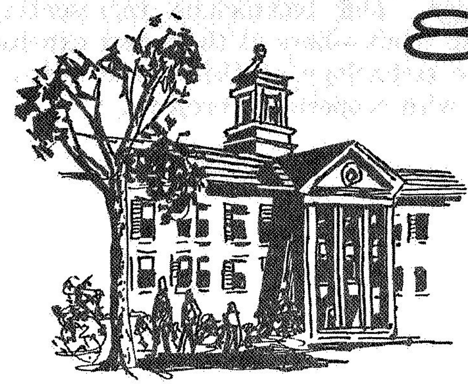
PERSONNEL EXCHANGES, EDUCATION, and TRAINING

During the second half of 1967, over 3,200 foreign nationals from 86 countries and separate jurisdictions visited NASA facilities for scientific and technical discussions or general orientation.

Under the NASA International University Fellowship Program, 62 students either entered the program or continued their studies. Fifteen countries and 19 universities participated in this program during the period. They were supported by their national space research sponsors or by the European Space Research Organization. This program is administered for NASA by the National Academy of Sciences.

One hundred and thirty postdoctoral and senior postdoctoral associates from 26 countries carried on research at NASA centers, including the Jet Propulsion Laboratory. This program is also administered by the National Academy of Sciences and is open to U.S. nationals.

Fifteen scientists, engineers, and technicians representing Germany, Japan, Mexico, and Spain—here at their own expense—received training in space technology at the Goddard Space Flight Center in connection with cooperative projects.



8 UNIVERSITY PROGRAMS

NASA's university program includes two parts: project-oriented research grants and contracts supported by NASA program offices and centers, and sustaining university grants for special training, research, and facilities. From 1958 through 1967, NASA invested about $572[1] million in universities; $379 million of that amount was in project-oriented grants and research contracts and $193 million was from the Sustaining University Program.

The approximately 1,400 project-oriented research grants and contracts now in effect are selected, supported, and monitored directly by NASA's program divisions and field installations. These grants and contracts cover research in diverse disciplines, including the physical and mathematical sciences such as astronomy and astrophysics; technological developments in aeronautics, electronics, controls, propulsion, space vehicles and instruments; atmospheric and earth sciences; life sciences; and behavioral sciences as related to the impact of aerospace science and technology on social and economic development. About half of the published scientific results of NASA's flight projects is based on work originating in the academic community.

The Sustaining University Program, established in 1961, was

[1] Not including California Institute of Technology's Jet Propulsion Laboratory or the Massachusetts Institute of Technology Apollo Guidance Contract.

used to strengthen universities which were contributing to the NASA program and to offset some of the burdens imposed on universities by heavy load of strictly project-related research.

SUSTAINING UNIVERSITY PROGRAM

During this period, a number of changes were made in the university program. Although NASA's broad objectives remain the same, the pace of the aerospace program has been modified and, correspondingly, the role of universities in the program has changed. Both the content and nature of the Sustaining University Program were adjusted to meet the changing conditions. Funding of new facilities on university campuses was held in abeyance, the Multidisciplinary Research portion of the program was reduced, and supplements to regular predoctoral training grants to universities were discontinued.

The four elements of the Sustaining University Program described below continued to be emphasized.

Multidisciplinary Research.—This element supports university research which is broader in scope and longer-ranged than the usual project-type research supported by other NASA program offices and centers. It stresses the development of coordinated programs with NASA field centers to strengthen joint government-university-industry research and cooperation; multidisciplinary studies of future technical needs for aerospace exploration, and examination of experience and knowledge from the space program that might be beneficial in dealing with other national problems; research on management and administration of large-scale scientific and technological programs; and of additional university competence contributing to the national aerospace effort. Multidisciplinary research grants continued at 56 universities.

Engineering Systems Design.—Pilot cooperative efforts in graduate education in engineering systems design were established at Stanford, Purdue, and Cornell Universities, Georgia Institute of Technology, and at the University of Kansas. This type of training is needed by engineers who can satisfy NASA's requirement for men to conceive, design, and develop the complex boosters, spacecraft, airplanes, and ground facilities which represent the main aerospace effort.

Management and Administration Research.—NASA supported graduate level training programs in public administration and management at the University of Pittsburgh and the University of Southern California. Research in the same fields was supported at Syracuse University, and plans were made for such a program at the University of New Mexico. Through these programs, university investigators can study NASA's experience in managing major aerospace projects and apply the knowledge to training and research in advanced management and administration and to the development of new methods, procedures, and ideas for NASA. In addition, such graduate education gives students the broad understanding of both management/administration and science/technology necessary to the future success of aeronautics and space programs.

Special Training Programs.—This category includes the Summer Faculty Fellowship Program, Summer Institutes for talented undergraduates, and a post-M.D. effort to provide advanced training in support of the manned space program.

Training

No new regular predoctoral training grants were issued during this period, but activity continued in the Predoctoral Training Program. From the traineeship grants issued in January 1967, 797 new students began their training in September 1967, making a total of 3,407 NASA trainees working full time toward the doctorate at 152 universities in the 50 states and the District of Columbia. Of these, 764 students began their training under the regular predoctoral program in space-related science and technology. In addition, 23 students at five institutions were selected specifically for training in engineering systems design and ten students at two institutions were selected specifically for training in administration and management.

The Summer Faculty Fellowship Program, which brings junior faculty members in engineering and science to NASA research centers for ten weeks of work and study, was established to help these instructors keep up with the latest technical developments in engineering and science. In this period, eleven universities and six field centers cooperated in offering research and study opportunities to about 200 faculty members.

NASA sponsored summer institutes for outstanding undergraduates during the summer of 1967 at Columbia University, the University of Southern California, University of Miami, and the University of California at Los Angeles. The principal objective is to acquaint selected upper division undergraduates with some of the substantive problems of space science and engineering. About 165 senior undergraduates received six weeks of specialized training in space science and technology in these institutes.

NASA continued to support training in aerospace medicine at two institutions—Harvard University and Ohio State University. In these efforts, a few select physicians receive advanced training concerned with environmental problems of man in space.

Resident Research Associateship Program

The National Research Council-National Academy of Sciences-National Academy of Engineering administer a program which is designed to allow postdoctoral and senior postdoctoral investigators to carry on advanced research at NASA field centers. Participants conducted research in fields such as astrophysics, airglow emission, high-energy physics, geomagnetism, instrumentation for direct atmospheric measurements, applied mathematics, electron microscope, comparative biochemistry, hypersonic aerodynamics, plasma flow, materials, and meteorites. The 153 scientists who were in this program were distributed among NASA centers as follows:

Goddard Space Flight Center		71
Institute for Space Studies, N.Y.	18	
Greenbelt, Maryland	53	
Ames Research Center		41
Marshall Space Flight Center		8
Langley Research Center		14
Manned Spacecraft Center		3
Jet Propulsion Laboratory		14
Electronics Research Center		2
Total		153

Research Facilities

The Space Sciences building at the University of Illinois, which was completed and dedicated, was the twenty-fifth completed under this program. They total 881,000 gross square feet of research space and accommodate over 2,500 scientists, engineers, and other researchers engaged in multidisciplinary research in space-related science and technology. In addition, three buildings already completed at the time of the 17th Semiannual Report were dedicated: The Space Sciences Building at Texas A&M on September 16; the Space Sciences Building at Cornell on October 19; and the Space Sciences and Technology Building at Georgia Tech on December 1. Cornerstone placement ceremonies were held for the Space Sciences Building at Rochester on October 3.

Table 8–1 summarizes the status of the 11 active grants.

Table 8–1. Research facilities in progress—December 31, 1967.

Fiscal year grant awarded	Institution	Topic	Area (1,000 s.f.)	Percent complete	Cost ($1,000)
1963	M.I.T.	Space Sciences	75	95	$ 3,000
1963	Wisconsin	Theoretical Chemistry	12	99	365
			87		$ 3,365
1965	Case Inst. of Tech.	Space Engineering	69	45	$ 2,226
1965	Rochester	Space Sciences	35	45	1,000
1965	Florida	Space Sciences	53	90	1,190
1965	Minnesota	Space Sciences	70	90	2,500
1965	Denver	Space Sciences	41	95	900
1965	Stanford	Space Engineering	65	40	2,080
			333		$ 9,896
1966	Wisconsin	Space Science & Engineering.	58	30	$ 1,694
1966	Washington	Aerospace Research	40	Design	1,500
1966	Kansas	Space Technology	56	Design	1,800
			154		$ 4,994
TOTALS			574		$18,225

Unsolicited Proposals

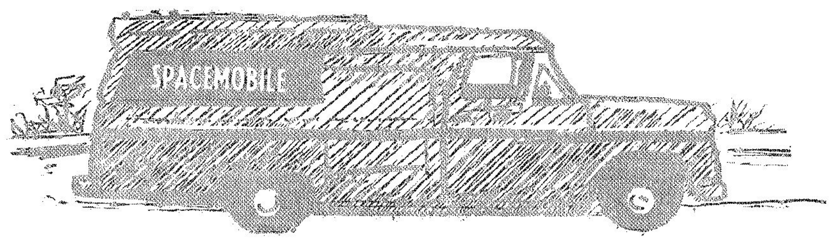
The Office of University Affairs is responsible for receipt and processing of proposals from universities and unsolicited proposals from all other sources. In the period, 1,472 proposals were received, 744 were rejected, 686 were funded, and as of the closing date 1,383 were still under review. The Office continued to prepare and distribute a monthly inventory of proposals under review, categorized by age and by responsible office. Although this service has markedly improved the NASA response time, further refinements and improvements were being tested.

MANAGEMENT OF GRANTS AND RESEARCH CONTRACTS

In December 1967, responsibility for actual negotiation and administration of grants and research contracts with universities and other non-profit scientific institutions was transferred from the Office of University Affairs. The purpose of this change was to centralize the grant and research contract business activities in the NASA Procurement Office, merge actual negotiation and administration operations in the Headquarters Contracts Office, and permit the Office of University Affairs to concentrate its efforts on the development of uniform agency-wide policies and guidelines for dealing with universities and on functional management of NASA's total university relationships.

Between July 1, 1967, and December 31, 1967, the Office of University Affairs and the Headquarters Contracts Division processed 621 procurement requests totaling $48.9 million and 323 grants and research contracts totaling $27.1 million.

9 INFORMATIONAL AND EDUCATIONAL PROGRAMS



To help meet the needs of education for the space age, NASA supplied educational materials, exhibits, lecturers, and consultants; sponsored conferences, seminars, and workshops; issued films and publications; and produced TV and radio programs. The Agency was also developing more efficient and economical methods of providing scientific and technical information to scientists, engineers, and program managers. Further, its Technology Utilization program continued to make available the inventions, discoveries and innovations from aerospace research and development for nonaerospace applications.

EDUCATIONAL PROGRAMS and SERVICES

In response to over 150,000 requests, NASA supplied educational materials on the Nation's aeronautics and space programs to students and teachers at elementary and secondary schools. The Agency also provided the publications, audiovisual materials, consultants, and some lecturers for 681 groups of more than 18,000 teachers. Related services included summer aerospace workshops and courses in 110 colleges and local school districts. The conferences, institutes, seminars, and other workshops were held in 39 states and in the District of Columbia. Answering inquiries on careers in the aerospace field, NASA continued to supply about 30,000 publications a year to guidance counselors and students.

To produce an *Aerospace Curriculum Resource Guide*—the first of its type in this country—NASA cooperated with the Massachusetts State Department of Education. The guide provides elementary and secondary schools of that state with numerous suggestions for enriching and modernizing their curricula through the use of space-related materials. Further, NASA assited in programs for the disadvantaged in Newport News, Va., Washington, D.C., Los Angeles, Calif., and at Navaho Indian Reservations in New Mexico and Nevada.

Spacemobiles

In 5,384 presentations before school children and educational and civic groups, spacemobile lecture-demonstration teams spoke on space science and exploration to 1,156,426 persons. Also, 27 spacemobile radio and TV programs reached an estimated audience of 2,568,000. Overseas there were spacemobile presentations in France, Libya, Brazil, Panama, Costa Rica, and the Philippines. Local lecturers, trained by NASA's spacemobile specialists, manned these units.

Educational Publications and Films

Thirteen new publications were released and seven new motion pictures produced (app. N). Among these were four booklets in the new *NASA Facts* science series for use by teachers of various grades in instructing in space science and exploration. Motion picture film catalogued and stored in NASA's depository amounted to 8,181,072 feet; 86,951 feet were supplied producers of educational and documentary motion pictures and telecasts.

Educational TV and Radio

NASA continued to provide the growing audience served by television and radio with information on aerospace research and development. Its monthly five-minute television program, *Aeronautics and Space Report*, covered a wide range of topics—the moon-mapping flights of Surveyor and Lunar Orbiter; research on future spacecraft; the Mariner V flight to Venus; jet aircraft noise reduction; and the rollout and launching of the Saturn V moon rocket. Two special programs were released: "The Fiftieth Year," a summary of NASA's participation in aeronautical research, and "Saturn: The Giant Step," a report on the flight of Saturn V.

For longer programs, NASA began to distribute ten half-hour films in *The Challenge of Space* series. The series consists of four motion pictures originally intended for other uses but adapted to television.

Production continued on several short films in the *Apollo Digest* series. These feature various facets of the Apollo Program and are jointly produced by NASA Headquarters, the Kennedy Space Center, Marshall Space Flight Center, and the Manned Spacecraft Center. They will be made available to television networks and to individual stations and producers.

In addition to providing this TV program material, NASA furnished guidance, information, and visual materials to the broadcasting industry. The Agency continued production and distribution of weekly five-minute programs in *The Space Story* series. Distributed to a substantial portion of the country's radio stations, these included reports on such topics as: Apollo; unmanned scientific space missions—Surveyor, Lunar Orbiter, Mariner to Venus, OGO, OSO, and ATS; and many aspects of advanced research for future air and space flights.

Other continuing radio services included the monthly 15-minute *NASA Special Reports* (for example, "Lunar Orbiter Results," "Langley 50th Anniversary," "Mariner V Results," "Apollo–4 Mission"); a series of one-minute informational announcements, *NASA Space Notes;* and periodic releases of *Audio News Feature* interviews on upcoming space missions.

SCIENTIFIC and TECHNICAL INFORMATION

To store and retrieve the expanding data resulting from aerospace research and development, information systems must undergo constant improvement. Efficient, economical techniques are required to provide more documents and journal articles to an increasing number of scientists, engineers, and program managers. NASA has made two substantial advances to meet this urgent need.

New NASA Thesaurus

The Agency published a preliminary edition of a new thesaurus to provide a standardized list of terms for indexing and retrieving documents in its scientific and technical information system. This approved vocabulary contains about 15,000 indexing terms (based primarily on the indexing vocabulary developed by NASA during 1962–66) accompanied by scope notes, subject categories, and cross references for each term. The *NASA Thesaurus*—in addition to its use in indexing all items processed in the Agency's scientific and technical information collection—will provide a common ground for indexing related files in other areas of technical documentation.

The *NASA Thesaurus* is closely related to the indexing vocabularies of other scientific and technical information systems. It was developed in collaboration with the Department of Defense's Project LEX—designed to produce a thesaurus of indexing terms to cover military fields. Project LEX, in turn, was carried out in the closest possible cooperation with the Engineers Joint Council, as the Council developed its thesaurus. This coordination assures effective communication among the technical information storage and retrieval systems of NASA, the Defense Department, and the Engineers Joint Council.

The RECON System

NASA also finished a series of tests of its planned RECON system for remote console interrogation of a large information bank. In this system, an engineer or scientist would sit at a console to conduct a remote "conversation" with a computer system storing information on scientific and technical documents. Answers to his inquiries would be supplied directly from documents stored in the computerized system, and he could check these answers on a viewing screen. Earlier tests conducted by two contractors demonstrated the feasibility and usefulness of this technique.

Technical Publications

In addition to the three-volume *NASA Thesaurus*, some other of the Agency's special publications are described in app. O.

TECHNOLOGY UTILIZATION

Numerous inventions, discoveries, and innovations derived from NASA's research and development were applied to nonaerospace industries, biomedicine and public health, education, and to various other facets of the Nation's economy. During 1967, 975 inventions and innovations from Agency and contractor laboratories were announced to business and industry through NASA's *Tech Briefs* and through compilations. Three of the compilations covered "Selected Machining and Metal Fabricating Technology," "Piping and Tubing Technology," and "Selected Shop Techniques."

The Agency also continued to publish *Technology Surveys* describing NASA's contributions in advancing the state-of-the-art of entire technical areas. Four were issued during the last half of 1967, a total of 17 to date. Twenty-six more were in various stages of preparation.

Industry, the universities, the medical community, and others responded increasingly to these Technology Utilization publications. During the year about 14,000 industrial inquiries were received for additional information on the technology announced in the *Tech Briefs* and related publications, an increase of 75 percent over 1966.

Biomedical Applications

NASA's three biomedical application teams—established at independent research institutes—expanded their relationships with biomedical research groups in university medical schools, research hospitals, clinics, and rehabilitation centers. A total of 180 medical problems were identified and specified by these teams. More than a dozen of them were solved by applying techniques developed through aerospace science and technology and several dozen more possible solutions were being evaluated.

The Social and Rehabilitation Service (SRS), Department of Health, Education, and Welfare, joined NASA in this program, and the Agency's biomedical application teams began to provide routine service to key research groups supported by the SRS. Also, the National Institute for Child Health and Human Development of the Department's Public Health Service began a project to examine the potential use of the biomedical application team approach.

Curriculum Enrichment Project

NASA's two-year pilot project, conducted by Oklahoma State University, to introduce the latest aerospace research and development information into standard engineering textbooks and classroom materials for graduate and senior undergraduate courses completed its first year. (*16th Semiannual Report*, p. 193.) Selected information from the Agency's technical reports was converted into 16 monographs for instructor and student use. Also, 21 visual briefs were prepared from short film clips produced by NASA laboratories during their tests and experiments. Professors at 39 universities were evaluating these educational materials in classroom settings.

Conferences

Several Technology Utilization conferences were held to call to the attention of nonaerospace industry—especially small businesses—technology emanating from NASA programs which could be useful to them. Some of these meetings for top executives of smaller companies were sponsored by the Agency and the Small Business Administration. They were conducted with the cooperation of the Office of State Technical Services, Department of Commerce; the Atomic Energy Commission; the Science Information Exchange, Smithsonian Institution; and the National Referral Center for Science and Technology, Library of Congress. Since the programs were highly successful, four more were planned for 1968.

Regional Dissemination Centers

NASA's eight Regional Dissemination Centers continued to match the results of Government-sponsored research and development with the needs of private industry. At the close of 1967, these Centers had a total annual membership of over 200 companies, not including organizations served on a pay-as-you-go basis.

COSMIC

The Computer Software Management Information Center (COSMIC) at the University of Georgia has gained wide acceptance by industry as a source of useful computer programs developed by NASA. By the end of 1967, 9,000 companies asked to be placed on the mailing list to receive regular announcements of new software—triple the number at the close of 1966. Over 1,000 COSMIC card decks and magnetic tapes were sold.

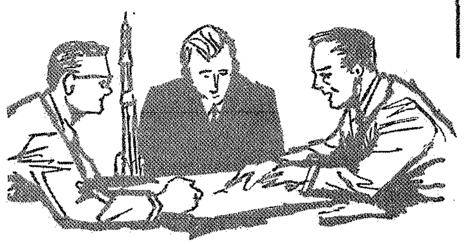
The Department of Defense and the Atomic Energy Commission plan to join NASA in disseminating their computer software through this Center.

Interagency Cooperation

Through joint Technology Utilization programs NASA cooperated with other Federal agencies to save money and avoid duplication in disseminating technical information to industry. The Agency continued to assist the Atomic Energy Commission in issuing *Tech Briefs* on new technology developed in AEC laboratories—98 of these were released in 1967.

In addition to sponsoring conferences with the Small Business Administration (SBA), NASA joined in SBA's new pilot program to distribute *Tech Aids* to 20,000 small companies. These publications, in general, contain technical information derived from Federal research programs, particularly NASA's. Also, cooperative programs continued with the Bureau of Reclamation, Department of the Interior; the Social and Rehabilitation Service, Department of Health, Education, and Welfare; and with other agencies.

10 PERSONNEL, MANAGEMENT, PROCUREMENT, AND SUPPORT FUNCTIONS



NASA placed increasing emphasis on its personnel, management, procurement, and other non-technical support activities during the period. Primary aims included upgrading the capabilities of its employee force, making its management structure more responsive to the changing mission requirements, and controlling costs throughout all program aspects.

PERSONNEL

The Agency's personnel program continued to stress training programs that would enhance the productivity of its employees, maintained its emphasis on improved employee-management relationships, furthered its equal employment opportunity program, and made certain key personnel assignments to assure better program management.

Training Activities

NASA continued its agency-wide seminars to provide specialized training for program and project teams, particularly in the areas of procurement and contract cost management.

The Agency conducted a two-week training program in financial reporting for field installation personnel. This program allowed these employees to observe the agency-wide reports prepared from installation data, to become acquainted with their counterparts at Headquarters, and to exchange ideas. Representatives of four installations participated in this activity.

Seventeen NASA employees entered nationally competitive fellowship award programs. Eight received Sloan fellowships, five going to MIT and three to Stanford. Other awards were as follows: National Institute of Public Affairs, four; Princeton-Woodrow Wilson, one; Industrial College of the Armed Forces, one; Congressional Operations Fellowship, two; and the Hugh L. Dryden Memorial Fellowship, one. This number of NASA participants is the largest ever to participate in such programs, six more than during the preceding year.

NASA installations also continued supporting graduate education; cooperative education; apprentice, science, and engineering lecture programs; and a wide variety of management and skills training.

Employee-Management Cooperation

NASA continued to support the government-wide program for Employee-Management Cooperation in the Federal Service (Executive Order 10988). Agency Headquarters approved the collective bargaining agreement between the Manned Spacecraft Center and Lodge 2284, American Federation of Government Employees (AFL–CIO) and the one between the Lewis Research Center and Lodge 2182, American Federation of Government Employees (AFL–CIO). It also approved a similar agreement between the Langley Research Center and the Newport News Association of the Pattern Makers League of North America (AFL–CIO).

The Langley Research Center granted informal recognition to Lodge 2755, American Federation of Government Employees (AFL–CIO). Meanwhile, the Goddard Space Flight Center granted informal recognition to Lodge 2748, American Federation of Government Employees (AFL–CIO).

On October 31, 1967, the Personnel Division informally settled an alleged unfair labor practice charge filed by Lodge 892, International Association of Machinists and Aerospace Workers (AFL–CIO) against the Langley Research Center.

Equal Employment Opportunity

Complying with Civil Service Commission directives, the Agency conducted a visual survey of minority group employment to provide statistical data needed to assess progress in the area of equal employment opportunity.

The NASA Lewis Research Center, in conjunction with the Cleveland Federal Executive Board, conducted a special preapprentice training program for 100 area Negro youths. The objective of this program was to improve the ability of Negroes to compete with others seeking training positions in construction trades apprentice programs.

Status of Women

NASA field establishments were directed to submit quarterly narrative reports on the Federal Women's Program. These reports are needed to comply with Civil Service Commission directives and to assess the progress in providing equal opportunity for women. During the period, the number of women employed in grades GS–12 and above increased from 231 to 236.

Key Executive Personnel Changes

During the period, 17 changes occurred within the Agency's key executive personnel staff. Four individuals were appointed to key positions, eleven were reassigned, and two terminated their services.

Key Appointments.—On August 27, Leonard Rawicz was appointed as Assistant General Counsel for Patent Matters. Previously, he had been the Chief Patent Advisor at the Goddard Space Flight Center. In October, he was also appointed as Vice Chairman of the Inventions and Contributions Board.

Miles Ross was appointed as Deputy Director for Center Operations, John F. Kennedy Space Center (September 17). He had previously been manager of the Florida Operations of TRW Systems, Inc.

Donald R. Morris was appointed (October 8) as Deputy Assistant Administrator for International Affairs. He previously served as Special Assistant to the Under Secretary of State and as a Foreign Affairs Officer.

On December 3, Francis J. Magliato was appointed as Executve Secretary, NASA. Mr. Magliato joined the staff of the Administrator in August 1966, coming from the NASA George C. Marshall Space Flight Center where he had been an executive assistant to the Center Director.

Reassignments.—On October 1, Dr. Homer E. Newell, Jr., was appointed as Associate Administrator. Dr. Newell served as Associate Administrator for Space Science and Applications from November 1, 1963. He had headed the space science programs of NASA from their inception in October 1958.

Clifford H. Nelson was appointed as Assistant Director (Group I), NASA Langley Research Center (October 2). From September 1963, Mr. Nelson had served as Project Manager, LUNAR ORBITER. Before that, he had been a research scientist and supervisor at the Langley Center.

On October 11, S. Neil Hosenball was appointed Deputy General Counsel. He served as Assistant General Counsel for Procurement Matters from January 1966; previously, he had been Chief Counsel at the NASA Lewis Research Center.

Edgar M. Cortright was appointed Deputy Associate Administrator for Manned Space Flight on October 16. He had been the Deputy Director, then Deputy Associate Administrator (from 1963), of the Space Science and Applications Program.

John A. Naugle was appointed Associate Administrator for Space Science and Applications (October 18), succeeding Dr. Newell. Dr. Naugle served as Deputy Associate Administrator for Space Science and Applications (Sciences) from May 1966. Earlier, he had been Director of Physics and Astronomy Programs.

On October 22, Oran W. Nicks was appointed as Deputy Associate Administrator for Space Science and Applications, succeeding Mr. Cortright. Previously, Mr. Nicks served as Director for the VOYAGER Program, and before that he had been Director of Lunar and Planetary Programs.

Also on October 22, Donald P. Hearth was appointed Director of Lunar and Planetary Programs. He had served as Deputy Director, VOYAGER Program, from February 1967, and as Assistant Director for Planetary Flight Programs, Lunar and Planetary Programs, from January 1966.

George H. Hage was appointed, on October 22, Deputy Director, APOLLO Program. He served as Deputy Associate Administrator for Space Science and Applications (Engineering) from July 1967. He came to NASA from the position of VOYAGER Program Manager with the Boeing Co., Seattle.

George S. Trimble, Jr. was appointed as Deputy Director, NASA Manned Spacecraft Center, Houston, Texas, (November 19). Mr. Trimble joined NASA in April 1967, as Director, Advanced Manned Missions Programs, in the Office of Manned Space Flight, NASA Headquarters.

On December 17, Vincent L. Johnson was appointed Deputy Associate Administrator for Space Science and Applications (Engineering), succeeding Mr. Hage. He previously served as Director of Launch Vehicle and Propulsion Systems (from June 1964), and as Program Manager, CENTAUR (from October 1962) in this same office.

On December 17, Paul E. Cotton was appointed Director, Programs and Resources Division of the Office of Advanced Research and Technology. He had served as Director, Manned Space Flight Management Operations (from September 1965) and, previously, as an executive assistant to the Associate Administrator for Manned Space Flight.

Terminations.—Richard L. Callaghan resigned from the position of Assistant Administrator for Legislative Affairs on July 3. He served in this capacity from October 1963. Earlier (from July 1962), he had been a Special Assistant to the Administrator.

General Charles R. Roderick, U.S. Air Force, Retired, resigned from the position of Special Assistant to the Administrator, October 25, 1967. He had joined NASA in this capacity June 1, 1967, following his retirment from the Air Force.

NASA Awards and Honors

During the period, NASA presented fifty awards, giving recognition to individuals and groups for their contributions to the Nation's space program.

Distinguished Service Medals.—Homer E. Newell, received the Distinguished Service Medal in recognition of his distinguished service as a scientist and administrator.

Edgar M. Cortright, Headquarters, received the Distinguished Service Medal in recognition of distinguished engineering and administrative leadership in the management of NASA's Office of Space Science and Applications and service in the establishment of the United States Lunar and Planetary Exploration Program.

Floyd L. Thompson, Langley Research Center, was awarded the Distinguished Service Medal in recognition of his many years of distinguished leadership and service in aeronautical and space research and development as Director of the Langley Research Center.

Raymond L. Bisplinghoff, formerly Headquarters, received the Distinguished Service Medal in recognition of his distinguished leadership and service in developing sound doctrine, advanced concepts, and practical methods for applying criteria valuable as guides to judgment in the allocation of resources in rapidly moving areas of complex aeronautical and space technology.

The Distinguished Public Service Medal.—This medal was presented to Charles Stark Draper, Massachusetts Institute of Technology, in recognition of his distinguished service in advancing the technology of aeronautics and space, applying new engineering concepts to complex large systems, and in developing new and effective ways to improve graduate engineering education.

The Exceptional Service Medal.—Twenty-one Exceptional Service Medals were presented as follows:

Name	*Location*
Roger B. Chaffee (Posthumous)	Manned Spacecraft Center
Donald R. Bellman	Flight Research Center
William J. Boyer	Langley Research Center
William Cohen	Headquarters
George C. Deutsch	Headquarters
Robert H. Gray	Kennedy Space Center
Howard H. Haglund	Jet Propulsion Laboratory
Charles F. Hall	Ames Research Center
Arthur F. Hood	Headquarters
James J. Kramer	Lewis Research Center
Laurence K. Loftin, Jr.	Langley Research Center
Joseph B. Mahon	Headquarters
Paul G. Marcotte	Goddard Space Flight Center
James S. Martin, Jr.	Langley Research Center
Benjamin Milwitzky	Headquarters
Clifford H. Nelson	Langley Research Center
Robert J. Parks	Jet Propulsion Laboratory
H. Warren Plohr	Lewis Research Center
Robert D. Reed	Flight Research Center
Lee R. Scherer	Headquarters
William M. Shea	Headquarters

The Exceptional Scientific Achievement Medal.—This medal was presented to the following eight individuals:

Name	*Location*
Michel Bader	Ames Research Center
Donald E. Gault	Ames Research Center
Walter B. Horne	Langley Research Center
Samuel S. Manson	Lewis Research Center
William H. Phillips	Langley Research Center
Eugene M. Shoemaker	U.S. Geological Survey
Israel Taback	Langley Research Center
Maurice D. White	Ames Research Center

The Exceptional Bravery Medal.—This medal was presented to the following six individuals:

Name	*Location*
Donald O. Babbitt	North American Rockwell
Stephen B. Clemmons	North American Rockwell
James D. Gleaves	North American Rockwell
Jerry W. Hawkins	North American Rockwell
L. D. Reece	North American Rockwell
Henry H. Rogers	Kennedy Space Center

The Group Achievement Award.—Four Group Achievement Awards were presented as follows:

Apollo 204 Review Board

Supersonic Transport NASA Evaluation Team
Lunar Orbiter Spacecraft and Operations Team
260-inch Solid Motor Project Team

Public Service Award.—NASA presented this award to the following six individuals:

Name	*Location*
Richard Cottrell	Aerojet General Corp.
Paul P. Datner	Aerojet General Corp.
William Feldman	Eastman Kodak Company
Robert J. Helberg	Boeing Corp.
Robert L. Roderick	Hughes Aircraft Company
Mark Sasso	RCA

Status of Personnel Force

These figures represent total employment (including temporaries) for the periods ending June 30, 1967, and December 31, 1967.

	June 1967	*December 1967*
Headquarters	2373	2176
Ames Research Center	2264	2171
Electronics Research Center	791	785
Flight Research Center	642	607
Goddard Space Flight Center	3997	3752
Kennedy Space Center	2867	2782
Langley Research Center	4405	4211
Lewis Research Center	4956	4623
Manned Spacecraft Center	5064	4728
Marshall Space Flight Center	7602	7288
NASA Pasadena Office	91	87
Space Nulcear Propulsion Office	113	117
Wallops Station	576	509
Western Support Office	119	103
TOTAL	35,860	33,939

INVENTIONS AND CONTRIBUTIONS BOARD

NASA's Inventions and Contributions Board is responsible for three principal functions, as described in detail in Chapter 10 of NASA's *17th Semiannual Report.* Briefly, the Board reviews petitions for waiver of patent rights that have been submitted by contractors, and recommends the proper disposition to the Administrator. It also recommends the granting of monetary awards to NASA and NASA-contractor employees who have reported inventions or made other significant contributions to the advancement of the space and aeronautics program. Finally, the Staff of the Board replies to correspondence which is received from sources outside NASA and which contains suggestions, contributions, and proposals offering solutions to the Agency's technical or scientific problems.

With regard to the second function, NASA broadened its monetary awards program during this reporting period by authorizing the Board to recommend granting the following awards:

1. A minimum of $25 to each NASA or NASA-contractor employee who participates in the development of a scientific or technical innovation that is subsequently published as a NASA Tech Brief.
2. A minimum award of $50 to each NASA or NASA-contractor employee who conceives and reports an invention upon which a U.S. patent application is filed.

In each of these cases, the recipient of the minimum award is also eligible for a supplemental award if a technical evaluation of the invention or innovation indicates that it has special merit.

The members and the Director of the Staff who are now serving on the Board were appointed by the Administrator of NASA on December 13, 1967, and their names are listed in app. I.

Petitions for Patent Waivers

In general, there are two types of petitions for patent waivers, as identified in the *17th Semiannual Report,* ch. 10 (waivers for specific inventions, and waivers for all inventions made during the performance of a contract). During the period covered by this report, the Staff analyzed, evaluated, and presented to the Board 67 petitions for waiver of patent rights to individual inventions. Following its consideration, the Board forwarded its findings and recommendations to the Administrator. The Administrator granted 56 petitions for waiver and denied 11. (Petitioners are listed in app. J).

During the same period, 14 petitions for blanket waiver, i.e., a waiver of patent rights to all inventions that may be made during the performance of a contract, were also analyzed and evaluated by the Staff, and presented to the Board. Of these, the Administrator granted 11 and denied 3 (listed in app. K). In addition, the Administrator granted 6 petitions for blanket waiver, prior to the issuance of a contract, that had been considered by the Advance Waiver Review Panel (listed in app. K). The Board also considered 3 additional petitions for patent waiver that were prepared and presented by the Staff, but deferred final action on them.

In November, the Staff of the Board was assigned the additional responsibility of preparing and transmitting an annual request for information to all petitioners who have been granted a waiver of U.S. patent rights by the NASA Administrator. This request seeks from each petitioner a report on activities completed during the past year and activities planned for the coming year directed toward the commercialization of the invention for which the petitioner received the patent waiver. If a petitioner has not promoted the commercialization of an invention appropriately, NASA, under certain circumstances, may void and withdraw the patent waiver from the petitioner to whom it was originally granted, and take title to the invention so that licenses can be granted to other companies which may wish to develop the invention for commercial purposes.

Approximately 200 waiver recipients were asked to supply the information described above; at the close of this reporting period, the staff was analyzing the replies received.

Monetary Awards for Inventions and Contributions

Under the authority of Section 306 of the Space Act, the Board recommended the granting of three types of monetary award during this period. The first type is for scientific and technical contributions which have undergone a detailed technical evaluation and are subsequently considered for an award of $250 or more. A total of 34 such contributions were considered by the Board. The Board recommended, and the Administrator granted monetary awards of more than $250 for two of these contributions. Titles of the contributions and names of the award winners are listed in app. L. An additional 23 contributions were also recommended by the Board for awards of more than $250, but final action on these cases had not been completed by the end of the reporting period. The remaining nine cases were considered but were judged to be of insufficient merit, and the Board recommended that no monetary awards be granted for them.

The second type of award authorized by the Space Act is the $50 *minimum* award that is made when a U.S. patent application is filed on an invention. During this period, a $50 minimum award was granted to each of 24 individuals who participated in the reporting of 13 inventions upon which U.S. patent applications were subsequently filed. The third type of Space Act award is a minimum award of $25, and it was granted to each of 178 individuals who participated in the development and reporting of scientific and technical innovations that were later published in the form of 120 NASA Tech Briefs.

Under the provisions of the Government Employees' Incentive Awards Act of 1954, the Board has another authority for granting monetary awards for inventions and other scientific and technical contributions. During this period, 110 such cases were considered by the Board and were granted monetary awards. A listing of these awards, arranged by the NASA Research Center which submitted them, appears in app. M. The names of the U.S. Government employees who received awards under this authority are listed in app. M.

ORGANIZATIONAL IMPROVEMENTS

NASA made certain organizational changes during the period to realign specific functions and to strengthen its executive structure.

At Headquarters, an Associate Administrator was appointed to provide a focal point for developing, reviewing, and coordinating Agency policy, programs, and plans. He also assists the Administrator with major decisions, including Source Evaluation Board actions. Reporting directly to the Associate Administrator are the Assistant Administrator for Policy and the Assistant Administrator for Program Plans and Analysis.

The Associate Deputy Administrator was assigned overall responsibility for executive leadership of NASA's external relationships with government and with the general public. Reporting to him are the Assistant Administrator for DOD and Interagency Affairs (formerly Office of Defense Affairs), the Assistant Administrator for International Affairs, the Assistant Administrator for Legislative Affairs, and the Assistant Administrator for Public Affairs.

An Assistant Administrator for Management Development was appointed to assist the Administrator in directing, controlling, and reviewing the activities that document management policies, systems, and other essential administrative regulations.

A Communications Center was established to review all NASA incoming mail and the outgoing mail from the Administrator's office, and to make certain that the appropriate organizational elements have been involved in preparing or coordinating it.

An Aerospace Safety Working Group was established to evaluate NASA's safety responsibilities and programs. The Working Group, consisting of senior NASA officials, was assessing the most productive and effective role for the Aerospace Safety Ad-

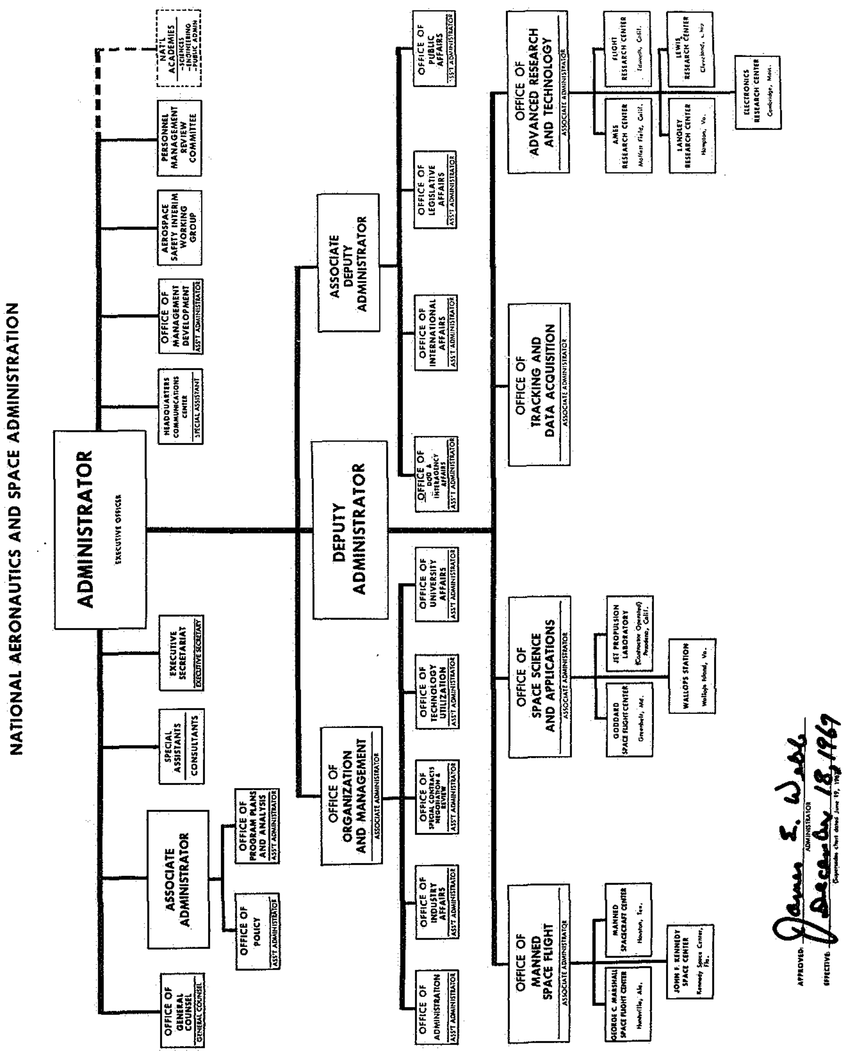


Figure 10–1. Organizational chart, December 18, 1967.

ivsory Panel which Congress authorized in NASA's Appropriation Act of 1968.

A NASA Personnel Management Review Committee was established to review the total NASA personnel management process—including policies, procedures, and practices—and to recommend appropriate changes.

NASA established the Manned Space Flight Safety Office within the Office of Manned Space Flight to coordinate the efforts of the field center safety organizations and to make sure they implemented the standards established by the NASA Safety Director. The Director of this new office has a dual responsibility: he reports to the Associate Administrator for Manned Space Flight for program guidance and policy direction, and he reports to the NASA Safety Director (as Assistant Safety Director for Manned Space Flight Programs) to help develop NASA-wide safety policy, guidance, and professional safety standards.

NASA integrated into a single organizational unit the various Headquarters program elements engaged in lunar exploration activities. This unit's purpose is to increase the effectiveness of directing or planning all Apollo and post-Apollo lunar exploration efforts. The newly established Apollo Lunar Exploration Office, located within the Office of Manned Space Flight, consists of two organizational elements—Flight Systems Development and Lunar Science. The Flight Systems Development element was primarily staffed by the Office of Manned Space Flight, while the Lunar Science element was staffed by the Office of Space Science and Applications.

In order to better align all NASA procurement functions, the Agency established the Grants and Research Contracts Division within the Procurement Office of the Office of Industry Affairs. This Division supervises for the Procurement Office the business aspects of NASA grants and research contract activities with universities. The Division was staffed with personnel transferred from the Office of University Affairs.

At the Ames Research Center, NASA established an Advanced Aircraft Programs Office within the Center's Full-Scale and Systems Research Division. The new office should result in the maximum integration of flight vehicle development efforts with the aeronautical research programs of the Center and of the Agency.

BOARD OF CONTRACT APPEALS

The NASA Board of Contract Appeals (established in 1958) adjudicates the appeals of the Agency's contractors that arise under the "Disputes" clause of NASA contracts. The Board is comprised of five members appointed by the Administrator. (Members of the Board are listed in app. F).

The Board, acting under procedures published in Title 41, Code of Federal Regulations, Part 18–54, has the authority to hold hearings; to order production of documents and other evidence; to take official notice of facts within general knowledge; and to decide all questions of fact and law raised by the appeal. The Board's decisions are final unless a motion for reconsideration is filed. Once such a motion is disposed of, a contractor has exhausted the administrative remedies afforded by NASA under a contract.

During the period of this report, 21 new appeals were filed with the Board, and the Board disposed of 36 appeals (most of which were filed before July 1, 1967). On December 31, 1967, the Board had 58 appeals pending on its docket (compared with 79 appeals pending on December 31, 1966).

CONTRACT ADJUSTMENT BOARD

The NASA Contract Adjustment Board considers requests by NASA contractors for equitable contractual relief under Public Law 85–804, when no other administrative legal remedy is available to such contractors. The Board, established under the authority of Public Law 85–804 (50 U.S.C. 1431–1435) and of Executive Order No. 10789, is comprised of five members appointed by the Administrator. (Members of the Board are listed in app. G).

The types of equitable relief which the Board may authorize include correcting mistakes or ambiguities in contracts, or formalizing informal commitments. Also, the Board may authorize amendment of a contract without consideration, if the contractor would otherwise suffer a loss as a result of Government action, or where a loss would impair the productive ability of a contractor deemed essential to the national defense. The Board's procedures are published in Title 41, Code of Federal Regulations, Part 18–17.

During this reporting period, the Board acted on three requests by contractors, granting the relief requested in one instance and denying it in the other two. The one case in which relief was granted involved a mutual mistake by the Government and the contractor in agreeing on specification revisions which were based on technical conclusions that, in the course of contract performance, proved to be invalid. The Board authorized an increase in the contract price and a modification of the work required to be performed in order to correct the mistake. The Board also had two other requests under consideration, but had not completed action on them.

The Board submits an annual report to Congress of all actions taken under the authority of P.L. 85–804 during the preceding calendar year.

FINANCIAL MANAGEMENT

The *Third Annual Financial Management Conference* was held in San Francisco in September. The main discussions dealt with how management uses financial data and how the financial manager can provide management with improved visibility of operations. Representatives of several Headquarters staff and program offices participated and served as discussion leaders. In addition, sessions led by field installation representatives provided a forum for discussing a number of technical problems of concern to installation financial management personnel.

The NASA *Contract Cost Management Seminar* sponsored by the Headquarters Financial Management Division was presented at five field installations during the period. These siminars are designed for project technical and administrative personnel and are intended to instill cost consciousness and promote efficient management usage of cost data reported by contractors. More than 100 trainees attended these seminars, and savings reported by the attendees amounted to over one million dollars, including one item of $878,000 for which an award was given.

On July 1, the Agency put into effect simplified procedures for reimbursing the Department of Defense for contract administration services, implementing the NASA–DOD Agreement of August 26, 1966 (NMI 1052.83). Under these new procedures, funding, accounting, and payment for DOD's services are handled only by Headquarters, instead of by each of the field installations. Comparisons with cost estimates are made at total rather than detail levels, eliminating much of the detailed identification of charges to installations or specific letters of delegation.

NASA began a program to make special analyses of financial management operations agency-wide. The first series of analyses focused on the relationship between costs and expenditures; R&D unliquidated obligations, with special emphasis on amounts outstanding for Program Year 1965 and before; and the relationships between the amounts of outstanding travel advances, per diem, and other travel expenses and unliquidated obligations for Fund Source 2, Limitation Travel. The Agency sent selected data to the various field installations for review and comment, with requests for follow-up action where appropriate.

To implement the "Freedom of Information Act" (P.L. 90–23; 5 U.S. Code 552) which took effect on July 4, 1967, NASA published in the Federal Register of July 1 a "Statement of Organization and General Information" (32 F.R. 9524; 14 CFR 1201). The Agency also published regulations governing the "Release of Information and Other Agency Records to Members of the Public" (32 F.R. 9487; 14 CFR 1206).

Under the regulations, NASA established a Headquarters Information Center and sixteen Field Information Centers to handle such public requests for NASA information and records. In addition, the Agency established a schedule of fees to cover the costs of searching for and reproducing records that are requested. A substantial amount of information and records pertaining to NASA is maintained at each Information Center, and is made available to members of the public for examination, without charge.

The Agency placed increased emphasis on its user charges program to make certain that an adequate charge is imposed in all applicable situations. A significant accomplishment in this regard was the development of a NASA-Wide User Charges Inventory. This inventory, containing a complete list of NASA user charge categories and the range of rates for each, will be forwarded to each installation for comparison with local rates for services and activities, and for comments and suggestions. In addition, activity under this program included review and action on installation requests for user charge approvals, encouragement of installations to monitor their user charges program on a continuing basis, and clarification of instructions on user charges policy and reporting.

NASA developed a Property Reporting Handbook covering contractors' semiannual reporting of NASA-owned property and space hardware; the final draft was submitted to the installations and to industry for review and comment. The Handbook incorporates reporting of Special Test Equipment (STE) and also includes provisions for meeting the reporting requirements of GAO relating to space hardware. The Agency expects to submit the Handbook to BOB for approval early in 1968.

Fiscal Year 1969 Program

Table 10–1 shows the planned level of effort in research and development, construction of facilities, and administrative operations for fiscal year 1969.

Table 10–1. NASA budget estimates, fiscal year 1969.

(In thousands)

Research and development:	
Apollo	$2,038,800
Apollo applications	439,600
Advanced mission studies	5,000
Physics and astronomy	141,900
Lunar and planetary exploration	107,300
Launch vehicle procurement	128,300
Bioscience	48,500
Space applications	112,200
Basic research	22,000
Space vehicle systems	35,300
Electronics systems	39,400
Human factor systems	21,700
Space power and electric propulsion systems	44,800
Nuclear rockets	60,000
Chemical propulsion	36,700
Aeronautical vehicles	76,900
Tracking and data acquisition	304,800
Sustaining university program	10,000
Technology utilization	4,000
Total, research and development	3,677,200
Construction of facilities	45,000
Administrative operations	648,200
Total	$4,370,400

Financial Reports, December 31, 1967

Table 10–2 shows fund obligations and accured costs incurred during the six months ended December 31, 1967. Appended to the table is a summary by appropriation showing current availability, obligations against this availability, and unobligated balances as of December 31, 1967.

Table 10–2. Status of appropriations as of December 31, 1967.

(In thousands)

Appropriations	*Six months ended December 31, 1967* *Obligations*	*Accrued costs*
Research and development:		
Apollo	$1,467,734	$1,181,435
Apollo applications	42,783	57,238
Advanced missions	285	2,874
Gemini	(1,541)	1,556
Completed missions	(2)	(2)
Physics and astronomy	77,672	69,089
Lunar and planetary exploration	86,418	87,921
Voyager	3,062	7,869
Launch vehicle procurement	45,467	66,671
Bioscience	24,048	23,014
Space applications	53,595	42,029
Space vehicle systems	13,144	17,660
Electronics systems	11,110	15,211
Human factor systems	6,699	7,211
Basic research	8,799	10,457
Space power and electric propulsion systems	18,556	29,114
Nuclear rockets	21,573	24,691
Chemical propulsion	12,719	17,633
Aeronautics	26,948	26,562
Tracking and data acquisition	119,307	120,066
Sustaining university program	1,362	21,486
Technology utilization	696	2,125
Operations	(58)	(13)
Reimbursable	39,146	45,930
Total, research and development	2,079,522	1,877,827
Construction of facilities	30,602	35,053
Administrative operations	319,891	321,145
Totals	$2,430,015	$2,234,025

Appropriation Summary	*Current availability*[1]	*Total obligations*	*Unobligated balance*
Research and development	$4,213,615	$2,079,552	$2,134,093
Construction of facilities	131,886	30,602	101,284
Administrative operations	630,677	319,891	310,786
Totals	$4,976,178	$2,430,015	$2,546,163

[1] The availability listed includes authority for anticipated reimbursable orders.

Table 10–3 shows NASA's consolidated balance sheet as of December 31, 1967, as compared to that of June 30, 1967. Table 10–4 summarizes the sources and applications of NASA's resources during the six months ended December 31, 1967. Table

10–5 provides an analysis of the net change in working capital disclosed in Table 10–4.

Table 10–3. NASA comparative consolidated balance sheet—December 31, 1967 and June 30, 1967

(In millions)

ASSETS	Dec. 31, 1967	June 30, 1967
Cash:		
Funds with U.S. Treasury	$4,428.9	$2,132.4
Accounts receivable:		
Federal agencies	37.3	26.2
Other	.8	1.5
	38.1	27.7
Inventories:		
NASA-held	39.7	39.1
Contractor-held	252.9	168.7
	292.6	207.8
Advances and prepayments:		
Federal agencies	10.4	10.1
Other	27.1	31.5
	37.5	41.6
Fixed assets:		
NASA-held	2,806.4	2,591.1
Contractor-held	595.3	557.7
Construction in progress	792.3	890.0
	4,194.0	4,038.8
Total assets	$8,991.1	$6,448.3
LIABILITIES AND EQUITY		
Liabilities:		
Accounts payable:		
Federal agencies	$120.7	162.6
Other	564.6	621.7
	685.3	784.3
Accrued annual leave	35.2	35.2
Total liabilities	720.5	819.5
Equity:		
Net investment	3,819.4	3,466.8
Undisbursed allotments	3,198.0	2,170.6
Unapportioned and unallotted appropriation	1,407.7	104.8
	8,425.1	5,742.2
Less reimbursable disbursing authority	(154.5)	(113.4)
Total equity	8,270.6	5,628.8
Total liabilities and equity	$8,991.1	$6,448.3

Table 10–4. Resources provided and applied—six months ended December 31, 1967.
(In millions)

RESOURCES PROVIDED

Appropriations:	
Research and development	$3,924.4
Construction of facilities	36.5
Administrative operations	627.9
Total appropriations	4,588.8
Revenues	45.2
Total resources provided	$4,634.0

RESOURCES APPLIED	*Total costs six months ended Dec. 31, 1967*	*Less costs applied to assets*	
Operating costs:			
Research and development	$1,877.8	$167.6	$1,710.2
Construction of facilities	35.1	35.1	-------
Administrative operations	321.1	3.9	317.2
Totals	$2,234.0	206.6	-------
Total operating costs	-------	-------	2,027.4
Increase in fixed assets:			
NASA-held	-------	-------	215.3
Contractor-held	-------	-------	37.6
Construction in progress	-------	-------	(97.7)
Total increase in fixed assets	-------	-------	155.2
Property transfers and retirements—net	-------	-------	(35.2)
Increase in working capital (Table 10–5)	-------	-------	2,486.6
Total resources applied	-------	-------	$4,634.0

Table 10–5. Net change in working capital—six months ended December 31, 1967.
(In millions)

	Dec. 31, 1967	*June 30, 1967*	*Increase*
Current assets:			
Funds with U.S. Treasury	$4,428.9	$2,132.4	$2,296.5
Accounts receivable	38.1	27.7	10.4
Inventories	292.6	207.8	84.8
Advances and prepayments	37.5	41.6	(4.1)
Total current assets	4,797.1	2,409.5	2,387.6
Current liabilities:			
Accounts payable	685.3	784.3	(99.0)
Working capital	$4,111.8	$1,625.2	
Increase in working capital	-------	-------	$2,486.6

COST REDUCTION PROGRAM

NASA's Internal Cost Reduction Program yeilded savings of $38,370,220, and its Contractor Cost Reduction Program reduced costs by $93,938,920 during the second half of 1967 (first half of fiscal year 68).

Cost reductions are designed to save money and increase efficiency in operations at the Agency's Headquarters and field installations, and through its principal conractors. In addition, these programs stimulate cost-conscious and innovative attitudes among NASA and contractor employees and foster the dissemination of cost reduction techniques throughout NASA and NASA-contractor installations.

The Internal Cost Reduction Program affects all NASA installations. The Contractor Cost Reduction Program includes 39 of NASA's major contractors. Since it was initiated in 1963, cumulative savings in the internal program have amounted to $755 million. Since the contractor program began in mid 1964, savings have amounted to $811 million. Thus, about $1.5 billion had been saved by both programs through calender year 1967. All of these savings had to meet NASA's strict criteria for cost reduction. A cost reduction qualifies for acceptance only if the action is identifiable, measurable, verifiable, and is computed to show the gains for not more than 12 months. No cost reduction action is to be taken which might impair reliability, quality, performance, or delivery schedules.

The Administrator reviews the progress and objectives of the program several times during the year. Twice a year, the Administrator reports to the President on the results and accomplishments achieved under the NASA-Internal Program and the NASA-Contractor Program.

NASA was continuing its practice of conducting on-site periodic reviews and evaluations of its internal and contractor cost reduction programs. The information gained from these reviews has permitted the Headquarters Cost Reduction Office to suggest improvements which the installations and the contractors could make in the management of their cost reduction programs.

Organizational changes during the last six months of the year increased top management's participation in the cost reduction program. The Deputy Administrator remained responsible for managing the program. The Cost Reduction Board is responsible for the day-to-day operation of the program through the Headquarters Cost Reduction Office.

The Board, under the chairmanship of the Associate Deputy

Administrator, was reorganized and now has as members the Associate Adminsitrator for Organization and Management, the Assistant Administrator for Industry Affairs, and the Deputy Associate Administrator (Management), Office of Manned Space Flight. The new Board provides better coverage of the Agency's operations as they relate to cost reduction. The Cost Reduction Steering Committee, composed primarily of program office representatives, was abolished on August and its functions were assumed by the Board.

PROCUREMENT AND SUPPLY MANAGEMENT

NASA's procurement improvement efforts were concentrated primarily in those areas involving new procedures for award and management of contracts. The Agency revised certain policies and procedures pertaining to Government Property, and it strengthened regulations concerning use of audit services in evaluating contractors proposals. It continued to participate with the Department of Defense in the Contractor Performance Evaluation Program, and, in addition, it placed increased emphasis on structuring and administering incentive contracts.

Management of Government Property

NASA delegates management of Government property in the possession of contractors to Department of Defense contract administration activities located at or near the contractor plants involved. The DOD is reimbursed for these services.

To evaluate DOD performance, NASA arranged to be represented on DOD management review teams at those contractor plants or in those contract administration regions where this Agency has a significant amount of business. In these reviews, NASA seeks to obtain a thorough study of property administration and management.

The Agency also took steps to improve the accuracy of excess inventory schedules submitted by contractors (these schedules identify materials and parts to be disposed of when a contract is completed or terminated). These inventory schedules form the basis for subsequent screening by potential users of excess materials and parts.

Further, NASA began a field assistance visit program to review the property programs at major NASA contractors and the property administration functions at NASA centers. These visits should provide direct expert assistance to NASA field organizations and result in improved practices and procedures throughout the Agency.

A recent revision of the NASA Procurement Regulation established a property management policy for NASA which is completely consistent with Department of Defense regulations. This policy permits the many contractors doing business with both agencies to operate by one set of rules.

NASA was also taking steps to upgrade the level of performance of NASA property administrators by encouraging attendance at training courses, and by providing these specialists with improved and standard property administration procedures.

These actions are in keeping with the President's memorandum of September 16, 1966, which emphasizes the need for "Cost Reduction in Procurement, Supply and Property Management."

Contract Audit as a Pricing Aid

NASA revised its procurement policy to require a review by contract audit services when a procurement action is estimated to exceed $100,000. The contracting officer can waive this requirement if the available information is clearly adequate for the proposed procurement. The policy also prescribes that when cost or pricing data are used in connection with a price negotiation, and when audit evaluation of the contractor's proposal was provided, the contracting officer must furnish a copy of the negotiation memorandum to the cognizant auditor. Where appropriate, the memorandum must include or be supplemented by information on how the auditor's advisory services can be made more effective in future negotiations with contractors.

Contractor Performance Evaluation

NASA was continuing to participate with the DOD in the Contractor Performance Evaluation Program (CPE). Eighteen major contracts were under evaluation during the period. A DOD/NASA Steering Committee for Contractor Evaluation, with a supporting working group, was established at the Assistant Secretary (DOD)—Assistant Administrator (NASA) level. This steering committee provides for the increased involvement of upper management in the evaluation of Government contractors.

Small Business Program

NASA arranged to reinstate the Small Business Joint Set-Aside Program, previously discontinued under a special SBA program. SBA assigned representatives to some of the NASA procurement activities. As additional personnel are recruited, more

SBA procurement representatives are to be assigned to the most active NASA procurement operations.

NASA participated in several federal procurement seminars offering advice and guidance to the business community on NASA procurement procedures and programs. In addition, the NASA Small Business Advisor and Small Business Specialists took part in a number of technology utilization meetings sponsored by NASA and SBA and usually co-sponsored by local members of the Congress. This program activity was steadily expanding.

Incentive Contracting

NASA had under administration 266 incentive contracts with a target value of $6.7 billion at the start of the six-month period commencing July 1, 1967. Little change occurred during the period because new contracts and additional obligations to existing contracts were offset partially by contract completions. One of those completed during the period was the Gemini contract. NASA also found it appropriate and in the best interests of the Government to convert a few existing incentive arrangements to Cost Plus Fixed Fee arrangements pending the readjustment and redefinition of interim schedule objectives. At the end of the period, NASA had incentive contracts valued at $6.2 billion under administration.

NASA continued to expand the incentive environment. At the end of 1964, NASA had 31 incentive contractors; the number increased to 67 in 1965 and went up to 100 in 1966. At the end of 1967, NASA had 155 incentive contractors, covering a wide range of support, development, and spacecraft missions.

Incentive contract statistics show that contracts below $5 million represent fifty-eight percent of the number of contracts but account for only three percent of the total dollar value. Contracts above $5 million and especially those above $50 million each receive a thorough periodic analysis to provide an evaluation of the effectiveness of incentive policies and procedures. These analyses and in-depth reviews of NASA's contracting practices have validated the rationale for selective application of incentive contracting concepts.

One of the most significant qualitative improvements made by NASA was the development of improved Cost Plus Award Fee (CPAF) contracting procedures. NASA published a comprehensive CPAF Contracting Guide during this period. The guidelines emphasize the evaluation of contract results rather than input or kinds of effort. They reflect the lessons learned from reviews and experience with 115 CPAF contracts valued at $1.3 billion.

NASA continued working with various universities and the DOD to improve incentive contracting procedures and to identify new concepts that can be applied in a practical manner. The Agency was also studying extracontractual influences in government contracting with the assistance of the University of New York at Buffalo. The conclusions resulting from this study should help all government contracting agencies to determine weighting of cost and performance parameters in incentives.

Summary of Contract Awards

NASA's procurement for the first 6 months of Fiscal Year (FY) 1968 (this report period) totaled $2,203 million. This is $582 million less than was awarded during the corresponding period of Fiscal Year 1967.

Approximately 85 percent of the net dollar value was placed directly with business firms, 3 percent with educational and other nonprofit institutions, 6 percent with the California Institute of Technology for operation of the Jet Propulsion Laboratory, 5 percent with or through other Government agencies, and 1 percent outside the United States.

Contracts Awarded to Private Industry

Ninety percent of the dollar value of procurement requests placed by NASA with other Government agencies resulted in contracts with industry awarded by those agencies in behalf of NASA. In addition, about 69 percent of the funds placed by NASA under the Jet Propulsion Laboratory contract resulted in subcontracts or purchases with business firms. In short, about 94 percent of NASA's procurement dollars was contracted to private industry.

Sixty-nine percent of the total direct awards to business represented competitive procurements, either through formal advertising or competitive negotiation. An additional 11 percent represented actions on follow-on contracts placed with companies that had previously been selected on a competitive basis to perform the research and development on the applicable project. In these instances, selection of another source would have resulted in additional cost to the Government by reason of duplicate preparation and investment. The remaining 20 percent included contracts for facilities required at contractors' plants for performance of their NASA research and development effort, contracts arising from unsolicited proposals offering new ideas and concepts, contracts employing unique capabilities, and procurements of sole-source items.

Small business firms received $85 million, or 5 percent, of NASA's direct awards to business. However, most of the awards to business were for large continuing research and development contracts for major systems and major items of hardware. These are generally beyond the capability of small business firms on a prime contract basis. Of the $143 million of new contracts of $25,000 and over awarded to business during the six months, small business received $21 million, or 15 percent.

In addition to the direct awards, small business received substantial subcontract awards from 82 of NASA's prime contractors participating in its Small Business Subcontracting Program. Total direct awards plus known subcontract awards aggregated $222 million, or 12 percent of NASA's total awards to business during the first half of Fiscal Year 1968.

Geographical Distribution of Prime Contracts

Within the United States, NASA's prime contract awards were distributed among 47 States and the District of Columbia. Business firms in 41 States and the District of Columbia, and educational institutions and other nonprofit institutions in 42 States and the District of Columbia participated in the awards. One percent of the awards went to labor surplus areas located in 5 States.

Subcontracting

Subcontracting effected a further distribution of the prime contract awards. NASA's major prime contractors located in 22 States and the District of Columbia reported that their larger subcontract awards on NASA effort had gone to 964 subcontractors in 40 States and the District of Columbia, and that 43 percent of these subcontract dollars had crossed state lines.

Major Contract Awards

Among the major research and development aggregate contract awards by NASA during the first six months of Fiscal Year 1968 were the following:

1. Grumman Aircraft Engineering Corp., Bethpage, N.Y. NAS 9–1100. Development of Apollo lunar module. Awarded $238 million; cumulative awards $1,463 million.

2. North American Rockwell Corp., Downey, Calif. NAS 9–150.

Design, develop and test Apollo command and service module. Awarded $222 million; cumulative awards $2,818 million.

3. The Boeing Company, New Orleans, La. NAS 8–5608. Design, develop and fabricate the S–IC stage of the Saturn V vehicle, construct facilities in support of the S–IC stage and provide launch support services. Awarded $187 million; cumulative awards $1,151 million.

4. North American Rockwell Corp., Downey, Calif. NAS 7–200. Design, develop, fabricate and test the S–II stage of the Saturn V vehicle and provide launch support services. Awarded $129 million; cumulative awards $1,047 million.

5. McDonnell Douglas Corp., Santa Monica, Calif. NAS 7–101. Design, develop and fabricate the S–IVB stage of the Saturn V vehicle and associated ground support equipment and provide launch support services. Awarded $92 million; cumulative awards $886 million.

6. General Electric Company, Huntsville, Ala. NASW–410. Apollo checkout equipment, related engineering design, quality and data management and engineering support; support services to Mississippi Test Facility. Awarded $77 million; cumulative awards $609 million.

7. North American Rockwell Corp., Canoga Park, Calif. NAS 8–19. Develop and procure 200,000-pound thrust J–2 rocket engine with supporting services and hardware. Awarded $54 million; cumulative awards $583 million.

8. International Business Machines Corp, Huntsville, Ala. NAS 8–14000. Fabrication, assembly and checkout of instrument units for Saturn I and V vehicles. Awarded $50 million; cumulative awards $231 million.

9. North American Rockwell Corp., Canoga Park, Calif. NAS 8–18734. Fabrication and delivery of F–1 engines; provide supporting services and hardware. Awarded $47 million; cumulative awards $84 million.

10. General Motors Corp., Milwaukee, Wisc. NAS 9–497 Guidance computer subsystem for Apollo command and service module. Awarded $39 million; cumulative awards $334 million.

11. Chrysler Corporation, New Orleans, La. NAS 8–4016. Fabricate, assemble, checkout and static test Saturn S–IB stage; provide product improvement program and spare parts support; modify areas of Michoud Plant assigned to contractor; provide launch support services. Awarded $32 million; cumulative awards $428 million.

12. Aerojet General Corp., Sacramento, Calif. SNP–1 Design, develop and produce a nuclear powered rocket engine (NERVA). Awarded $26 million; cumulative awards $424 million.

13. TRW, Inc., Houston, Texas. NAS 9–4810. Gemini-Apollo mission trajectory and Apollo spacecraft systems analysis programs. Awarded $16 million; cumulative awards $63 million.

14. International Business Machines Corp., Houston, Texas NAS 9–996. Design, develop and implement real time computer complex for Integrated Mission Control Center at the Manned Spacecraft Center. Awarded $16 million; cumulative awards $105 million.

15. The Boeing Company, Washington, D.C. NASW–1650. Apollo/Saturn V technical integration and evaluation Awarded $16 million; cumulative awards $25 million.

16. Radio Corporation of America, Princeton, N.J. NAS 5–10306. Design, development, test and fabrication of Tiros M R&D flight model spacecraft and Tiros operational spacecraft A through E. Awarded $15 million; cumulative awards $21 million.

17. TRW, Inc., Redondo Beach, Calif. NAS 5–3900. Design, develop, fabricate and test Orbiting Geophysical Observatories. Awarded $14 million; cumulative awards $49 million

18. General Electric Company, King of Prussia, Pa. NAS 2–1900. Design, fabricate, deliver and provide operational support for Biosatellites. Awarded $14 million; cumulative awards $74 million.

19. Philco Corporation, Palo Alto, Calif. NAS 9–1261. Equipment and construction of facilities for the Integrated Mission Control Center. Awarded $14 million; cumulative awards $115 million.

20. Bendix Corporation, Kennedy Space Center, Fla. NAS 10–1600. Apollo launch support services at Kennedy Space Center Awarded $13 million; cumulative awards $56 million.

Major Contractors

The 25 contractors receiving the largest direct awards (net value) during the first six months of Fiscal Year 1968 were as follows:

Contractor and place of contract performance	*Thousands*
1. North American Rockwell Corp. *Downey, Calif.	$482,059
2. Grumman Aircraft Engrg. Corp. Bethpage, N. Y.	257,595

3. Boeing Company *New Orleans, La.	216,387
4. McDonnell Douglas Corp. *Santa Monica, Calif.	113,036
5. General Electric Company *Daytona Beach, Fla.	103,717
6. International Business Machines Corp. *Huntsville, Ala.	80,243
7. Bendix Corp. *Owings Mills, Md.	41,703
8. General Motors Corp. *Milwaukee, Wisc.	39,690
9. Radio Corporation of America *Princeton, N. J.	32,786
10. Chrysler Corp. *New Orleans, La.	31,590
11. TRW, Inc. *Houston, Texas	31,453
12. Aerojet-General Corp. *Sacramento, Calif.	29,072
13. General Dynamics Corp. *San Diego, Calif.	23,589
14. Philco-Ford Corp. *Houston, Texas	17,988
15. Lockheed Aircraft Corp. *Houston, Texas	17,021
16. LTV Aerospace Corp. *Dallas, Texas	16,855
17. Federal Electric Corp. *Kennedy Space Center, Fla.	16,514
18. Sperry Rand Corp. *Huntsville, Ala.	12,228
19. Bellcomm, Inc. Washington, D.C.	10,000
20. Trans World Airlines, Inc. *Kennedy Space Center, Fla.	9,665
21. Union Carbide Corp. *Sacramento, Calif.	8,470
22. Brown Engineering, Co., Inc. *Huntsville, Ala.	8,303
23. Martin Marietta Corp. *Denver, Colo.	7,596
24. Mason-Rust New Orleans, La.	6,176
25. Catalytic-Dow (Joint Venture) Kennedy Space Center, Fla.	6,065

*Awards during the period represent awards on several contracts which have different principal places of performance. The place shown is that which has the largest amount of the awards.

LABOR RELATIONS

Significantly fewer mandays were lost because of work stoppage on NASA construction projects during the period of this report than were lost during the preceding six months. Construction project strikes at all NASA centers resulted in only 1,019 mandays lost during the last half of 1967; 2,316 mandays were lost during the first half.

Non-construction contracts were unaffected by time losses during this period. During the previous period, 1,456 mandays were lost on such contracts.

NASA continued improving its labor-management relations at the John F. Kennedy Space Center and Cape Kennedy, where all projects (construction and industrial) experienced only one work stoppage during the period. Stability of labor relations at KSC continued, while the number of industrial employees and construction activities increased.

The NASA Office of Labor Relations continued to increase and intensify planning for preventive labor relations programs at all NASA centers.

RELATIONSHIPS WITH OTHER GOVERNMENT AGENCIES

Coordination of aeronautics and space R&D activities between NASA and the Department of Defense continued at an increased tempo. The Office of Defense Affairs was redesignated as the Office of DOD and Interagency Affairs to better organize NASA's cooperative effort with other government agencies.

Although NASA's cooperation in space and aeronautics is predominantly with the DOD, the Agency has working relationships with other Government agencies such as the Department of Transportation, Atomic Energy Commission, Department of Commerce, Department of Agriculture, and the Department of Interior. Formal boards such as the Aeronautics and Astronautics Coordinating Board (AACB) and the NASA–FAA Coordinating Committee, numerous interagency coordinating groups, and personal daily contacts between individuals at all levels within the agencies maintain this coordination

The exchange of personnel between NASA and DOD continued. As of December 31, 1967, 323 military personnel were on detail to NASA. Of these, 189 were from the Air Force, 99 from the Army, 32 from the Navy, and 3 from the Marine Corps. Thirteen NASA employees were assigned to organizations within the DOD.

The principal formal mechanism for the coordination of research and development activities between NASA and DOD continues to be the AACB and its six specialized panels. The AACB initiated a comprehensive review of existing and anticipated aerospace test facilities, coordinated the space science programs of the two agencies, and coordinated the proposed Fiscal Year 1969 facilities budgets of the two agencies to eliminate unwarranted duplication.

The flow of information between NASA and the DOD continued, with formal and informal briefings covering such subjects as launch vehicles, nuclear space power and rockets, electric propulsion, lunar and planetary explorations, space vehicle systems, life sciences, space applications, ground based tracking and data acquisition, and other topics of interest to both agencies.

Key NASA program officials gave one briefing on NASA's programs to the Air Force Chief of Staff and his principal assistants. This briefing was so well received that the Chief of Naval Operations requested a similar briefing for interested Navy officials.

Additional agreements between NASA and other agencies were consummated. Areas covered by the agreements included the exchange of technical data regarding the F–12/SR–71 aircraft, the X–15 program, use of the X–24A research vehicle in a joint lifting body flight research program, the XB–4B flight research program, interagency support between the Air Force Eastern Test Range and the Goddard Space Flight Center, and additional provisions for the detail of officers to the Manned Spacecraft Center, Houston, Texas.

NASA and DOD continued to provide logistic support for each other's programs. These efforts included tracking and recovery for satellite programs, DOD flight training for NASA astronauts and research pilots, and NASA support of the MOL program. DOD made extensive use of NASA's unique facilities—its wind tunnels, shock tubes, and ballistic ranges. NASA arranged to use an Air Force C–141 aircraft to work on the national effort to reduce aircraft noise. This plane will be used in noise evaluation tests at Wallops Station, Va.

Appendix A

Congressional Committees on Aeronautics and Space

(July 1—December 31, 1967)

Senate Committee on Aeronautical and Space Sciences

CLINTON P. ANDERSON, New Mexico, *Chairman*
RICHARD B. RUSSELL, Georgia
WARREN G. MAGNUSON, Washington
STUART SYMINGTON, Missouri
JOHN STENNIS, Mississippi
STEPHEN M. YOUNG, Ohio
THOMAS J. DODD, Connecticut
HOWARD W. CANNON, Nevada
SPESSARD L. HOLLAND, Florida
WALTER F. MONDALE, Minnesota
MARGARET CHASE SMITH, Maine
BOURKE B. HICKENLOOPER, Iowa
CARL T. CURTIS, Nebraska
LEN B. JORDAN, Idaho
EDWARD W. BROOKE, Massachusetts
CHARLES H. PERCY, Illinois

House Committee on Science and Astronautics

GEORGE P. MILLER, California, *Chairman*
OLIN E. TEAGUE, Texas
JOSEPH E. KARTH, Minnesota
KEN HECHLER, West Virginia
EMILIO Q. DADDARIO, Connecticut
J. EDWARD ROUSH, Indiana
JOHN W. DAVIS, Georgia
WILLIAM F. RYAN, New York
THOMAS N. DOWNING, Virginia
JOE D. WAGGONNER, JR., Louisiana
DON FUQUA, Florida
GEORGE E. BROWN, JR., California
LESTER L. WOLFF, New York
WILLIAM J. GREEN, Pennsylvania
EARLE CABELL, Texas
JACK BRINKLEY, Georgia
BOB ECKHARDT, Texas
ROBERT O. TIERNAN, Rhode Island
JAMES G. FULTON, Pennsylvania
CHARLES A. MOSHER, Ohio
RICHARD L. ROUDEBUSH, Indiana
ALPHONZO BELL, California
THOMAS M. PELLY, Washington
DONALD RUMSFELD, Illinois
EDWARD J. GURNEY, Flordia
JOHN W. WYDLER, New York
GUY VANDER JAGT, Michigan
LARRY WINN, JR., Kansas
JERRY L. PETTIS, California
DONALD E. LUKENS, Ohio
JOHN E. HUNT, New Jersey

Appendix B

National Aeronautics and Space Council

(July 1—December 31, 1967)

HUBERT H. HUMPHREY, *Chairman*
Vice President of the United States

DEAN RUSK
Secretary of State

ROBERT S. MCNAMARA
Secretary of Defense

JAMES E. WEBB, *Administrator*
National Aeronautics and Space Administration

GLENN T. SEABORG, *Chairman*
Atomic Energy Commission

Executive Secretary
EDWARD C. WELSH

Appendix C

Principal NASA Officials at Washington Headquarters

(December 31, 1967)

JAMES E. WEBB	Administrator
DR. ROBERT C. SEAMANS, JR	Deputy Administrator
DR. HOMER E. NEWELL	Associate Administrator
WILLIS H. SHAPLEY	Associate Deputy Administrator
HAROLD B. FINGER	Associate Administrator for Organization and Management
WILLIAM E. LILLY	Assistant Administrator for Administration
DR. BERNHARDT L. DORMAN	Assistant Administrator for Industry Affairs
BERNARD MORITZ	Assistant Administrator for Special Contracts Negotiation and Review
DR. RICHARD L. LESHER	Assistant Administrator for Technology Utilization
FRANCIS B. SMITH	Assistant Administrator for University Affairs
DEMARQUIS D. WYATT	Assistant Administrator for Program Plans and Analysis
JACOB E. SMART	Assistant Administrator for Policy
ADM. W. FRED BOONE, USN (Ret.)	Assistant Administrator for Defense Affairs
PAUL G. DEMBLING	General Counsel
ARNOLD W. FRUTKIN	Assistant Administrator for International Affairs
ROBERT F. ALLNUTT	Assistant Administrator for Legislative Affairs
JULIAN SCHEER	Assistant Administrator for Public Affairs
DR. GEORGE E. MUELLER	Associate Administrator for Manned Space Flight
DR. JOHN E. NAUGLE	Associate Administrator for Space Science and Applications
EDMOND C. BUCKLEY	Associate Administrator for Tracking and Data Acquisition
DR. MAC C. ADAMS	Associate Administrator for Advanced Research and Technology

(Telephone information: 963–7101)

Appendix D

Current Official Mailing Addresses for Field Installations.

(December 31, 1967)

Installation and telephone number	Official	Address
Ames Research Center; 415-961-1111.	Dr. H. Julian Allen, Director	Moffett Field, Calif. 94035.
Electronic Research Center; 617-491-1501.	Mr. James C. Elms, Director	575 Technology Square, Cambridge, Mass. 02139.
Flight Research Center; 805-258-3311.	Mr. Paul Bikle, Director	Post Office Box 273, Edwards, Calif. 93523.
Goddard Space Flight Center; 301-474-9000.	Dr. John F. Clark, Director	Greenbelt, Md. 20771.
Goddard Institute for Space Studies; 212-UN6-3600.	Dr. Robert Jastrow, Director	2880 Broadway, New York, N.Y. 10025.
Jet Propulsion Laboratory; 213-354-4321.	Dr. W. H. Pickering, Director.	4800 Oak Grove Dr., Pasadena, Calif. 91103.
John F. Kennedy Space Center; 305-867-7110.	Dr. Kurt H. Debus, Director	Kennedy Space Center, Fla. 32899.
Langley Research Center; 703-722-7961.	Dr. Floyd L. Thompson, Director.	Langley Station, Hampton, Va. 23365.
Lewis Research Center, 216-433-4000.	Dr. Abe Silverstein, Director	21000 Brookpark Rd., Cleveland, Ohio 44135.
Manned Spacecraft Center; 713-HU3-0123.	Dr. Robert R. Gilruth, Director.	Houston, Tex. 77058.
George C. Marshall Space Flight Center; 205-877-1100.	Dr. Wernher von Braun, Director.	Marshall Space Flight Center, Ala. 35812.
Michoud Assembly Facility; 504-255-3311.	Dr. George N. Constan, Manager.	Post Office Box 26078, New Orleans, La. 70126.
Mississippi Test Facility; 601-688-2211.	Mr. Jackson M. Balch, Manager.	Bay St. Louis, Miss. 39520.
KSC Western Test Range Operations Division; 805-866-1611.	Mr. H. R. Van Goey, Chief	Post Office Box 425, Lompac, Calif. 93436.
Plum Brook Station; 419-625-1123.	Mr. Alan D. Johnson, Director.	Sandusky, Ohio 44871.
Wallops Station; 703-VA4-3411	Mr. Robert L. Krieger, Director.	Wallops Island, Va. 23337.
Western Support Office; 213-451-7411.	Mr. Robert W. Kamm, Director.	150 Pico Blvd., Santa Monica, Calif. 90406.

Appendix E

NASA's Historical Advisory Committee

(December 31, 1967)

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JAMES LEA CATE, Department of History, University of Chicago

A. HUNTER DUPREE, Department of History, University of California (Berkeley)

WOOD GRAY, Department of History, George Washington University

LAURENCE KAVANAU, Executive Vice President, Space and Information Division, North American Aviation, Inc.

MARVIN W. MCFARLAND, Chief, Science and Technology Division, Library of Congress

ALAN T. WATERMAN, Former Director, National Science Foundation (deceased November 30, 1967)

Executive Secretary: EUGENE M. EMME, NASA Historian

Appendix F

NASA's Board of Contract Appeals

(December 31, 1967)

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Members	WOLF HABER
	DONALD W. FRENZEN
	DANIEL M. ARONS
Recorder	(MRS.) EVELYN KIRBY

Appendix G

NASA's Contract Adjustment Board

(December 31, 1967)

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	FRANCIS J. SULLIVAN
	MELVYN SAVAGE
	WILLIAM E. STUCKMEYER
Counsel to Board	E. M. SHAFER

Appendix H

NASA's Space Science and Applications Steering Committee

(December 31, 1967)

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Secretary: Margaret B. Beach

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Douglas R. Lord
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Oran W. Nicks
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Robert C. Cameron, Goddard Space Flight Center
Roland L. Carpenter, Jet Propulsion Laboratory
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Gordon P. Garmire, California Institute of Technology
Kenneth Greisen, Cornell University
Frederick T. Haddock, University of Michigan
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Appendix I

NASA's Inventions and Contributions Board

(December 31, 1967)

Chairman	ERNEST W. BRACKETT.
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	JAMES O. SPRIGGS.

Appendix J

Patent Waivers Granted and Denied for Separate Inventions Upon Recommendation of the Agency's Inventions and Contributions Board

(July 1—December 31, 1967)

Invention	Petitioner	Action on petition
Non-Destructive Test Methods for Electrical Components.	Electra Manufacturing Company.	Grant.
Temperature Independent and Linearly Temperature Dependent Current Source for Drift-Offset Compensation of Direct-Coupled Amplifier.	TRW Systems Inc.	Grant.
Gas Ring Laser Gyroscope System	Massachusetts Institute of Technology.	Grant.
A Signal Modulated Self-Regulated Voltage Regulation-Amplifier.	Collins Radio Company	Grant.
Double Epitaxial Layer, High Power, High Speed Transistor.	Westinghouse Electric Corporation.	Grant.
D. C. Sensing Transformer	General Electric Co.	Grant.
Porous Plate Separator System	General Electric Co.	Grant.
Phase-Lock Loop Drop-Out Control	Motorola Incorporated	Grant
Metabolic Rate Meter	Isomet Corporation	Grant
Clamp for Shrinking Electrical Insulating Sleeving-Infrared Heat Module.	North American Rockwell Corp.	Grant.
Automatic Phasing System	Litton Industries	Grant.
Silicon Carbide Semiconductor Junction Devices	Tyco Laboratories	Grant
Laminar Flow Meter Element	Hamilton Standard Division of United Aircraft Corp.	Grant.
Controller	Honeywell, Inc.	Grant.
An Interlocking Contact System for Power Semiconductors.	Westinghouse Electric Corporation.	Grant
Microbalance	TRW, Inc.	Grant.
A Fraunhofer Holograph System	Technical Operations, Inc.	Grant.
Redundancy Method and Apparatus	TRW, Inc.	Denial.
Helmet Feed-port	United Aircraft Corp.	Grant.
Apparatus for Handling Micron Size Range Particulate Material.	TRW, Inc.	Grant.
Sequential Frequency Combiner for Frequency Systems.	Varian Associates	Grant.
Frequency Correction Circuit for an Averaging Frequency Combiner.	Varian Associates	Grant.
General String Cutter	North American Rockwell Corp.	Grant.
Antenna Assembly	Keltec, Inc.	Grant.
A Bender—Mode Piezoelectric Optical Scanner	General Telephone & Electronics Lab.	Grant.
Position Indicator for a Display System	Stanford Research Institute	Grant.
Chemical Source of Electrical Current Catalyst Suitable for use Therein and Method for the Manufacture thereof.	Pennsylvania Research Assoc. Inc.	Grant.
Liquid Helium Transfer System	General Electric Co.	Grant.
Mosaic of Semi-Conductor Elements Interconnected in an XY Matrix.	Westinghouse Electric Corporation.	Grant.

Invention	Petitioner	Action on petition
Switching System for an Array of Elements	Westinghouse Electric Corporation.	Grant.
Optical Instrument	California Inst. of Technology	Grant.
Thermostatic Surface	Oklahoma State University	Grant.
Semiconductor Fabrication Technique Permitting Examination of Epitaxially Grown Layers.	Westinghouse Electric Corporation.	Grant.
Process for Concentrating Metal Ions	California Inst. of Technology	Grant.
Alternate Methods of Preparing Hydrocarbon Base Ferrofluids.	AVCO Corp.	Grant
Means for Preparing Thixotropic Fluid that is Ferromagnetic.	AVCO Corp.	Grant.
Means for Preparing Thermally Stable Ferrofluid	AVCO Corp.	Grant.
Co-Axial Arc Heater with Variable Arc Length	Westinghouse Electric Corporation.	Grant.
Opposed Arc Welding	North American Rockwell Corp.	Grant.
Method of Exchanging Surfactants on Surface of Ferrofluid Particles.	AVCO Corp.	Grant.
Means for Preparation of Magnetic Ferrofluids in Alternate Carrier Liquids.	AVCO Corp.	Grant.
Means for Preparation of Magnetically Stronger Ferrofluid of Low Viscosity (control of dispersant quantity).	AVCO Corp.	Grant.
Means for Preparation of Magnetically Stronger Colloidal Ferrofluid of Low Viscosity (control of dispersant chain length).	AVCO Corp.	Grant.
Means for Preparing Viscous, Newtonian Fluids	AVCO Corp.	Grant.
Floating Hot Fluid Nozzle Ring	North American Rockwell Corp.	Grant.
Confidential	Electric Storage Battery Company.	Grant.
Confidential	Electric Storage Battery Company	Grant.
Confidential	Electric Storage Battery Company.	Grant.
Improved Brushless D. C. Motor	Sperry Rand Corp. Sperry Farragut Co.	Grant.
Starting Circuit for Brushless D. C. Motor	Sperry Rand Corp. Sperry Farragut Co.	Grant
Motor Armature	Sperry Rand Corp. Sperry Farragut Co.	
A Linear, Temperature Stable, Bi-Phase Demodulator.	Collins Radio Co.	Grant
AC to DC Converter	Collins Radio Company	Grant
Captive Plastic Seal	North American Rockwell Corp.	
High Power Transistor Structure	ITT/Semiconductor Division	Grant
Improvement in Apparatus for Absolute Pressure Measurement.	National Research Corporation	Grant
Compact Solar Still	Melpar, Inc.	Denial.
Cryogenic Heat Transfer Control System	General Electric Company	Denial.
Increasing Efficiency of Switching Type Regulator Circuits.	Sanders Associates, Incorporated.	Denial.
Propellant-lined, Hypervelocity Acceleration Devices.	Charles A. Rodenberger (Employee of Texas A&M University).	Grant.
Process for the Synthesis of 1, 1-Bis (trifluoromethoxy) difluorethylene, $(CF_3O)_2C{=}CF_2$.	Peninsular Chem-research, Inc.	Denial.
Polymers of 1, 1-Bis (trifluoromethoxy) difluorethylene $(CF_3O)_2C{=}CF_2$.	Peninsular Chem-research, Inc.	Denial.
Control Apparatus	Honeywell, Inc.	Denial.

Patent Waivers Granted and Denied for Separate Inventions Upon Recommendation of the Agency's Inventions and Contributions Board—Continued

Invention	Petitioner	Action on petition
Process for the Synthesis of Trifluorovinyloxy Sulfurpentafluoride $SF_5OCF{=}CF_2$.	Peninsular Chem-research, Inc.	Denial.
Polymers of Trifluoromethyl-2, 2-difluorovinyl Ether ($CF_3OCF{=}CF_2$) and Trifluoromethyl-1, 2-difluorovinyl Ether ($CF_3OCF{=}CHF$).	Peninsular Chem-research, Inc.	Denial.
Process for the Synthesis of Trifluoromethyl-2, 2-difluorovinyl Ether ($CF_3OCH{=}CF_2$) and Trifluoromethyl-1, 2-difluorovinyl Ether ($CF_3OCF{=}CHF$).	Peninsular Chem-research, Inc.	Denial.
Body Seal	Litton Systems, Incorporated	Denial.

Appendix K

Patent Waivers Granted and Denied for All Inventions Made during Performance of Contract Upon Recommendation of the Agency's Inventions and Contributions Board

(July 1—December 31, 1967)

Contract description [1]	Petitioner	Action on petition
Investigation of New Concepts of Adaptive Devices.	Sperry Rand Corp.	Granted.
Design and Fabrication of an Optical Processing System.	Technical Operations, Incorporated.	Granted.
Non-Destructive Diagnostic Testing	General Electric Company	Granted.
Study of Cold Substrate Deposition of Thin Film Passive-Elements.	General Precision, Inc. Librascope Group.	Granted.
Study and Design of High Performance Fuel Cells.	Esso Research and Engineering Company.	Granted.
Perform Studies, Designs, Develop, Fabricate and Test Sealed Nickel-Cadmium Battery Cells.	Texas Instruments, Incorporated.	Granted.
Development of Long Life Catalyst Beds	Rocket Research Corporation.	Denied.
Strapdown Inertial and Navigational System	Honeywell Incorporated	Granted.
Study Effects of Wall Coatings and Use of Various Buffer Gases at Different Pressures and Thereafter Construct Two Temperature Controlled Prototype Rubidium Maser Frequency Standards.	Hewlett-Packard Co.	Granted.
Study of Structural Behavior of Thin Ceramic Film as Useful Materials in Space Vehicle Structures.	National Research Corporation	Granted.
Discharge Chamber Studies with Oxide Cathode Research for Mercury Bombardment Ion Thrustors.	Hughes Aircraft Co.	Granted.
Study of Failure Modes in Silicon Solid-State Devices.	Philco-Ford Corp. Microelectronics Div.	Granted.
Design, Fabricate, and Test an Engineering Model of a Thermionic System including Heat Pipe and Thermionic Converter Development.	Radio Corporation of America.	Denied.
Development of the Fission Gas Containment Concept Employing a UO_2-W-Coated Particle Dispersion Fuel.	General Electric Company	Denied.
Photocathode Improvements	Block Engineering, Incorporated.	Granted.
Design, Fabricate, Test and Deliver a Sterilizable Magnetic Tape Recorder.	Ampex Corporation	Granted.
Fabricate, Assemble, and Test Flight Telemetry System and Operational Support Equipment.	Texas Instruments Incorporated.	Granted.
Fabrication of a Modified Bendix Model M–310 Magnetic Electron Multiplier.	Bendix Corporation/ Scientific Instruments Division.	Granted.

Patent Waivers Granted and Denied for All Inventions Made during Performance of Contract Upon Recommendation of the Agency's Inventions and Contributions Board—Continued

Contract description [1]	Petitioner	Action on petition
Fabricate, Assemble, and Test Computer Equipment in the Nature of Flight Data Storage Subsystem and Associated Operational Support Equipment.	Texas Instruments Incorporated.	Granted.
Development of a Universal Multi-Modal Vibration Test Fixture.	Bolt, Beranek, and Newman Incorporated.	Granted.

[1] Waiver before execution of contract.

Petitions Deferred
Ion Physics Corporation (BW-843)
General Precision Incorporated (BW-842)
Atlantic Research Corporation and Victory Engineering Corporation (BW-815)

Appendix L

Scientific and Technical Contributions Recognized by the Agency's Inventions and Contributions Board

(July 1—December 31, 1967)

Awards Granted Under Provisions of Section 306 of the Space Act of 1958.

Contribution	Inventors	Employer
Technique for Quantitative Measurement of Aerodynamic Heat Transfer to Supersonic Wind Tunnel Models of Complicated Shapes.	Robert A. Jones , James L. Hunt.	Langley Research Center.
Aerodynamic Spike Nozzle	Thomas E. Cowell, Ira B. Madison.	North American Rockwell Corporation.

Appendix M

Awards Granted NASA Employees Under Provisions of the Incentive Awards Act of 1954

(July 1—December 31, 1967)

Contribution	Inventor (s)
AMES RESEARCH CENTER:	
Current Measuring Apparatus	Ralph T. Hood
Stabilization of Gravity Oriented Satellites	Bruce E. Tinling and Vernon K. Merrick.
Balanced Bellows Spirometer	George R. Holden and Joseph R. Smith, Jr.
Apparatus and Methods for Measuring Forces	Vernon L. Rogallo
Ballistocardiograph	Vernon L. Rogallo
Cable Cutter and Stripper	Franklin E. Thompson
Transfer Valve	Albert A. Puccinelli and Joseph R. Smith, Jr.
Three-Axis Finger Tip Controller	Armando E. Lopez
Proportional Controller	Earl O. Menefee
Thermally Operated Measuring Apparatus	Grant W. Coon
Shock-Layer Radiation Measurement	Thomas N. Canning
ELECTRONICS RESEARCH CENTER:	
Gunn-Type Microwave Generators	Wilhelm Rindner and Harold Roth
Luminescent Screen Composition	Edwin H. Hilborn
GODDARD SPACE FLIGHT CENTER:	
Method of Making Tubes	John J. Park
Display for Binary Characters	John R. Cressey and Charles E. Cote.
Automatic Acquisition System for Phase-Lock Loop	Ralph E. Taylor
Control Apparatus	Leo J. Veillette
Ripple Add and Ripple Subtract Binary Counters	Rodger A. Cliff and David H. Schaefer.
Method and Apparatus for Computing Square Roots	Rodger A. Cliff
Scanning Aspect Sensor	Bruce R. Pincus
Self-Erecting Reflector	Hossein Bahiman, John D. Gates, and William Korvin.
Data Processor Having Multiple Sections Activated at Different Times.	Rodger A. Cliff
Position Sensing Device	Maxwell G. Strange
Position Location and Data Collection System and Method.	Charles R. Laughlin, Jr., Gay E. Hilton, Richard C. Lavigne, and Roger C. Hollenbaugh.
Synchronous Counter	Duane K. McDermond
Retrodirective Modulator	Peter O. Minott and Michael W. Fitzmaurice.
Passively Regulated Water Electrolysis Rocket Engine.	Daniel J. Grant

Contribution	Inventor (s)
JOHN F. KENNEDY SPACE CENTER:	
Valve Seat	Elvis D. Wallace
Controlled Release Device	Terry W. Burcham
Go, No-Go Flared Tube Gage	Francis D. Griffin
Ace S/C Electronic Checkout System	Gary L. Woods, Walter E. Parsons, Harold G. Johnson, G. Merritt Preston, Thomas S. Walton, and Jacob C. Moser.
Transient Suppresses Coil	Charles W. Marion
Apparatus for Tensile Testing	Elvis D. Wallace
Weatherproof Helix Antenna	Herbert E. Cribb
BCD to Decimal Decoder	Frank Byrne
LANGLEY RESEARCH CENTER:	
Contour Densitometer	Reginald J. Extron
Pulse Duration Multiplier	Nelson J. Groom
Adaptive Compression of Communication Signals	Wilford E. Sivertson, Jr.
Jet Shoes	John D. Bird, Howell D. Garner, Ernest D. Lounsberry, and David F. Thomas, Jr.
Water Reclamation System	Dau C. Popma and Vernon G. Collins
Buoyant Anti-Slosh System	David A. Evensen and John P. Raney.
Station Keeping of a Gravity-Gradient Stabilized Satellite.	William H. Phillips
Silicon Controlled Rectifier (SCR) Blocking Pulse Gate Amplifier.	Eugene L. Kelsey, and Hugh M. Holt.
Transient-Compensated Silicon Controlled Rectifier (SCR) Inverter.	Hugh M. Holt, Eugene L. Kelsey, and Stacey M. Mills.
Condenser-Separator Apparatus	Franklin W. Booth
Condenser-Separator	Franklin W. Booth
Ionization Gage with Low X-Ray Limit	Forrest P. Clay and Leonard T. Melfi
Automatic Balancer	Gordon E. Mercer
Null Device for Hand Controller	John F. Newcomb
Flexible Ring Slosh Damping Baffle	David G. Stephens and George W. Brooks.
Fatigue-Resistant Shear Pin	Thomas W. E. Hankinson
Exclusive-Or Logic Circuits	William G. Batte
Absolute Spectral Sensitometer	Gale A. Harvey
Spacecraft Experiment Pointing and Attitude Control System.	Peter R. Kurzhals
Variable Geometry Manned Orbital Vehicle	Bernard Spencer, Jr., and Beverly Z. Henry, Jr.
A Hot Air Balloon Deceleration and Recovery System.	Stanley H. Scher, and James C. Dunavant.
Controlled Glass Bead Peening	Charles R. Manning, Jr., Thomas T. Bales, Wayne B. Lisagor, and Marion B. Seyffert.
Negative Impedance Display	Hans-Juergen C. Blume
A Backpack Carrier	Amos A. Spady, Jr., and Frank G. Read.
Frangible Tube Energy Dissipation	John R. McGehee, Melvin E. Hathaway, and Edmond J. Zavada.
Test Unit Free-Flight Suspension System	Wilmer H. Reed, III
Reduced Gravity Simulator	Donald E. Hewes, and Amos A. Spady, Jr.
Steering System	Upshur T. Joyner
Bonding Procedure	Charles B. King
Multilegged Support System	Weymouth B. Crumpler
Rotating Space Station Simulator	Donald E. Hewes
File Card Marker	Betty Lee S. Phillips

Awards Granted NASA Employees Under Provisions of the Incentive Award Act of 1954—Continued

Contribution	Inventor (s)
LANGLEY RESEARCH CENTER: Continued	
Switch Status Checker	Leon V. Taylor, and Thomas B. Ballard.
Adjustable Attitude Guide Device	Joseph V. Boyle
Fluidic Sun Sensor	Howell D. Garner
LEWIS RESEARCH CENTER:	
Method of Making Membranes	Frank A. Arrance* and Daniel G. Soltis.
Generator for a Space Power System	Dale W. Cooper, and Perry W. Kuhns.
Ion Thrustor Cathode	Paul D. Reader, Harold R. Kaufman, and William R. Kerslake.
Capacitance Type Force Transducer	Dean C. Glenn
Combustion Chamber	John W. Gregory, and Donald L. Nored.
Electrode and Insulator with Shielded Dielectric Junction.	Robert C. Finke
Apparatus and Method for Measurement of Electrical Signals.	Robert C. Finke, and Walter M. Krawczonek.
Multi-Alarm Summary Alarm	James D. Heckelman
Self-Lubricating Fluoride-Metal Composite Materials	Harold E. Sliney
Reduced Gravity Liquid Configuration Simulator	William A. Olsen, Jr., and Isadore I. Pinkel.
Control of Transverse Instability in Rocket Combustors.	Marcus F. Heidmann, and Charles E. Feiler.
Electrically Conductive Polyfluorinated Ethylene	Harold F. Leibecki
* An employee of the Douglas Aircraft Company.	
LEWIS RESEARCH CENTER: Continued	
Improved Silicon Solar Cell	Joseph Mandelkorn
Extrusion Die for Refractory Metals	Charles A. Gyorgak, and Robert J. Hoover.
Liquid Flow Sight Assembly	Herbert L. Minkin, and Howard E. Hobart.
Electronic Cathode	William R. Kerslake
Burning Rate Control of Solid Propellants	Louis A. Povinelli, and Marcus F. Heidmann.
Pulsed Differential Comparator Circuit	John C. Sturman
Stable Dispersion Strengthened Materials	John W. Weeton, Max Quatinetz, and Norman W. Orth.
Method and Apparatus for Making Curved Reflectors	Austin F. Reader, Walter E. Russell, and Edward A. Werner.
Boiler for Generating High Quality Vapor	Vernon H. Gray, and Allan W. Joslyn.*
* An employee of Manned Spacecraft Center.	
MANNED SPACECRAFT CENTER:	
Improved Pneumatic Body	Matthew I. Radnofsky, and Glenn Shewmake.
Orbital Escape Vehicle	Caldwell C. Johnson
Recording System	James E. Kessel
Inflatable Tether	William C. Huber, and Edwin Samfield.
Dome Control System	Kenneth D. Cashion
Space Suit Heat Exchanger	Elton M. Tucker
GEORGE C. MARSHALL SPACE FLIGHT CENTER:	
Welding Skate and Track	Vaughn Herbert Yost

Contribution	Inventor (s)
GEORGE C. MARSHALL SPACE FLIGHT CENTER: Continued	
Apparatus for Dynamic Testing	George Landwehr von Pragenau, and Wilhelm Angele.
Hydraulic Support for Dynamic Testing	George Landwehr von Pragenau
Control System for a Pressure Balance	Bumon J. Pruett, and Euple I. Palmer.
Image Magnification Adapter for Cameras	Fred L. Moffitt
Magnetic Memory Matrix System	George A. Bailey
Discrete Activity Indicator System	George A. Bailey
Extensometer	Carrol D. Hooper
Method and Device for Preventing High Voltage Arcing in Electron Beam Welding.	Joe R. Short
Method and Apparatus for Magnetomotive Precision Sizing and Joining of Large Diameter Tubes.	Robert J. Schwinghamer, and J. D. Bennight.
Internal Flare Angle Gauge	Norman D. Elder, and William A. Wall, Jr.
Horizontal Cryostat for Fatigue Testing	Orvil Y. Reece
Electrical Feed-Through Connection for Printed Circuit Boards and Printed Cable.	James F. Blanche
Device for Measuring Products of Inertia Automatically.	Gene T. Carpenter
Satellite Despin Device	John J. Milly
Pulse Amplitude and Width Detector	Murrel D. Sladen, and Hugh W. Staley.
Anemometer with Braking Mechanism	Robert E. Turner, and Dennis W. Camp.
Electron Beam Position Locator	Edward L. Shriver
Evaporant Source for Vapor Deposition	George D. Adams
Static Inverter	Dorrance L. Anderson, Albert E. Willis, Carl E. Winkler, and John M. Gould.
Technical Abstract of Apparatus for Welding Torch Angle and Seam Tracking Control.	William A. Wall, Jr., and Vaughn H. Yost.
Heat Pipe Thermionic Diode Power System	Ambrose W. Byrd
Docking Structure for Spacecraft	Josef F. Blumrich, and Rondal G. Crawford.
Electric Field Meter	Russell D. Shelton
Welding Skate with Computerized Control	William A. Wall, Jr.

Incentive Awards Act Awards by Centers

(July 1—December 31, 1967)

Centers	Number of inventions	Number of awardees	Number of persons	Amount of awards
Ames Research Center	11	14	13	$ 5,600.
Electronics Research Center	2	3	3	500.
Flight Research Center	----	----	----	----
Goddard Space Flight Center	14	22	20	3,600.
John F. Kennedy Space Center	7	12	12	3,500.
Langley Research Center	27	44	40	10,350.
Lewis Research Center	21	35	31	3,950.
Manned Spacecraft Center	6	9	9	2,800.
George C. Marshall Space Flight Center	22	29	26	9,150.
Wallops Station	----	----	----	----
Total	110	168	154	$39,450.

Appendix N

EDUCATIONAL PUBLICATIONS AND MOTION PICTURES

(December 31, 1967)

NASA released these 13 new educational publications during the last six months of 1967. Single copies are available to the public without charge from the Office of Public Affairs, Special Events Division, Code FGE-1, National Aeronautics and Space Administration, Washington, D.C. 20546, or may be purchased in quantity from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Other publications are listed in a folder supplied from the same address at NASA.

BOOKLETS

From Runnymede to Ganymede (SOSA, Vol. IV, No. 1).—Abstract from an address by James E. Webb, NASA Administrator, delivered at the Celebration of the Prelude to Independence, Williamsburg, Va., May 27, 1967. 15 pp.

Goals for Urban America (SOSA, Vol. IV, No. 2).—Abstract from an address by NASA's Administrator, delivered at a colloquium on Urban Government in the Decade Ahead held at the Fels Institute of Local and State Government, University of Pennsylvania (Philadelphia), May 23, 1967. 13 pp.

Medical Benefits from Space Research (EP-46).—Describes how knowledge and technology developed from or discovered in space programs contributes to advances in medicine for the benefit of mankind. December 1, 1967. 16 pp.

NASA FACTS (Basic Series)

Illustrated narratives describing programs, techniques, and other aspects of the Nation's civilian space program for the peaceful exploration and utilization of space.

Lunar Orbiter (NF-32).—The story of Lunar Orbiter, the series of unmanned spacecraft guided into low altitude orbits around the moon, which have contributed to development of a topographic map of the moon, provided other scientific information about the lunar environment, and helped to select sites for future manned landings. 12 pp.

Manned Space Flight: Projects Mercury and Gemini (NF-9).—Describes the achievements of these two projects which laid a solid foundation for the Project Apollo program to land American explorers on the moon. 12 pp.

Pioneer (NF-31).—The Pioneer program in which spacecraft orbiting the sun are transmitting scientific data about the interplanetary space environment and contributing to knowledge of the sun. 8 pp.

'imulators (NF–36).—Descriptions of some of the devices by which NASA exhaustively tests on the ground elements and situations that men and materials may face during flight in earth's atmosphere and in space. 8 pp.

'urveyor (NF–35).—Description of this NASA program in which unmanned craft have been landed on the moon, telecast pictures of the moonscape near and far, helped to select sites for future manned landings, and reported on other aspects of the moon's surface and environment. 12 pp.

NASA FACTS (Organization Series)

A series covering the work of each NASA center.

'light Research Center (O–4).—Describes the work of the center at Edwards, Calif. Among its projects are the X–15 research airplane, the XB–70, and wingless lifting bodies. 4 pp.

NASA FACTS (Science Series)

Series designed for teachers to use in explaining basic science concepts n space exploration.

'pacecraft Tracking and Communication (S–2).—The techniques and systems by which NASA tracks, commands, and acquires data from spacecraft. 4 pp.

Telemetry (S–3).—Discusses and explains telemetry (one phase of earth communication with spacecraft) which is the science of measuring at one point and transmitting the results to a distant station for evaluation and use. 4 pp.

The Countdown (S–4).—A description and explanation of the step-by-step process that culminates in the launch of a rocket vehicle. 4 pp.

Weightlessness (S–5).—Description and explanation of the phenomenon of zero gravity, or weightlessness, experienced by man and inanimate objects in space. 4 pp.

MOTION PICTURES

The Agency released seven new motion pictures during the same report period. These may be borrowed—without charge other than return mailing and insurance costs—from the Media Development Division, Code FAD–2, National Aeronautics and Space Administration, Washington, D.C. 20546, or from any NASA center. (Other films are listed in a brochure supplied from the same addresses.)

The Challenge of Unanswered Questions (HQ–148).—1967, color, 15½ min., 16mm. Presents the principal features of the aurora—one of the most mysterious and fascinating of natural phenomena—and explores the theories of its cause and the instruments and techniques used in studying it. Also shows the life and experiences of a graduate student working with Dr. Sydney Chapman at the Institute of Goephysics, University of Alaska.

Great Is the House of the Sun (HQ–144).—1967, color, 21 min., 16mm. Shows the technique used by scientists at the University of Hawaii in studying the characteristics of solar radiations and their effect on the upper atmosphere.

Ceramics in Space (HQ–142).—1967, color, 19½ min., 16 mm. Using ceramics as a typical field of scientific study the film shows how a graduate student develops the academic discipline needed to conduct original research, including scientific literature searches; definition of the problem; design, analysis and performance of experiments; and data collection and evaluation. The relationships between student, faculty advisor, and other scientific disciplines are illustrated. Features James I. Mueller, Ph.D., Professor of Ceramic Engineering, University of Washington.

Assignment: Shoot the Moon (HQ-167).—1967, color, 28 min., 16mm. A dramatic portrait of the moon as seen by the Lunar Orbiter, Ranger, and Surveyor spacecraft. The viewer travels across the surface of the moon to examine in detail the major craters, the lunar soil, the back side of the moon and other significant features. In addition, summarizes what man has learned about the moon and how this new knowledge will aid manned lunar landings.

Closeup of the Moon (HQ-169).—1967, color, 11 min., 16mm. A brief report on Lunar Orbiter's photography showing detail of craters and other terrain features of the moon.

Flight to Tomorrow (HQ-168).—1967, color, 28 min., 16mm. Through comparison with present-day jets, this film illustrates various types of NASA's aeronautical research—the development of supersonic transports, hypersonic flight studies, vertical take-off and landing aircraft, stability of light private aircraft, jet noise reduction, and advances in aircraft safety.

The Apollo 4 Mission (HQ-181).—1967, color, 15:40 min., 16mm. The film depicts the preparation, launch, and recovery operations of the successful flight of the first 7.5 million pound-thrust Saturn Five vehicle with its Apollo spacecraft. The actual course of the flight is portrayed through animation. Included are color photography from inside the Saturn and views of the earth from an altitude of 11,000 miles.

Appendix O

TECHNICAL PUBLICATIONS

(July 1—December 31, 1967)

The following special publications, among those issued during the report period by NASA's Scientific and Technical Information Division, are sold by the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, D.C. 20402, or by the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Springfield, Va. 22151, at the prices listed.

Space-Cabin Atmospheres. Part IV: One- Versus Multiple-Gas Systems (NASA SP-118)—By Emmanuel M. Roth. The engineering trade-offs of one- versus multiple-gas systems for space cabin atmospheres are considered. The analysis contains an evaluation of the physiological considerations which set boundaries for the physical environment within the cabin, the interaction between the physiological and hardware parameters for the environmental control system, and the effect of physiologically acceptable gas mixtures on weight and power for different missions. 132 pp. GPO $1.00.

Fuel Cells (NASA SP-120).—A comprehensive review of fuel-cell research sponsored by the U.S. Government from 1950 to 1964 is presented. Research on hydrogen-oxygen, hydrocarbon, amalgam, thermally regenerative, thermogalvanic, redox, hydrazine, ammonia, and biochemical fuel cells is discussed. Their potential applications as power sources and their construction and manufacturing techniques are considered. Finally, 800 different reports on various aspects of the research are listed. 439 pp. GPO $2.75.

Conference on the Closed Life Support System (NASA SP-134).—The proceedings of a conference held at Ames Research Center, Moffett Field, Calif., April 14–15, 1966, to report the findings of some preliminary studies on a program for the development of a "closed" ecological life support system. 227 pp. CFSTI $3.00.

Meteor Orbits and Dust: The Proceedings of a Symposium (NASA SP-135).—Results of a symposium held August 9–13, 1965, at Cambridge, Mass., and sponsored by NASA and the Smithsonian Institution Astrophysical Observatory. Included are flight data obtained by Pegasus I and II and smaller Explorer satellites on meteoroid penetration hazards. 142 pp. GPO $2.50.

Interstellar Grains (NASA SP-140).—Proceedings of a conference held at the Rensselaer Polytechnic Institute, Troy, N.Y., August 24–26, 1965, sponsored by the National Science Foundation and supported in part by NASA and the New York State Atmospheric Sciences Research Center. Included are papers dealing with interstellar extinction in the far infrared, visible, and far ultraviolet regions; the spatial distribution of polarization; the wavelength dependence of polarization; the scattering properties of grains; the structure and chemistry of grains; and the interactions of grains with the interstellar medium. 269 pp. GPO $1.25.

Oxide Dispersion Strengthened Alloys (NASA SP-143).—By Nicholas J. Grant, Howard J. Siegel, and Robert W. Hall. The report of a special panel of the NASA Research Advisory Committee on Materials set up to study the extent of commercial development of oxide-dispersed alloys since about 1950 when sintered aluminum powder (SAP), generally considered the prototype of such alloys, was announced. The monograph gives emphasis to the questions of why this development has been so slow. Observations are based primarily on material available through the open literature. 25 pp. GPO $0.15.

A Survey of Attitude Sensors for Spacecraft (NASA SP-145).—By Norman M. Hatcher. A report designed to alleviate the difficulty in understanding attitude sensors by describing the fundamental principles of operation of the many designs that have been developed and indicating their potential usefulness. Current areas of research are listed and certain problem areas indicated. In addition, the performance of many sensors in space is mentioned. 18 pp. CFSTI $3.00.

Surveyor III: A preliminary Report (NASA SP-146).—Preliminary scientific results of Surveyor III tests of the characteristics and structure of lunar surface materials are presented. The spacecraft, equipped with a soil-mechanics surface sampling device, made 8 bearing tests and 14 impact tests, and dug 4 trenches as well. This device, together with the TV system, the radar, temperature measurements, and landing dynamics significantly increased knowledge of the Moon in the Surveyor III landing area. 159 pp. CFSTI $3.00.

1967 Summer Study of Lunar Science and Exploration (NASA SP-157).—Results and recommendations of eight panels of prominent scientists who participated in a study of lunar exploration held at the University of California, Santa Cruz, Calif., July 31–August 13, 1967, under the auspices of NASA's Manned Spacecraft Center. 398 pp. CFSTI $3.00.

Surveyor V: A Preliminary Report (NASA SP-163).—This book summarizes the scientific results of the Surveyor V mission. Data obtained from the alpha-backscattering experiment which measured the chemical composition of the lunar surface and the bar-magnet experiment which determined the magnetic characteristics of the surface material are presented. Analysis of the TV pictures of the lunar surface and measurement of the Moon's temperature and bearing strength are included. 161 pp. CFSTI $3.00.

Models of Trapped Radiation Environment. Volume IV: Low Energy Protons (NASA SP-3024)—By Joseph H. King. This report, the fourth in a series describing model environments of the particle radiations trapped in the geomagnetic field, contains a model of the low-energy proton flux for energies below 4 MeV. Preceding volumes have described protons of energies greater than 4 MeV trapped in the inner zone and electrons trapped in the inner and outer zones and at synchronous altitudes. 62 pp. CFSTI $3.00.

Handbook of the Physical Properties of the Planet Venus (NASA SP-3029)—By L. R. Koenig, F. W. Murray, C. M. Michaux, and H. A. Hyatt. This is a summary of the present knowledge and the latest hypotheses regarding the physical properties of the planet Venus. The information—compiled from numerous sources—covers orbit, configuration, temperature mass, shape, rotation, and internal structure of the planet. 132 pp. GPO $0.60.

Handbook of the Physical Properties of the Planet Mars (NASA SP-3030) —By C. M. Michauz. This is a summary of the present knowledge and the latest hypotheses regarding the physical properties of the planet Mars. The information—compiled from numerous sources—covers orbit, configuration, temperature mass, shape, rotation, and internal structure of the planet. 167 pp. GPO $0.70.

Electron Densities and Scale Heights in the Topside Ionosphere: Alouette I Observations Over the American Continents. Volume IV: Summary Graphs (NASA SP-3034)—By Kwok-Long Chan and Lawrence Colin. This is the last of four volumes presenting data on electron density and plasma scale height at various heights and times in the topside ionosphere. The measurements were made over the American continents by the Alouette I satellite at a sunspot minimum epoch of the solar cycle. In this volume, figures are presented which summarize the tabulated data on the first three volumes. 321 pp. CFSTI $3.00.

Tabulated Communication Characteristics of a Steady-State Model of Inter-Planetary Space (NASA SP-3042).—By Ronald J. Hruby, Austin H. Somes, John Dimeff, and Howard Tashjian. The changes in an electromagnetic wave as it passes through interplanetary and coronal space depend on the intervening plasma and magnetic fields. These changes are presented here as a function of the transmission range and the view angle relative to the Earth-Sun line in the ecliptic plane. This information can be used to determine the total change in an electromagnetic wave between any two points in the Earth-Sun volume, excluding the magnetosphere. 524 pp. CFSTI $3.00.

Astronautics and Aeronautics, 1966: Chronology on Science, Technology, and Policy (NASA SP-4007).—A chronology of events and statements of the ninth year of the space age, compiled from open public sources as a ready reference for current use by space technologists, scholars, students, and writers, as well as for future analysts and historians. 479 pp. GPO $1.50.

Soldering Electrical Connections (NASA SP-5002) (Fourth Edition).—A revised edition of the 1964 booklet *Reliable Electrical Connections*, this book describes good soldering techniques, based on methods used at NASA's George C. Marshall Space Flight Center. 66 pp. GPO $0.30.

Advanced Valve Technology (NASA SP-5019).—By Louis C. Burmeister, John B. Loser, and Eldon C. Sneegas. A revised and enlarged edition describing the research and development since 1959 in NASA centers and by NASA contractors on valve improvements that are likely to be helpful in solving leakage, thermal, and reliability problems throughout industry. Included are studies of materials, compatibility problems, lubrication, and response times of these control elements in fluid systems. 183 pp. GPO $1.00.

Thermal Insulation Systems: A Survey (NASA SP-5027).—By Peter E. Glaser, et al. Advances in thermal insulation helpful to designers of both natural gas pipelines and surgical tools are reviewed from findings of aerospace researchers. Fundamental principles and measurement techniques are discussed as well as the placement of insulation systems, materials and structure of multi-layer systems, and supports for insulation. Cryogenic applications are emphasized but insulations for use at high temperatures are also described. 148 pp. GPO $0.60.

Structural Design Concepts (NASA SP-5039).—By L. Albert Scipio. This survey identifies NASA contributions to the field of structural design, describes the development of materials that have been associated with these advances, and gives examples of the ways in which these materials may be used. Although written primarily for the designer rather than the analyst, the survey does cover structural types (including material systems), structural concepts, and design synthesis and optimization. 174 pp. GPO $0.70.

Contamination Control Principles (NASA SP-5045).—This publication describes concepts and data generated by the progress made in the field of controlling contamination in the space age. It presents a basic model and the fundamental principles of controlling contamination in an industrial plant and can be helpful in pharmaceutical, electronic, and other modern industries as well as in aerospace ventures. 55 pp. GPO $0.40.

Analytical Chemistry Instrumentation (NASA SP-5083).—By J. S. Whittick, R. F. Muraca, and Leonard A. Cavanagh. This Technology Survey summarizes NASA-sponsored innovations in the field of analytical chemistry instrumentation from 1959 to 1964. A description is given of the advances in the design, development, and application of the instruments used by many scientists in ultraviolet, infrared, and x-ray spectrometry and other means of determining contents of materials of all kinds with great precision as well as life-detection techniques likely to be helpful in medical research. 134 pp. GPO $0.60.

Elements of Design Review for Space Systems (NASA SP-6502).—This publication, intended to serve as an aid for instructing technically trained personnel in the implementation and evaluation of a design review program, describes in detail those reviews performed by the contractor with customer participation and touches lightly on the various reviews and approval conducted by the customer. The design review activity is described not only in its total aspect, but also in its operation at each of the various hardware levels, program milestones and project types. 57 pp. CFSTI $3.00.

Failure Reporting and Management Techniques in the Surveyor Program (NASA SP-6504).—This document describes the management techniques utilized in the Surveyor program for the effective use of failure reporting as a mission assurance tool. This represents a significant improvement over normal practice in the failure reporting area. 46 pp. CFSTI $3.00.

Parts and Materials Application Review for Space Systems (NASA SP-6505).—This document, one of a series on evaluation of NASA's reliability programs for the manufacture of space vehicles, defines the parts and materials application review activity for project management and provides a guide for the performance of effective reviews by parts and materials specialists and design engineers. 53 pp. CFSTI $3.00.

Preparing Contractor Reports for NASA: Repro Typing and Layout (NASA SP-7007) (Second Edition).—By Proctor P. Taylor, Jr. A revised edition to the ground rules for the production of suitable reproducible copy with a minimum of effort. Topics discussed are: (1) the typewriter; (2) the reproducible layout sheet; (3) section headings; (4) spacing; (5) hyphenation; (6) error correction; (7) typing tables and figures; (8) the reproducible layout; (9) figuring reductions; and (10) typing equations. 14 pp. GPO $0.15.

Preparing Contractor Reports for NASA: Technical Illustrating (NASA SP–7008) (Second Edition).—By Proctor P. Taylor, Jr. A revised edition to the guidelines for proper selection of size, shape, and style of illustrations for use in printed technical publications for NASA. 29 pp. GPO $0.15.

Lasers and Masers, A Continuing Bibliography (NASA SP–7009(02)).—A bibliography of annotated references on the characteristics and applications of lasers and masers that were introduced into the NASA information system between February 1966–April 1967. 441 pp. CFSTI $3.00. Previously issued under the same title: NASA SP–7009(01), reflecting NASA acquisitions February 1965–April 1966 (420 pp. CFSTI $3.00), and NASA SP–7009, January 1962–February 1965 (280 pp. CFSTI $3.00).

A Selected Listing of NASA Scientific and Technical Reports for 1966 (NASA SP–7028).—An annotated listing of NASA reports and journal articles announced during 1966 in *Scientific and Technical Aerospace Reports* (*STAR*). Included are Special Publications, Technical Reports, Technical Notes, Technical Memorandums, Technical Translations, and Contractor Reports. The arrangement of this publication is the same as that of *STAR*. 2070 pp. GPO $9.75.

NASA Thesaurus. Volumes I, II, and III (NASA SP–7030).—An alphabetical listing of terms by which the documents in the NASA scientific and technical information system are indexed and retrieved. Volume I and II contain the subject terms and complete cross-reference structure that comprise the Thesaurus proper; Volume III consists of four appendixes which arrange the Thesaurus elements in other ways for purposes of further explication and utility, namely, Hierarchical Display; Category Term Listing; Permuted Index; and Postable Terms. 1503 pp. GPO $8.50—set.

NASA Specifications and Standards (NASA SP–9000).—First edition of an up-to-date listing of specifications and standards originated by NASA, its Centers, and Jet Propulsion Laboratory through December 1966. 380 pp. CFSTI $3.00.

A Guide to NASA Data Handbooks (NASA SP–9001).—A comprehensive listing of NASA-sponsored technical data handbooks in the NASA Central Information System. 183 pp. CFSTI $3.00.

Appendix P

NASA Launch Vehicles

Vehicle	Stages	Payload in pounds: 345-mile orbit	Payload in pounds: Escape	Payload in pounds: Mars/Venus	Principal use
Scout	4	310			Launching small scientific satellites, reentry experiments, and probes (Explorer XXX, SERT Ion engine, SECOR V, French-built FR-1).
Delta	3	880	150	120	Launching scientific, meteorological, and communications satellites (TIROS IX, Orbiting Solar Observatories—OSO I and II, Ariel, Telstar I, Relay, Syncom II, Interplanetary Monitoring Platforms (Explorers XXI and XXVIII), Energetic particles satellite (Explorer XXVI).
Thrust Augmented Delta (TAD).	3	1,300	250	220	Launching scientific, meteorological, communications, and Bioscience satellites, and lunar and planetary probes (Pioneer VI, TIROS M, TIROS operational satellites OT-3 and OT-2, Syncom III, Commercial Communications Satellite Early Bird I, Radioastronomy Explorers, Biosatellites A—F, INTELSAT I and II communications satellites, international satellites for ionospheric studies—ISIS).
Thor-Agena	2	1,600			Launching scientific, communications, and applications satellites (Echo II, Nimbus I, Polar Orbiting Geophysical Observatory, Orbiting Geophysical Observatory II).
Thrust Augmented Thor-Agena (TAT).	2	2,200			Launching geophysics and astronomy and applications satellites (OGO C, D, and F, and Nimbus B).
Atlas-Agena	2½	6,000	950	600	Launching heavy scientific satellites, and lunar and planetary probes (Rangers VII, VIII and IX, Mariners III and IV, Orbiting Geophysical Observatory—OGO-I).
Atlas-Centaur	2½	9,900	2,600	1,600	Launching heavy unmanned spacecraft as lunar soft landers (Surveyor, Mariner).
Saturn IB	2	28,500			Launching Project Apollo spacecraft.
Saturn V	3	250,000	98,000	70,000	Do.

Appendix Q

Major NASA Launches

(July 1--December 31, 1967)

Name, date launched, mission	Vehicle	Site [1]	Results
Surveyor IV, July 14 .... Spacecraft designed to soft-land on the moon to photograph its surface and environment, also to manipulate the lunar soil.	Atlas-Centaur ..	ETR	Planned to land in the Sinus Medii (Central Bay), the spacecraft's flight was flawless until about 3 minutes before impact when contact was suddenly lost with it.
Explorer XXXV (Interplanetary Monitoring Platform-E), July 19 .... Satellite to investigate magnetic fields, cosmic rays, solar wind plasma, interplanetary dust, and micrometeorites.	Thor-Delta	ETR	Inserted into lunar orbit (between 500 and 5000 miles) to supply monthly data on the tail of the earth's magnetosphere at the distance of the moon and on interactions of the solar wind with the moon.
OGO-IV, July 23 .... NASA's fourth Orbiting Geophysical Observatory to study relationships of the phenomena and radiations of the sun with the earth's environment during a period of increasing solar activity.	Thor-Agena	WTR	From its low polar orbit of 250 to 560 miles, the spacecraft views nearly the entire surface of the earth daily. Among investigations carried out by the Observatory's 20 experiments were measurements of the composition, density, and temperature of the atmosphere, observations of emissions from airglow and aurorae, measurements of energetic particles, and observations of Very Low Frequency radiations. Also continued surveying the world's magnetic field.
Lunar Orbiter V, August 1 .... Fifth and last of NASA's unmanned orbiting photographic laboratories to provide detailed pictures of selected areas on the front and far sides of the moon of major interest to scientists, and supplement photographic coverage of potential landing sites for manned Apollo spacecraft.	Atlas-Agena	ETR	Spacecraft completed mapping the lunar surface. Provided high resolution and wide angle pictures of 36 sites for scientists and supplemental photographs of five possible landing areas for astronauts. Also measured meteoroids and radiation in the environment near the moon.

[1] See footnote at end of table.

Major NASA Launches—Continued.

(July 1—December 31, 1967)

Name, date launched, mission	Vehicle	Site [1]	Results
Biosatellite II, September 7. Recoverable biological satellite for use in determining the effects of the space environment on various life processes.	Thor-Delta	ETR	Spacecraft placed into an orbit between 187 and 202 miles; capsule recovered in mid-air by an Air Force plane over the Pacific 45 hours later. Specimens of the satellite's 13 experiments were in good condition and were being studied.
Surveyor V, September 8. NASA's third spacecraft designed to softland on the moon and transmit TV pictures of its landing site. Would also analyze the lunar soil.	Atlas-Centaur	ETR	Landed in the Sea of Tranquillity (Mare Tranquillitatis) on September 11 to send back the first on-site chemical analysis of the soil of an extraterrestrial body (similar to the basalt commonly found on earth). Also transmitted 18,006 pictures during first lunar day of possible landing areas for astronauts.
Intelsat II–D, September 27. Commercial communications satellite launched by NASA for ComSat. Will also support the Apollo manned lunar landing program.	Thor-Delta	ETR	Achieved synchronous orbit 22,300 miles over the Western Pacific to supplement and backup Intelsat II–B, launched in January.
OSO–IV, October 18. The fourth Orbiting Solar Observatory, to carry nine experiments for studying ultraviolet radiation and X-rays emitted by the sun.	Thor-Delta	ETR	As planned, the spacecraft made solar observations in the ultraviolet and X-ray regions of the spectrum, and observations with a protonelectron telescope. (In earth orbit 337 to 359 miles.)
RAM C–1, October 19. Reentry physics probe of use in designing hypersonic aircraft, lifting entry vehicles, slender missiles, and other advanced vehicles.	Scout	WI	Spacecraft attained maximum reentry speed of 25,168 fps at 245,672 feet to land 10 miles from aiming point north east of Bermuda. Water injection experiment reduced length of communications blackout.
ATS–III, November 5. Applications Technology Satellite III carrying nine experiments in communications, meteorology, earth photography in color, navigation, and stabilization and pointing.	Atlas-Agena	ETR	Achieved synchronous orbit of 22,300 miles at 47° west longitude. Satellite's multicolor camera took over 100 pictures of the earth's surface clearly identifying major geographical features of North and South America and other continents. Image dissector camera took monochrome photographs of the same areas. Self-contained navigation system scheduled for spring 1968 testing.

Major NASA Launches—Continued.

(July 1—December 31, 1967)

Name, date launched, mission	Vehicle	Site[1]	Results
Surveyor VI, November 7 .... Spacecraft to softland in the moon's Sinus Medii to photograph possible landing sites for astronauts and further analyze the lunar soil.	Atlas-Centaur ..	ETR	Analyzed lunar soil for 27 hours, verifying the results of Surveyor V analysis that it was similar to earth's basalt. When commanded from earth performed the first lift-off maneuver on the moon. Also photographed the stars Sirius, Canopus, Capella, and Vega. Transmitted 30,065 TV pictures of lunar surface during first lunar day.
Apollo 4, November 9 .... First launch of Apollo/Saturn V to demonstrate launch vehicle capability and spacecraft development. Also to test Apollo heat shield and simulate performance of new hatch at lunar reentry velocity.	Saturn V	ETR	Spacecraft launched into earth orbit; S-IVB fired again and lifted payload to 11,240 miles; service module propulsion system then powered command module to lunar-reentry velocity of 36,537 fps. Command module landed 9 miles from aiming point in Pacific 8½ hours later. First flight of Apollo/Saturn V a major success.
ESSA VI, November 10 .... Weather satellite orbited by NASA for the Environmental Science Services Administration (ESSA) to maintain continuous worldwide Automatic Picture Transmission, APT, coverage.	Thor-Delta	WTR	Spacecraft launched into near-polar orbit between 872 and 921 miles. Its two TV systems were transmitting APT pictures to ground stations as planned.
Pioneer VIII, December 13 .... Third in the recent Pioneer spacecraft series, which will measure magnetic and electric fields, cosmic rays, the solar wind, and electron density in space.	Thor-Delta	ETR	All experiments were returning valuable data. Spacecraft sent into an orbit 92,131,930 to 101,130,940 miles about the sun.

[1] ETR—Eastern Test Range, Cape Kennedy, Fla.
WTR—Western Test Range, Point Arguello, Calif.
WI—Wallops Island, Va.

Appendix R

Grants and Research Contracts Obligated*

(July 1—December 31, 1967)

ALABAMA:		
NGR-01-003-008	Auburn University, W. A. SHAW Computer techniques for multivariant function model generation, emphasizing programs applicable to space vehicle guidance (Agreement period 3/68—3/69).	$27,756
ALASKA:		
NGR-02-001-046	Alaska, University of, S. I. AKASOFU Morphology of auroras by wide-angle lens photography (Agreement period 8/67—7/68).	18,182
NGR-02-001-048	Alaska, University of, W. B. MURCRAY Photometry to determine luminosity versus height and horizontal extent (Agreement period 8/67—7/68).	25,434
NSR-02-001-035	Alaska, University of, K. B. MATHER Construct and operate image orthicon television systems to detect artificial auroras (Agreement period 9/67—6/68).	103,055
ARIZONA:		
NsG-120 (NGR-03-002-001)	Arizona, University of, R. W. G. WYCKOFF Generation and detection of ultralong-wavelength x-rays and quantitative studies of their interactions with matter (Agreement period 5/67—4/70).	49,934
NsG-458 (NGR-03-002-019)	Arizona, University of, S. A. HOENIG Development of chemisorption detectors for specific components of planetary atmospheres (Agreement period 9/67—8/70).	29,991
NGR-03-002 107	Arizona, University of, C. Y. FAN Basic research in astrophysics and space science (Agreement period 9/67—8/68).	45,295
NSR-03-002-131	Arizona, University of Conference on beam-foil spectroscopy (Agreement period (Agreement period 8/67—6/68).	6,000
NGR-03-002-136	Arizona, University of, L. P. HUELSMAN Analysis and synthesis of distributed-lumped-active networks by digital computer (Agreement period 9/67—8/68).	22,124
NGR-03-041-001	Sensory Systems Laboratory, H. A. BALDWIN Interpretation of telemetered physiological responses (Agreement period 10/67—9/68).	30,481

*The grants listed in this appendix are reported to the Congress in compliance with the requirements of the grants statute, 42 U.S.C. 1891–93 (72 Stat. 1793).

Contracts have prefix NASr or NSR; grants have prefix NsG or NGR; transfer of funds to Government agencies have prefix R. Earlier grants and contracts are listed in appendices of previous NASA Semiannual Reports to Congress.

ARKANSAS:		
NsG-713 (NGR-04-001-007)	Arkansas, University of, M. K. TESTERMAN. Investigation of laser properties relevant to the measurement of different physical parameters. (Agreement period 7/67—5/68).	44,874
NGR-04-001-014	Arkansas, University of, G. V. DALRYMPLE. The role of nucleotide metabolism in the repair of radiation injury (Agreement period 9/67—9/68).	25,000
CALIFORNIA:		
R-05-051-001	U.S. Army—Corps of Engineers, T. B. KERR. Conduct radioisotopic investigation of littoral transport around Point Conception, California (Agreement period 7/67—6/69).	30,000
NsG-172 (NGR-05-002-005)	California Institute of Technology, W. G. KNAUSS. Experimental and theoretical research on failure criteria for viscoelastic materials typical of solid rocket propellants (Agreement period 7/67—6/70).	62,230
NsG-426 (NGR-05-002-007)	California Institute of Technology, R. B. LEIGHTON. Space related research in selected fields of physics and astronomy, including cosmic rays interplanetary magnetic fields, solar physics, theoretical astrophysics, planetary spectroscopy and infrared astronomy (Agreement period 4/67—3/70).	400,600
NGR-05-002-031	California Institute of Technology, F. STRUNWASSER. Neural control of hibernations in mammals (Agreement period 9/67—8/68).	55,000
NGR-05-002-034	California Institute of Technology, H. ZIRIN. Research in solar flares and the solar atmosphere (Agreement period 9/67—8/68).	198,740
NsG-101 (NGR-05-003-003)	California, University of (Berkeley), M. CALVIN. Studies of reflection spectra, meteorite analysis, paleobiochemistry, and biochemical evolution as bases for studying extraterrestrial life (Agreement period 11/67—10/68).	325,000
NsG-243 (NGR-05-003-012)	California, University of (Berkeley), S. SILVER. Interdisciplinary space-oriented research in the physical, biological and engineering sciences (Agreement period 2/67—1/70).	425,000
NsG-479 (NGR-05-003-020)	California, University of (Berkeley), T. H. JUKES. Chemistry of living systems (Agreement period 7/67—6/68).	400,000
NsG-513 (NGR-05-003-024)	California, University of (Berkeley), N. PACE. Primate hemodynamics and metabolism under conditions of weightlessness, for the purpose of defining and verifying an experiment suitable for use in a biosatellite (Agreement period 8/67—7/68).	250,000
NsG-704 (NGR-05-003-079)	California, University of (Berkeley), A. D. MCLAREN. An investigation of enzyme assay techniques for life detection in extraterrestrial soils (Agreement period 7/67—6/70).	55,000
NsG-707 (NGR-05-003-039)	California, University of (Berkeley), H. WEAVER. An experimental study of advanced infrared detectors for use in planetary spectroscopy (Agreement period 8/67—9/67).	13,000
NGR-05-003-080	California, University of (Berkeley), R. COLWELL. Multispectral Photographic Terrain Analyses, Based on Statistical Analyses of Spectrometric Data (Agreement period 9/67—6/68).	38,500
NGR-05-003-118	California, University of (Berkeley), R. OSTWALD. Nutritional requirements and breeding behavior of perognathus (Agreement period 7/67—6/68).	10,000

CALIFORNIA—Continued

NGR-05-003-125	California, University of (Berkeley), C. W. CHURCHMAN A study of technological and urban management, with particular emphasis on applying space technology and related technological knowledge of the solution of urban problems (Agreement period 1/67—12/67).	63,000
NGR-05-003-134	California, University of (Berkeley), M. CALVIN Analytical techniques for identification and study of organic matter in returned lunar samples (Agreement period 6/67—5/68).	75,000
NGR-05-003-230	California, University of (Berkeley), S. SILVER Structure of solar magnetic and velocity fields (Agreement period 10/67—9/68).	20,000
NGR-05-003-243	California, University of (Berkeley), R. S. MULLER Field effect transistor stress transducers (Agreement period 6/67—5/69).	18,000
NSR-05-003-100	California, University of (Berkeley), A. E. WHITFORD Development of low noise photomultiplier tubes for astronomical application (Agreement period 4/67—11/67).	6,334
NGR-05-004-021	California, University of (Davis), E. M. BERNAUER Redistribution of body fluids, tissue components, and renal function during non-active state (Agreement period 9/67—9/68).	4,000
NGR-05-004-035	California, University of (Davis), R. E. SMITH The role of brown fat in the thermogenesis of animals and man (Agreement period 9/67—8/68).	40,000
NsG-237 (NGR-05-007-003)	California, University of (Los Angeles), W. F. LIBBY AND J. D. FRENCH. Interdisciplinary space-oriented research in the physical, biological and engineering sciences (Agreement period 4/67—3/70).	13,854
NsG-502 (NGR-05-007-011)	California, University of (Los Angeles), J. D. FRENCH AND W. R. ADEY. Neurophysiological and behavioral studies of chimpanzees, including establishment of a group of implanted animals suitable for space flight (Agreement period 7/67—9/67).	55,700
NGR-05-007-067	California, University of (Los Angeles), G. W. WETHERILL. Chemical and isotopic studies of returned lunar material (Agreement period 7/67—6/68).	17,600
NGR-05-007-077	California, University of (Los Angeles), I. R. KAPLAN Investigation of techniques for analysis of ancient sediments and extraterrestrial materials (Agreement period 7/67—9/67).	10,000
NGR-05-007-091	California, University of (Los Angeles), Y. MINTZ AND A. ARAKAWA. Investigation of optimum meteorological satellite techniques by numerical simulation experiments (Agreement period 1/68—12/68).	110,000
NSR-05-007-181	California, University of (Los Angeles), C. STARR NASA laboratory study (Agreement period 12/67—11/68).	24,800
NsG-321 (NGR-05-009-004)	California, University of (San Diego), J. R. ARNOLD Investigation of the cosmogenci radioactivity and origin of meteorites, and the geochemistry of the solar nebula (Agreement period 9/66—3/70).	120,117

NsG-541 (NGR-05-009-021)	California, University of (San Diego), H. C. UREY AND B. NAGY. Analysis of the organic and inorganic constituents of carbonaceous and other selected stoney meteorites (Agreement period 10/67—9/68).	60,000
NGR-05-009-075	California, University of (San Diego), P. M. BANKS Velocity distributions and electron moment equations (Agreement period 9/67—8/68).	33,781
NGR-05-009-076	California, University of (San Diego), J. A. FEJER Theory of wave propagation and wave-particle interaction in the earth's atmosphere (Agreement period 10/67—9/68).	40,000
NSR-05-009-046	California, University of (San Diego), C. E. MCILWAIN Auroral particle experiment (Agreement period 6/67—5/69).	80,381
NGR-05-010-008	California, University of (Santa Barbara), J. M. SLOSS Elliptic differential equations (Agreement period 8/67—8/68).	20,456
NGR-05-010-020	California, University of (Santa Barbara), T. P. MITCHELL. Librational dynamics of deformable satellites (Agreement period 11/67—10/68).	15,215
NGR-05-029-001	San Francisco, University of, A. FURST Study of the brain amino acids and biogenic amines under various atmospheric mixtures (Agreement period 5/67—4/68).	20,000
NGR-05-046-002	San Jose State College, B. CLARK Factors influencing the perception of angular acceleration in man (Agreement period 9/67—8/68).	40,411
NsG-433 (NGR-05-018-003)	Southern California, University of, J. P. HENRY AND J. P. MEEHAN. Investigation of the role of experiences in the etiology of animal and human physiological and behavioral responses to situational stress in later life.	64,266
NGR-05-018-007	Southern California, University of, D. L. JUDGE Measurement of absolute photon flux using a superconducting bolometer (Agreement period 8/67—7/68).	35,996
NSR-05-018-089	Southern California, University of, A. J. ROWE Evaluate and explore feasibility of GREMEX simulation exercise (Agreement period 6/67—12/67).	30,941
NASr-49(26) (NSR-05-019-164)	Stanford Research Institute, R. A. YOUNG Support the electron beam field mapping experiment through the development and operation of a ground-based image tube camera and spectroscopic system (Agreement period 1/67—3/68).	17,300
NASr-49(31)	Stanford Research Institute A study of the capabilities and benefits of navigational/communication satellites (Agreement period 9/67—6/68).	81,295
NsG-81 (NGR-05-020-004)	Stanford University, J. LEDERBERG Cytochemical studies of planetary microorganisms (Agreement period 9/67—8/68).	410,000
NsG-174 (NGR-05-020-008)	Stanford University, R. A. HELLIWELL Investigation of experimental techniques for measurement of very-low-frequency electromagnetic phenomena in the ionosphere (Agreement period 3/67—2/70).	65,067
NsG-377 (NGR-05-020-014)	Stanford University, V. R. ESHLEMAN Theoretical experimental radio and radar studies of lunar and planetary ionospheres, atmospheres, and surfaces, the sun, and interplanetary medium (Agreement period 10/67—9/70).	220,000

CALIFORNIA—Continued

NsG-703 (NGR-05-020-056)	Stanford University, P. A. STURROCK. Theoretical studies of turbulence in plasmas (Agreement period 6/67—5/68).	35,575
NGR-05-020-066	Stanford University, W. E. SPICER. Photoemission studies of solids (Agreement period 5/67—4/68).	43,951
NGR-05-020-077	Stanford University, F. W. CRAWFORD. The nature and characteristics of space-related plasma resonance phenomena (Agreement period 5/67—6/68).	73,816
NGR-05-020-102	Stanford University, K. KARAMCHETI. Theoretical studies of some nonlinear aspects of hypersonic panel flutter (Agreement period 9/67—8/68).	38,888
NGR-05-020-168	Stanford University, W. C. DEMENT. Combined physiological-neuropharmacological and biochemical investigation of the basic mechanism of rapid eye movement (REM) sleep (Agreement period 9/67—8/68).	75,000
NGR-05-020-176	Stanford University, F. W. CRAWFORD. Investigation of space-related "Whistler" propagation phenomena in laboratory plasmas (Agreement period 6/67—6/68).	59,800
NGR-05-020-177	Stanford University, R. E. SMITH. Subcellular localization of pituitary enzymes (Agreement period 9/67—8/68).	21,340
NGR-05-020-223	Stanford University, M. ANLIKER. Biomechanics within the field of cardiovascular physiology (Agreement period 7/67—6/68).	80,000
NGR-05-020-243	Stanford University, H. ASHLEY. Refined methods of aeroelastic analysis and optimization (Agreement period 9/67—8/68).	9,868
NGR-05-020-244	Stanford University, R. C. ATKINSON. Instructional strategies for optimizing the learning process (Agreement period 1/68—12/68).	78,731
NGR-05-020-250	Stanford University, J. D. BALDESCHWIELER. Study of abiogenic reaction mechanisms by cyclotron resonance spectroscopy (Agreement period 8/67—7/68).	24,927

COLORADO:

NsG-625 (NGR-06-002-018)	Colorado State University, J. B. BEST. Mechanisms of integration and behavior (Agreement period 7/67—6/68).	44,533
NGR-06-002-038	Colorado State University, R. JENSEN. Multidisciplinary space-related research in the physical, engineering and life sciences (Agreement period 9/67—8/70).	100,000
NGR-06-002-053	Colorado State University, C. B. WINN. Theoretical investigation of an electrically propelled geodetic satellite (Agreement period 8/67—1/68).	27,500
NGR-06-003-034	Colorado, University of, W. A. RENSE. Ultraviolet radiation research to support rocket and satellite solar ultraviolet experiments (Agreement period 7/67—6/68).	87,936
NGR-06-003-057	Colorado, University of, R. H. GARSTANG. Basic research in solar physics (Agreement period 9/67—8/68).	57,000

NGR-06-003-064	Colorado, University of, C. A. BARTH Rocket research program in the ultraviolet airglow and aurora of planetary atmospheres (Agreement period 7/67—6/68).	155,000
NGR-06-003-069	Colorado, University of, W. A. RENSE Solar physics research (Agreement period 8/67—8/68).	167,524
NGR-06-003-075	Colorado, University of, A. BUSEMANN The feasibility of large sonic boom reductions (Agreement period 7/67—6/68).	37,595
NGR-06-003-077	Colorado, University of, C. A. BARTH Spectrophotometry of auroral radiations (Agreement period 7/67—6/68).	20,534
R-06-012-017	U.S. Environmental Science Services Adm. Design and develop both ground stations and flight packages for measuring electron densities from ARCAS rockets also instrumented to measure solar protons during PCA events (Agreement period 7/67—12/67).	50,000
R-06-012-026	U.S. Environmental Science Services Admin., M. GADSDEN. To investigate the escitation of nitrogen band systems in polar cap glow auroras (Agreement period 9/67—8/68).	21,000
R-45 (R-06-006-003)	U.S. National Bureau of Standards, A. F. SCHMIDT Continue investigations and studies of liquid hydrogen and other cryogenic fluids (Agreement period 11/67—10/68).	255,000
R-68 (R-06-006-006)	U.S. National Bureau of Standards, J. J. KELLEHER Research relevant to frequency-sharing communications satellites systems (Agreement period 5/67—4/68).	50,000

CONNECTICUT:

NGR-07-010-001	Fairfield University, W. R. CALLAHAN Spectroscopic measurements of earth radiance (Agreement period 11/67—11/68).	15,000
NGR-07-009-001	Rensselaer Polytechnic Institute of Connecticut, Inc., H. J. SCHWARTZ. Study of non-magnetic ionization gauge with low x-ray limit (Agreement period 9/67—8/68).	20,800
NsG-208 (NGR-07-004-009)	Yale University, H. J. MOROWITZ Determination and analysis of the properties and characteristics of extremely small free-living, self-replicating cells (Agreement period 11/67—10/68).	20,670
NsG-374 (NGR-07-004-011)	Yale University, R. GALAMBOS Electrophysiological studies of the brain, including improvement of experimental techniques and methodology (Agreement period 10/67—9/68).	13,445
NsG-724 (NGR-07-004-015)	Yale University, M. M. CHEN An experimental and theoretical research on plasma sheaths and boundary layers around stagnation point electrodes (Agreement period 6/67—5/68).	31,271
NGR-07-004-040	Yale University, K. K. TUREKIAN Trace elements in lunar materials in relation to processes of formation (Agreement period 7/67—6/68).	25,613

DISTRICT OF COLUMBIA:

R–09–038–002	U.S. Department of Agriculture Studies leading to identification of agriculture/forestry experiments utilizing manned-orbiting space stations (Agreement period 9/67—12/67, 10/67—9/68).	225,000 425,000
NSR–09–046–001	American Society for Public Administration Establish a national academy of public administration (Agreement period 8/67—7/70).	265,155
R–104(02) (R–09–019–902)	U.S. Atomic Energy Commission, C. A. TOBIAS Biological research with heavy ion beams. (Lawrence Radiation Laboratory, Berkeley, California) (Agreement period 1/68—12/68).	250,000
R–104(08) (R–09–019–908)	U.S. Atomic Energy Commission, F. J. DE SERRES AND R. E. VON BORSTEL. Research and development in connection with two biological experiments for possible inclusion on biosatellite flights. (Oak Ridge Nat'l. Laboratory, Tennessee) (Agreement period 7/67—12/67).	178,500
NASr–238 (NSR–09–008–001)	Fed. of American Societies for Experimental Biology, P. L. ALTMAN. The accumulation, analysis, compilation of data, and preparation of a camera-ready of a handbook on environmental biology (Agreement period 9/67—8/68).	25,000
NGR–09–010–030	George Washington University, L. H. MAYO Multidisciplinary program of policy studies in science and technology (Agreement period 9/67—8/70).	400,000
NSR–09–010–027	George Washington University, C. W. SHILLING Scientific communication research in space biology (Agreement period 7/67—12/67).	72,341
R–141 (R–09–021–005)	U.S. Library of Congress, P. L. BERRY Literature abstracts in the field of aerospace medicine (Agreement period 7/67—6/68).	55,213
R–09–021–011	U.S. Library of Congress Abstracts of foreign published scientific articles (Agreement period 7/67—6/68).	10,000
NASr–62 (NSR–09–012–010)	National Academy of Sciences Administration of the NASA International University Program (Agreement period 10/67—9/68).	255,000
NASr–239 (NSR–09–012–017)	National Academy of Sciences, H. H. HESS Organize and conduct summer study in exobiology and prepare reports thereon (Agreement period 7/66—12/66).	5,174
NSR–09–012–901	National Academy of Sciences, C. J. LAPP The NASA postdoctoral and senior postdoctoral resident research associateship program in space sciences and technology (Agreement period 9/68—8/69).	2,550,000
NSR–09–012–903	National Academy of Sciences, H. ODISHAW Support to the National Academy of Sciences Space Science Board (Agreement period 12/66—11/67, 12/66—11/67).	37,000 29,000
NSR–09–012–908	National Academy of Sciences To conduct a biogravitational symposium (Agreement period 2/67—1/68).	43,000
NSR–09–012–909	National Academy of Sciences A study and report on the probable future usefullness of satellites in practical earth-oriented applications (Agreement period 1/67—10/68).	159,000

NSR-09-013-009	National Science Teachers Association, R. H. CARELTON Conduct of a series of twelve youth science congresses by the National Science Teachers Association (Agreement period 9/67—8/68).	58,635
R-09-136-001	U.S. Navy—Naval Oceanographic Office Studies leading to the identification of oceanograph marine technology experiments utilizing manned orbiting space stations with existing or modified Apollo hardware (Agreement period 7/67—6/68).	376,000
R-107 (R-09-029-003)	U.S. Navy—Naval Research Laboratory, H. FRIEDMAN Solar instrumentation for advanced orbiting observatories (Agreement period 8/67—7/68).	350,000
R-09-029-036	U.S. Navy—Naval Research Laboratory, M. J. KOOMEN Observation of the white light corona from a rocket (Agreement period 3/67—2/68).	160,000
R-09-029-063	U.S. Navy—Naval Research Laboratory, H. FRIEDMAN To provide hardware for Fellows of the Hulbert Center (Agreement period 7/67—6/68).	300,000
R-48 (R-09-030-003)	U.S. Navy—Office of Naval Research, F. B. ISAKSON Provide balloon support at Fort Churchill, during the Summer of 1966 for NASA sponsored scientists (Agreement period 9/67—8/68).	46,350
NSR-09-015-044	Smithsonian Institution, S. R. GALLER Interdisciplinary communications program conferences (Agreement period 10/67—9/68).	145,386
FLORIDA:		
NGR-10-004-041	Florida State University, W. SCHWARTZ Microbial activity in non-aqueous systems (Agreement period 9/67—8/68).	26,156
NGR-10-005-082	Florida, University of, D. C. GOODMAN Dynamic interactions between cerebellum and primary vestibular neurons in the vestibular nuclear complex (Agreement period 9/67—8/68).	32,275
NsG-689 (NGR-10-007-008)	Miami, University of, S. W. Fox Space related biology, molecular evolution and aspects of extraterrestrial environment (Agreement period 10/67—9/68).	166,220
R-39 (R-10-009-002)	U.S. Navy—School of Aviation Medicine, D. E. BEISCHER Research on the effect of very strong magnetic fields and of magnetic-field-free environments on man and animals (Agreement period 10/67—9/68).	50,000
R-75 (R-10-009-003)	U.S. Navy—School of Aviation Medicine, H. J. SHAEFER Energy dissipation characteristics in tissue for ionizing radiation in space (Agreement period 2/68—7/68).	7,500
R-93 (R-10-009-004)	U.S. Navy—School of Aviation Medicine, A. GRAYBIEL Physiological and psychological effects of gravitational and inertial forces on man in a manner which extends man's basic knowledge of the area and simultaneously applies this knowledge to operational problems (Agreement period 1/68—12/68).	242,500
NGR-10-008-009	South Florida, University of, R. E. WILSON Star tracking guidance techniques (Agreement period 10/67—9/68).	24,883
NGR-10-008-011	South Florida, University of, H. K. EICHHORN-VON WURMB. The use of flying spot digitizers for the measurement of astrometric plates (Agreement period 9/67—2/68).	4,526

GEORGIA

NGR-11-001-012	Emory University, B. W. ROBINSON Control and analysis of primate behavior by brain telestimulation and telemetry (Agreement period 8/67—7/68).	85,000
NGR-11-001-026	Emory University, N. A. BAILY Radiation measurement of radiobiological hazards of man in space (Agreement period 10/67—9/68).	40,000
NGR-11-002-068	Georgia Institute of Technology, J. D. CLEMENT The attenuation of radiant energy in hot seeded hydrogen—an experimental study related to the gaseous core nuclear rocket (Agreement period 9/67—8/68).	58,599
R-137 (R-11-004-001)	U.S. Dept. of Health, Education and Welfare, J. R. BAGBY. Research on microbiological sterilization problems (Agreement period 7/68—9/68).	213,000

HAWAII:

NsG-328 (NGR-12-001-002)	Hawaii, University of, K. WATANABE Theoretical and experimental investigation of electron emission, conductivity and luminescence of selected solids under vacuum ultaviolet excitation (Agreement period 9/67—8/68).	25,483
NsG-676 (NGR-12-001-004)	Hawaii, University of, J. L. WEINBERG Photoelectric study of the night-sky radiation from zodiacal light, airglow, and starlight (Agreement period 9/67—8/68).	100,000
NASr-5 (NSR-12-001-003)	Hawaii, University of, H. C. MCALLISTER Design studies and experimental evaluations of a stigmatic spectrograph with nominal dispersion of 1A/mm and resolution of 0.01A, useful in the spectral range from 1000 A to 3000 A, and of sufficient compactness and speed to be suitable for use in a rocket vehicle (Agreement period 9/66—8/67, 9/67—8/68).	15,211 248,554

ILLINOIS:

NsG-333 (NGR-14-001-008)	Chicago, University of, T. FUJITA Meteorological interpretation of satellite radiation data (Agreement period 10/67—9/68).	60,000
NsG-441 (NGR-14-001-012)	Chicago, University of, H. FERNANDEZ-MORAN Investigations in space-related molecular biology, including consideration of the molecular organization of extraterrestrial matter (Agreement period 1/68—9/68).	150,000
NGR-14-004-028	Illinois Institute of Technology Numerical solutions and visual display of flow over aerodynamic bodies (Agreement period 9/67—8/68).	29,822
NASr-65(09) (NSR-14-003-909)	IIT Research Institute, Y. HARADA Graphite-Metal composites (Agreement period 9/67—8/68).	98,962
NASr-65(23) (NSR-14-003-170)	IIT Research Institute, R. MARSHALL The study of a spectrally selective ultraviolet film of high quantum efficiency (Agreement period 10/67—9/68).	73,560
NsG-24 (NGR-14-005-002)	Illinois, University of (Urbana), E. C. YEH Theoretical and experimental studies of ionospheric electron control and irregularities (Agreement period 7/67—6/68).	100,000

NsG-395 (NGR-14-005-009)	Illinois, University of (Urbana), R. MITTRA — A study of selected radiation and propagation problems related to antennas and probes in magneto-ionic media (Agreement period 9/67—8/68).	47,871
NGR-14-005-074	Illinois, University of (Urbana), H. W. ADES — Physiological responses of central vestibular pathways and diffuse ascending systems to vestibular stimulation (Agreement period 10/67—9/68).	160,000
NGR-14-008-009	Southern Illinois University, D. T. HAIMO — Transforms related to generalized heat equations (Agreement period 6/67—6/68).	8,608
INDIANA:		
NGR-15-003-007	Indiana University, W. D. NEFF — An experimental investigation of the neurological correlates of information reception (Agreement period 10/67—9/68).	23,750
NGR-15-004-026	Notre Dame, University of, J. L. MASSEY — Convolutional coding techniques for data protection (Agreement period 9/67—9/68).	25,000
NGR-15-004-028	Notre Dame, University of, G. F. DALELIO — Synthesis of polymers with high residues at high temperatures (Agreement period 9/67—9/68).	15,000
NGR-15-008-004	Rose Polytechnic Institute, H. A. SABBAGH — A theoretical analysis of static and dynamic behavior of some maser systems (Agreement period 10/67—6/68).	10,000
IOWA:		
NSR-16-001-025	Iowa, University of, D. A. GURNETT — A very-low-frequency radio noise experiment to be flown on a Javelin sounding rocket (Agreement period 8/67—7/68).	76,095
NGR-16-001-031	Iowa, University of, C. C. WUNDER — Physiological and developmental changes resulting from reduced gravitational force with animals chronically adjusted to centrifugal fields (Agreement period 8/67—7/68).	15,813
NSR-16-001-056	Iowa, University of, L. A. FRANK — Measurements of low-energy electrons and protons at low altitudes over the auroral zone on Javelin Sounding Rocket 8.46 UI (Agreement period 9/67—8/68).	41,946
KANSAS:		
NGR-17-002-042	Kansas, University of, R. H. HIMES — Biochemical studies of thermophilic bacteria (Agreement period 10/67—9/68).	27,626
NGR-17-004-014	Kansas, University of, K. H. LENZEN — Investigation of trajectory and mission analysis for aerospace vehicles (Agreement period 9/67—8/68).	9,230
KENTUCKY:	Kentucky, University of, R. C. BIRKEBAK — Thermal radiation characteristics and thermal conductivity of lunar material (Agreement period 7/67—6/68).	30,000
NGR-18-001-035	Kentucky, University of, J. H. LIENHARD — Study of interacting effects of geometry and gravity upon the peak and minimum boiling heat fluxes (Agreement period 9/67—8/68).	30,400

LOUISIANA:		
NGR-19-001-016	Louisiana State University, R. W. PIKE Evaluation of the energy transfer in the char-zone during ablation (Agreement period 9/67—5/68).	16,000
NGR-19-001-018	Louisiana State University, A. ZETTL Symmetry in non-self adjoint boundary value problems (Agreement period 7/67—6/68).	8,674
MARYLAND:		
R-35 (R-21-005-011)	U.S. Army Chemical Corps Biological Labs., C. R. PHILLIPS. Research to determine the effects of ethylene oxide on the sterilization of electronic components and other materials used in space vehicles; determine contaminants of spacecraft components and materials, search for sterilants for plastics and determine sterilization procedures (Agreement period 9/67—8/68).	34,000
NsG-450 (NGR-21-015-001)	Institute for Behavioral Research, I. GOLDIAMOND AND C. B. FERSTER. Experimental studies of perceptual processes Agreement period 9/67—8/68).	64,182
NsG-193 (NGR-21-001-001)	Johns Hopkins University, W. G. FASTIE Rocket and laboratory experiments and analysis on the ultraviolet spectra of the upper atmosphere (Agreement period 7/67—7/68, 7/67—7/68).	276,000 30,000
NsG-220 (NGR-21-002-005)	Maryland, University of, D. A. TIDMAN Theoretical investigations in dynamics of astrophysical plasmas including studies of the structure of plasma shock waves, solar corona, and their possible radio emission (Agreement period 2/67—1/70).	79,000
NsG-283 (NGR-21-002-006)	Maryland, University of, T. D. WILKERSON Studies of particle phenomena in the interplanetary plasma and of the excitation and ionization cross-Sections of the hydrogen, helium, oxygen, and nitrogen atoms and molecular combinations (Agreement period 6/67—5/68).	85,000
NsG-436 (NGR-21-002-010)	Maryland, University of, J. WEBER Study on theoretical and experimental research on gravitational radiation (Agreement period 7/67—6/68).	80,193
NsG-566 (NGR-21-002-026)	Maryland, University of, R. G. GRENELL Neurobiological substrates of behavior (Agreement period 9/67—6/68).	90,805
NGR-21-002-040	Maryland, University of, R. G. GRENELL Study of protein hydration in isolated cell surface structure (Agreement period 7/67—12/67, 11/67—10/68).	12,833 59,112
NGR-21-002-059	Maryland, University of, E. R. LIPPINCOTT AND Y. T. PRATT. Investigations on equilibrium and non-equilibrium systems in pre-biological atmospheres (Agreement period 9/67—8/68).	110,001
NGR-21-002-109	Maryland, University of, C. O. ALLEY Feasibility studies and techniques for laser ranging to optical retro-reflection on the Moon (Agreement period 4/67—6/68).	50,000
NSR-21-003-002	National Biomedical Research Foundation, M. O. DAYHOFF To conduct a study of thermodynamic properties of molecular complexes of organic molecular systems (Agreement period 10/67—6/68).	69,996

MASSACHUSETTS:

NsG-685 (NGR-22-007-021)	Harvard University, G. R. HUGUENIN. Long wavelength extension of solar radio burst observations (Agreement period 9/67—8/68, 9/67—8/68, 9/67—8/68).	18,942 72,755 122,563
NGR-22-007-056	Harvard University, R. W. P. KING. Theoretical and experimental investigations of antennas and waves in plasma (Agreement period 9/67—8/68).	54,306
NGR-22-007-059	Harvard University, K. R. PORTER. The effects of stress on collagen biogenesis (Agreement period 10/67—9/68).	36,038
NGR-22-091-002	College of the Holy Cross, R. C. GUNTER. Investigation of the effect of space environment on replica gratings (Agreement period 6/67—5/68).	16,250
NsG-691 (NGR-22-009-048)	Massachusetts Institute of Technology, G. SILVERMAN. Study of the resistivity of microorganisms to thermal inactivation by dry heat (Agreement period 7/67—6/68).	35,102
NGR-22-009-059	Massachusetts Institute of Technology, Z. M. ELIAS. The use of stress functions in thin shell theory (Agreement period 9/67—9/68).	25,212
NGR-22-009-091	Massachusetts Institute of Technology, R. E. STICKNEY. Study of transport properties of thermal plasmas (Agreement period 11/67—10/68).	35,000
NGR-22-009-102	Massachusetts Institute of Technology, K. BIEMANN. Study of mass spectrometric techniques applicable to the search for organic matter in the lunar crust (Agreement period 6/67—8/67).	25,000
NGR-22-009-123	Massachusetts Institute of Technology, F. PRESS. Experimental techniques in lunar passive seismography (Agreement period 7/67—6/68).	39,500
NGR-22-009-124	Massachusetts Institute of Technology, G. C. NEWTON. Studies in control optimization, stabilization and computer algorithms (Agreement period 9/67—8/68).	50,197
NGR-22-009-135	Massachusetts Institute of Technology, S. H. CRANDALL. Response of building structures to environmental noise of seismic, acoustic and aerodynamic origin (Agreement period 5/67—4/58).	37,730
NGR-22-009-234	Massachusetts Institute of Technology. Thermal interactions in semiconductor devices (Agreement period 7/67—12/67).	9,700
NGR-22-009-250	Massachusetts Institute of Technology. A study of applications of satellite altimetry to oceanography and orbit determination (Agreement period 9/67—4/68).	33,458
NGR-22-009-262	Massachusetts Institute of Technology. Study of advanced geodetic applications and missions (Agreement period 9/67—2/68).	38,387
NGR-22-009-269	Massachusetts Institute of Technology, J. A. FAY. Quasi-steady plasma acceleration (Agreement period 9/67—9/68).	36,511
NGR-22-009-277	Massachusetts Institute of Technology, A. RICH. The prebiotic synthesis of polynucleotides and polynucleotide, directed polypeptides (Agreement period 10/67—9/68).	44,442
NGR-22-010-025	Massachusetts, University of, J. STRONG. To study the solar chromosphere from balloon altitudes (Agreement period 9/67—8/68).	93,077

MASSACHUSETTS—Continued

NGR-22-011-020	Northeastern University, J. WARGA. Optimization of trajectories by modern mathematical control theory and functional analysis (Agreement period 9/67—9/68).	30,000
NsG-87 (NGR-09-015-002)	Smithsonian Institution, F. L. WHIPPLE. *Optical Satellite Tracking program* (Agreement period 10/67—9/68).	970,000
NGR-09-015-023	Smithsonian Institution, C. SAGAN. Selected studies in exobiology, planetary environments and problems related to the origin of life (Agreement period 10/67—9/68).	67,000
NSR-22-014-001	Woods Hole Oceanographic Institution, E. T. DEGANS. Biogeochemistry of terrestrial and extraterrestrial organic matter (Agreement period 7/67—6/68).	31,300

MICHIGAN

NsG-226 (NGR-23-002-001)	Detroit, University of, A. SZUTKA. Synthesis of morphine-like substances from simple precursors (Agreement period 12/67—11/68).	23,000
NsG-475 (NGR-23-004-001)	Michigan State University, L. G. AUGENSTEIN. Selected studies of molecular organization and mental function (Agreement period 8/67—7/68).	9,943
NGR-23-007-001	Michigan Technological University, C. E. WORK. Investigation of the influence of cyclic prestressing on fatigue of metals (Agreement period 10/67—3/69).	11,752
NsG-124 (NGR-23-005-005)	Michigan, University of, J. W. FREEMAN. Research on heat resistant alloys (Agreement period 4/67—3/68).	47,500
NsG-525 (NGR-23-005-015)	Michigan, University of, A. NAGY. Theoretical and experimental investigation of plasma waves, space vehicle plasma sheaths, and ionospheric electron temperatures (Agreement period 9/67—8/68).	80,770
NsG-640 (NGR-23-005-041)	Michigan, University of, H. C. EARLY. Basic engineering studies of techniques for acceleration of a particle to hypervelocity by an electrically heated propellant plasma (Agreement period 9/67—8/68).	51,847
NsG-698 (NGR-23-005-035)	Michigan, University of, G. W. STROKE. To investigate novel techniques for ruling improved large diffraction gratings (Agreement period 7/67—11/67).	35,176
NGR-23-005-183	Michigan, University of, J. E. ROWE. *Frequency multiplication in high-energy electron beams* (Agreement period 10/67—9/68).	75,000
NGR-23-005-185	Michigan, University of, J. R. P. FRENCH. Investigate the application of new bioelectronics to cardiovascular stresses (Agreement period 5/67—2/68).	10,596
NASr-54(05) (NSR-23-005-905)	Michigan, University of, L. M. JONES. Survey measurements of upper air structure (Agreement period 4/67—7/67).	90,000
NASr-54(12) (NSR-23-005-912)	Michigan, University of, H. F. ALLEN. Design engineering and fabrication for installation of meteorological instruments in a NASA aircraft for atmospheric radiation measurements (Agreement period 1/67—12/67).	30,000

MINNESOTA:

NsG-327 (NGR-24-003-001)	Mayo Foundation, E. H. WOOD Studies of the effects of acceleration on cardiovascular and respiratory dynamics (Agreement period 11/67—10/68).	60,000
NGR-24-005-063	Minnesota, University of, W. CHESTON Multidisciplinary research in space sciences and technology (Agreement period 6/67—5/70).	635,005
NGR-24-005-105	Minnesota, University of, V. R. MURTHY Elemental and isotopic studies of lunar materials (Agreement period 9/67—8/68).	26,100
NASr-248 (NSR-24-005-025)	Minnesota, University of, A. O. C. NIER Investigation of the neutral constituents of the atmosphere in the 100-200 km altitude range (Agreement period 1/68—6/68).	94,119

MISSISSIPPI:

NGR-25-001-008	Mississippi State University, G. E. JONES Microwave spectroscopic identification of atmospheric contaminants (Agreement period 10/67—9/68).	42,149

MISSOURI:

NASr-63(14) (NSR-26-002-912)	Midwest Research Institute Match aerospace technology information resources with technical program needs of the Department of the Interior (Agreement period 10/67—10/68).	10,330
NGR-26-003-023	Missouri, University of (Columbia), R. L. WIXON Application of nitrogen metabolism in autotrophic bacteria to chemosynthetic bioregeneration in space missions (Agreement period 10/67—9/68).	20,230
NGR-26-004-021	Missouri, University of (Columbia), X. J. MUSACCHIA Effects of radiation on gastro-intestinal function and cyclic turnover of intestinal epithelium (Agreement period 7/67—6/68).	42,341
NGR-26-004-025	Missouri, University of (Columbia), F. E. SOUTH An Investigation of mammalian adaption to deep hypothermia and of hypothermia-hibernation relationships (Agreement period 7/67—6/68).	32,500
NGR-26-008-042	Washington University, J. KLARMANN Gamma ray experiment based on spark chambers and nuclear emulsions (Agreement period 11/67—4/68).	49,683

MONTANA:

NsG-430 (NGR-27-001-001)	Montana State University, I. E. DAYTON Multidisciplinary research in space science and engineering (Agreement period 7/67—6/70).	125,000

NEVADA:

NGR-29-001-008	Nevada, University of, P. ATLICK Investigations of methods for the calculations of atomic photoionization cross sections (Agreement period 9/67—8/68).	25,084
NGR-29-001-016	Nevada, University of, F. WINTERBERG Investigation of the propagation of plasma waves in inhomogeneous plasmas (Agreement period 9/67—9/68).	25,781

NEW HAMPSHIRE:		
NsG-231 (NGR-30-001-001)	Dartmouth College, C. J. LYON. Investigation of the effects of plant growth hormones on plant development in the absence of gravitational effects (Agreement period 9/67—8/68).	31,598
NsG-614 (NGR-30-002-008)	New Hampshire, University of, R. E. HOUSTON. Relationships between lower-ionospheric effects observed by VHF-absorption techniques, and cosmic-ray and geomagnetic activity (Agreement period 10/67—9/68).	16,113
NGR-30-002-028	New Hampshire, University of, L. J. CAHILL. Sounding rocket investigation of auroral displays (Agreement period 5/68—4/69).	91,621
NEW JERSEY:		
NGR-31-001-059	Princeton University, E. DOWELL. Investigation of non-linear problems and mathematical methods in aeroelasticity (Agreement period 4/67—3/68).	24,320
NGR-31-001-068	Princeton University, L. D. DAVISSON. Study of advanced communication techniques (Agreement period 7/67—6/68).	15,000
NSR-31-001-902	Princeton University, D. T. HARRJE. Reference book on liquid propellant rocket combustion instability (Agreement period 6/67—11/68).	76,300
NGR-31-004-026	Rutgers State University, D. A. LUPFER. Sputtering of thin ferroelectric films (Agreement period 8/67—3/68).	15,154
NEW MEXICO:		
R-09-019-040	U.S. Atomic Energy Commission, H. D. SIVINSKI. Support of the planetary quarantine activities of bioscience programs (Agreement period 10/67—9/68).	287,000
NEW YORK:		
NSR-33-003-009	American Institute of Aeronautics & Astronautics, Inc., J. J. GLENNON. Scientific and technical information service, including abstracting and indexing, covering published aerospace literature (Agreement period 7/67—6/68).	1,685,000
NGR-33-013-029	City College of the City University of New York, R. PFEFFER. The effect of particle and fluid properties on the heat transfer coefficient and pressure drop of a dilute flowing gas-solid suspension (Agreement period 10/67—9/69).	23,124
NsG-445 (NGR-33-008-012)	Columbia University, H. M. FOLEY, R. NOVICK, L. WOLTJER AND P. W. GAST. Theoretical and analytical studies of planetary and stellar structure, evolution and dynamical processes; and applicability of geophysical methods to such studies (Agreement period 9/67—8/68).	21,000
NGR-33-008-055	Columbia University, O. L. ANDERSON. The measurement of physical properties, including the Gruneisen constant, on lunar geological specimens (Agreement period 8/67—11/67).	40,500
NGR-33-008-098	Columbia University, M. B. FRIEDMAN. Research into the theory of the superboom (Agreement period 8/67—7/68).	30,750
NASr-156 (NSR-33-009-004)	Cornell Aeronautical Laboratory, Inc., J. W. FORD. Basic research in techniques for warm fog dispersal designed to improve airport utilization (Agreement period 10/67—9/68).	156,543

NGR-33-010-042	Cornell University, F. K. MOORE Study of high temperature heat transfer (Agreement period 7/67—6/68).	50,740
NGR-33-010-047	Cornell University, P. R. MCISAAC Advanced concepts of microwave power amplification and generation utilizing linear beam devices (Agreement period 11/67—10/68).	30,208
NGR-33-010-054	Cornell University, A. R. SEEBASS Sonic boom research (Agreement period 9/67—8/70).	58,500
NGR-33-010-057	Cornell University, F. K. MOORE Sonic boom phenomena (Agreement period 9/67—8/69).	49,068
NGR-33-010-041	Cornell University Medical College, D. V. BECKER Physiologic consequences of experimental isolation (Agreement period 1/68—12/68).	16,000
NsG-155 (NGR-33-011-001)	Dudley Observatory, C. L. HEMENWAY Collection and analysis of micrometeorites (Agreement period 8/67—9/68).	150,000
NGR-33-011-009	Dudley Observatory, R. D. MERCER Feasibility study for use of YF-12 aircraft as a scientific instrument platform for observing the 1970 solar eclipse (Agreement period 8/67—1/68).	9,550
NGR-33-015-066	New York, State University of (Albany), H. S. TUAN Theoretical investigations on the properties of radio wave propagation in interplanetary space Agreement period 10/67—9/68).	9,256
NGR-33-015-068	New York, State University of, G. W. STROKE Proposed novel techniques for interferometrically controlled ruling of improved large diffraction gratings (Agreement period 10/67—9/68).	84,698
NGR-33-015-013	New York, State University of (Stony Brook), R. P. TEWARSON. Product form of inverses of sparse matrices (Agreement period 9/67—8/68).	16,588
NGR-33-016-038	New York University, H. FREEMAN Investigation of computer techniques for analyzing three dimensional geometric configurations (Agreement period 7/67—6/68).	30,492
NGR-33-016-057	New York University, M. A. RUDERMAN Selected topics in astrophysics (Agreement period 5/67—8/67).	10,000
NGR-33-016-119	New York University, A. FERRI Engine effect on sonic boom; unsteady engine inlet interaction (Agreement period 6/67—5/68).	29,920
NGR-33-006-020	Polytechnic Institute of Brooklyn, K. K. CLARKE A space communications study (Agreement period 9/67—9/68).	74,953
NsG-100 (NGR-33-018-003)	Rensselaer Polytechnic Institute, S. E. WIBERLEY Interdisciplinary materials research (Agreement period 5/68—4/71).	300,000
NsG-261 (NGR-33-018-007)	Rensselaer Polytechnic Institute, P. HARTECK Chemistry of planetary atmospheres (Agreement period 9/67—8/70).	112,000
NGR-33-018-066	Rensselaer Polytechnic Institute, J. B. HUDSON A study of surface effects in gauges for ultrahigh vacuum pressure measurements (Agreement period 9/67—8/68).	24,980
NsG-209 (NGR-33-019-002)	Rochester, University of, W. VISHNIAC Microbiological and chemical studies of planetary soils (Agreement period 9/67—8/68).	90,000

NEW YORK—Continued		
NsG-574 (NGR-33-019-014)	Rochester, University of, E. KINNEN A study of adaptive and non-linear control systems and theory, applying the direct method of Lyapunov (Agreement period 10/67—9/68).	23,000
NGR-33-019-042	Rochester, University of, M. F. KAPLON Cosmic ray research (Agreement period 7/67—5/68).	49,964
NGR-33-022-023	Syracuse University, V. WEISS Crack propagation in strain controlled fatigue (Agreement period 9/67—8/68).	32,325
NASr-206 (NSR-33-022-006)	Syracuse University, I. SWERDLOW Social science work concerning (1) management and public policy implications of decisions-making in space and related programs, and (2) prospects for developing interdisciplinary research and training at the graduate level (Agreement period 7/67—9/67).	5,655
NORTH CAROLINA:		
NSR-34-007-003	North Carolina Science & Technology Research Ctr. An experimental technology utilization program directed to the enhancement and acceleration of the process of transferring new technology derived through government sponsorship to uses additionally benefiting the private and public sectors of society (Agreement period 4/67—3/68).	120,526
NsG-588 (NGR-34-002-007)	North Carolina State University (Raleigh), R. W. LADE. Theoretical and experimental studies of radiation-induced damage to semiconductor surfaces and effects of damage on device performance (Agreement period 7/67—6/68).	20,000
NGR-34-002-024	North Carolina State University (Raleigh), F. O. SMETANA. Study of transpiration effects on pressure indicators in the transition regime (Agreement period 7/67—6/68).	19,739
NGR-34-002-036	North Carolina State University (Raleigh), F. O. SMETANA. An experimental investigation of the cryoentrainment pump (Agreement period 11/67—10/68).	11,365
NGR-34-002-042	North Carolina State University (Raleigh), E. R. MANRING. Photometry of vapor clouds released above the Earth (Agreement period 6/67—5/68).	31,702
OHIO:		
NASr-100(10) (NSR-36-002-067)	Battelle Memorial Institute The preparation of interpretive reports on selected subjects (Agreement period 7/67—2/68).	11,500
NASr-100(11)	Battelle Memorial Institute Application of satellite techniques to development of geodetic points in the deep ocean (Agreement period 9/67—8/68).	47,800
NSR-36-002-062	Battelle Memorial Institute, C. B. SCLAR An investigation of shock wave damage in minerals of lunar rocks as revealed by electron microscopy (Agreement period 8/67—7/68).	24,750
NsG-654 (NGR-36-003-035)	Cast Institute of Technology, S. V. RADCLIFFE An investigation of the effects of hydrostatic pressure cycling on the mechanical behavior of body centered cubic refractory metals and alloys (Agreement period 6/67—5/68).	31,500

NGR-36-004-013	Cincinnati, Univresity of, R. J. KROLL Investigation of the longitudinal vibration of liquid-fueled launch vehicle (Agreement period 9/67—9/68).	20,500
NGR-36-004-030	Cincinnati, University of, L. MEIROVITCH Dynamic characteristics of a variable-mass flexible missile (Agreement period 9/67—8/68).	29,780
NsG-437 (NGR-36-005-001)	Fels Research Institute, E. S. VALENSTEIN Experimental studies of reinforcing brain stimulation, including consideration of behavioral consequences (Agreement period 9/67—8/70).	50,000
NsG-448 (NGR-36-008-005)	Ohio State University, C. LEVIS Theoretical and experimental investigations of spacecraft antenna problems in the varied operational environments of far-out space and atmospheric re-entry, including considerations of immersion in a hot plasma sheath and of omni-directional coverage (Agreement period 8/67—7/68).	45,000
NGR-36-008-040	Ohio State University, M. H. RIZVI Ranking problems in multivariate normal (statistical) populations (Agreement period 7/67—6/68).	11,711
NGR-36-008-041	Ohio State University, J. H. DINES AND L. B. ROBERTS Cardiovascular responses to environmental vibrations (Agreement period 8/67—7/68).	20,000
NGR-36-008-093	Ohio State University, I. I. MUELLER Data analysis for the National Geodetic Satellite Program (Agreement period 8/67—7/69).	98,700
NSR-36-008-028	Ohio State University, A. W. LEISSA A study of continuum vibrations (Agreement period 7/67—6/69).	58,865
NGR-36-014-006	Xavier University, R. E. MILLER Micropulsations in the visible range (Agreement period 8/67—7/68).	12,856

OKLAHOMA:

NsG-300 (NGR-37-001-001)	Oklahoma City University, J. P. JORDAN Interdisciplinary studies of the effects of the space environment on biological systems (Agreement period 11/67—10/68).	50,000
NGR-37-002-031	Oklahoma State University, L. FOLKS Statistical methods and subjective probability (Agreement period 2/67—1/68).	20,460

OREGON:

NGR-38-003-009	Oregon, University of, D. P. WEILL Plagioclase thermometry of igneous rocks (Agreement period 5/67—4/70).	64,832

PENNSYLVANIA:

NGR-39-002-023	Carnegie Institute of Technology, J. L. SWEDLOW Analysis of notches and cracks (Agreement period 1/68—12/68).	37,500
NsG-270 (NGR-39-004-001)	Drexel Institute of Technology, P. C. CHOU Theoretical analysis of liquid filled fuel tanks impacted by hypervelocity particles (Agreement period 9/67—8/68).	48,564
NGR-39-004-007	Drexel Institute of Technology, C. GATLIN Multidisciplinary research in space science and technology (Agreement period 6/67—5/70).	100,000
NGR-39-005-066	Franklin Institute, A. A. WYLLER Structural and spectral studies of sunspots (Agreement period 9/67—8/68).	51,725

PENNSYLVANIA—Continued		
NGR-39-007-011	Lehigh University, F. ERDOGAN Investigation of fatigue crack propagation in thin plates and shells (Agreement period 2/68—1/69).	43,465
NsG-114 (NGR-39-009-002)	Pennsylvania State University, W. J. ROSS Ionospheric studies using beacon satellite transmissions (Agreement period 10/67—9/68).	55,000
NsG-324 (NGR-39-009-008)	Pennsylvania State University, E. C. POLLARD Cellular biophysics: a study of the structure and function of living cells (Agreement period 7/67—6/68).	170,000
NGR-39-009-041	Pennsylvania State University, A. M. KRALL Stabilization for differential systems (Agreement period 6/67—5/68).	18,217
NGR-39-009-096	Pennsylvania State University, G. LACHS A theoretical and experimental investigation of the quantum mechanical effects on communication systems (Agreement period 9/67—8/68).	29,664
NsG-335 (NGR-39-010-003)	Pennsylvania, University of, E. THOROGOOD Molecular biology of nitrogen fixing nodules in common legumes (Agreement period 10/67—9/68).	50,063
NGR-39-011-067	Pittsburgh, University of, G. R. FITTERER The development of solids electrolyte techniques to determine the rate constants for the oxidation of metals and alloys (Agreement period 9/67—8/68).	22,579
NGR-39-011-079	Pittsburgh, University of, R. S. DOUGALL Experimental determination of the heat-transfer and vapor-void characteristics of subcooled forced-convection boiling of Freon-113 at high pressures with emphasis on the bubble layer (Agreement period 9/67—8/69).	63,038
NGR-39-011-080	Pittsburgh, University of, D. C. STONE Research program in public administration (Agreement period 11/67—11/70).	103,000
NGR-39-011-083	Pittsburgh, University of, T. M. DONAHUE Photometer observations of auroral oxygen and nitrogen emissions (Agreement period 10/67—9/68).	7,150
	University City Science Center Biomedical systems analysis program (Agreement period 9/67—5/68).	50,031
	Villanova University, G. C. YEH Kinetic study of electrically activated reaction systems (Agreement period 9/67—8/68). 9/66—8/67	3,000 15,000
RHODE ISLAND:		
	Brown University, J. P. LASALLE Theory of differential equations and their relationship to dynamical systems theory (Agreement period 1067—9/70).	122,412
SOUTH CAROLINA:		
NGR-40-002-015	Brown University, W. N. FINDLEY	75,000
R-124 (R-41-003-001)	U.S. Atomic Energy Commission, S. P. RIDEOUT Investigation of stress-corrosion cracking of alloy Ti 8 Al-1 V (Agreement period 7/66—6/68).	
NGR-41-001-016	Clemson University, T. G. PROCTOR Studies on the existence of almost periodic solutions for certain differential and functional equations containing almost periodic members (Agreement period 5/67—5/68).	12,720

SOUTH DAKOTA:

NGR-42-001-002	South Dakota School of Mines and Technology, C. L. GRUBER. Experimental studies of the optically induced free carrier light modulation (Agreement period 9/67—9/68).	11,313

TENNESSEE:

NGR-43-001-029	Tennessee, University of, J. S. BRADLEY. Principal solutions of non-oscillatory linear differential equations (Agreement period 7/67—6/68).	11,808
NGR-43-002-015	Vanderbilt University, M. G. BOYCE. Application of calculus of variations to the optimization of multistage trajectories (Agreement period 1/68—12/68).	23,000
NGR-43-002-026	Vanderbilt University, J. W. WILLIAMSON. Study of the performance of an externally-pressurized journal bearing utilizing standing shocks in the bearing film (Agreement period 9/67—8/68).	13,651

TEXAS:

NsG-390 (NGR-44-003-001)	Baylor University, P. KELLAWAY. *Physiological mechanism of auditory masking and* of correlations between physiological and psychological observations (Agreement period 7/67—6/70).	34,853
NsG-257 (NGR-44-005-002)	Houston, University of, J. ORO AND A. ZLATKIS. Studies in organic cosmochemistry, including compound formation under primitive earth conditions, and organic material in selected meteorites (Agreement period 2/67—11/67).	30,000
NGR-44-005-020	Houston, University of, ZLATKIS, LOVELOCK, BECKER AND ORO. Carbonaceous matter in returned lunar samples (Agreement period 7/67—8/67).	10,000
NGR-44-005-065	Houston, University of, C. DALTON. The hydrodynamic stability of pipe flow (Agreement period 7/67—6/68).	22,967
NsG-6 (NGR-44-006-001)	Rice University, F. R. BROTZEN. Research on the physics of solid materials, including study of the basic laws governing the behavior of solids at high temperatures (Agreement period 7/68—6/71).	300,000
NGR-44-006-076	Rice University, B. J. O'BRIEN. Study of short period pulsations using an image orthicon or TV system (Agreement period 9/67—8/68).	15,000
NsG-711 (NGR-44-007-004)	Southern Methodist University, H. A. BLUM. Heat transfers across surfaces in contact: practical effects of transient temperatures and pressure environments (Agreement period 6/67—5/68).	16,226
NGR-44-004-030	Southwest Center for Advanced Studies, W. J. HEIKKILA. Electron collision frequency under ionospheric conditions (Agreement period 9/67—8/68).	116,888
NASr-94(10) (NSR-44-008-068)	Southwest Research Institute. Design studies and evaluation of a superconducting bolometer—Phase II (Agreement period 6/67—1/68).	38,500
NSR-44-008-070	Southwest Research Institute. Preparing and conducting a symposium on friction and wear (Agreement period 12/67—3/68).	30,049

TEXAS—Continued		
NGR-44-001-044	Texas A&M University, J. A. STRICKLIN The nonlinear static and dynamic analysis of shells of revolution with asymmetrical stiffness properties (Agreement period 1/68—12/68).	49,800
NGR-44-009-018	Texas Christian University, M. D. ARNOULT Distance and rate judgments in simulated space (Agreement period 9/67—8/68).	27,023
UTAH:		
NGR-45-001-011	Brigham Young University, D. E. JONES Analysis and interpretation of magnetic field measurements between Earth and Mars received from Mariner IV (Agreement period 10/67—9/68).	32,530
NGR-45-002-008	Utah State University, F. B. SALISBURY Response of higher plants to ultraviolet light and other stress factors (Agreement period 9/67—8/68).	36,000
NGR-45-003-029	Utah, University of, M. L. WILLIAMS Cumulative damage effects on viscoelastic fracture (Agreement period 11/67—10/68).	36,546
NGR-45-003-037	Utah, University of, M. L. WILLIAMS Paramagnetic resonance effect in voscoelastic materials (Agreement period 1/68—12/68).	31,973
VIRGINIA:		
NGR-47-003-004	Old Dominion College, M. PITTMAN Investigation of spectral properties of ultraviolet gratings (Agreement period 9/67—8/68).	25,000
NGR-47-003-005	Old Dominion College, G. S. OFELT Investigation of gas temperature measurements using ultra-violet excitation (Agreement period 9/67—8/68).	42,383
NGR-47-003-007	Old Dominion College, G. L. GOGLIA A theoretical and experimental investigation of the vortex-sink rate sensor (Agreement period 9/67—2/69).	24,000
NGR-47-003-008	Old Dominion College, R. L. WILLIAMS Studies in heterocyclic synthesis (Agreement period 6/67—5/68).	12,102
NGR-47-004-006	Virginia Polytechnic Institute F. W. BULL, J. A. JACOB: Multidisciplinary, space-related research in engineering and the physical and life sciences (Agreement period 9/67—8/70).	36,000
NGR-47-004-030	Virginia Polytechnic Institute, R. A. COMPARIN An analytical investigation of thrust vector control by secondary injection (Agreement period 9/67—8/68).	26,519
NGR-47-004-033	Virginia Polytechnic Institute, K. GOTOW Research in high energy nuclear physics (Agreement period 7/67—6/68).	100,000
NGR-47-005-081	Virginia, University of, L. W. FREDRICK Application of shearing and Kosters prisms to the alignment of optical telescope (Agreement period 6/67—11/67).	4,712
NsG-710 (NGR-47-006-011)	College of William & Mary, J. D. LAWRENCE Atmospheric investigations by laser techniques (Agreement period 7/67—6/68).	20,860

WASHINGTON:

NsG-401 (NGR-48-002-003)	Washington, University of, R. J. H. BOLLARD Analytical and experimental study, using photoelastic methods, to establish a stress analysis of a viscoelastic model subjected to transient temperature and time-dependent loading (Agreement period 9/67—9/68).	44,325
NsG-484 (NGR-48-002-004)	Washington, University of, J. I. MUELLER Multidisciplinary research activity in the materials sciences with emphasis on investigations of inorganic nonmetallic (ceramic) materials (Agreement period 6/68—5/71).	300,000
NsG-632 (NGR-48-002-009)	Washington, University of, J. K. BUETTNER Spectrometric investigations of the emissivity of natural surface and materials, and feasibility studies of microwave experiments for future meteorological satellites (Agreement period 9/67—8/68).	25,000
NGR-48-002-047	Washington, University of, M. E. CHILDS An investigation of the interaction of a shock wave and a turbulent boundary layer in axially symmetric internal flow (Agreement period 9/67—12/68).	25,710
NSR-48-002-054	Washington, University of, H. G. AHLSTROM Investigation of various areas of fluid dynamics (Agreement period 9/67—9/68).	22,700

WEST VIRGINIA:

NGR-49-001-012	West Virginia University, E. C. CARTER Economic feasibility and impact of vertical or short take-off and landing aircraft for the Appalachian Region (Agreement period 9/67—2/68).	9,472

WISCONSIN:

NsG-618 (NGR-50-002-006)	Wisconsin, University of, A. D. CODE Investigations and studies of ultraviolet stellar spectra and associated instrumentation (Agreement period 4/67—3/70).	50,000
NGR-50-002-051	Wisconsin, University of, J. R. CAMERON Applications of the direct photon absorption techniques for measuring bone-mineral contents, in vivo (Agreement period 10/67—10/67).	30,000
NGR-50-002-083	Wisconsin, University of, V. C. RIDEOUT Cardiovascular system study with computer modeling (Agreement period 9/67—8/68).	36,378

FOREIGN:

NGR-52-059-001	McMaster University, A. B. KRISTOFFERSON A study of attention and psychological time (Agreement period 9/67—8/68).	30,876
NGR-52-026-011	Toronto, University of, R. C. TENNYSON Buckling of circular cylindrical shells in axial compression (Agreement period 7/67—6/69).	16,228

Appendix S

Institutions Currently Participating in NASA's Predoctoral Training Program

(December 30, 1967)

Adelphi University
Alabama, University of
Alaska, University of
Alfred University
Arizona State University
Arizona, University of
Arkansas, University of
Auburn University
Baylor University
Boston College
Boston University
Brandeis University
Brigham Young University
Brooklyn, Polytechnic Institute of
Brown University
California Institute of Technology
California, University of, at Berkeley
California, University of, at Los Angeles
California, University of, at Riverside
California, University of, at San Diego
California, University of, at Santa Barbara
Carnegie Institute of Technology
Case Institute of Technology
Catholic University of America
Chicago, University of
Cincinnati, University of
Clark University
Clarkson College of Technology
Clemson University
Colorado School of Mines
Colorado State University
Colorado, University of
Columbia University
Connecticut, University of
* Cornell University
Dartmouth College
Delaware, University of
Denver, University of
Drexel Institute of Technology
Duke University
Duquesne University
Emory University
Florida State University
Florida, University of
Fordham University
George Washington University
Georgetown University
* Georgia Institute of Technology
Georgia, University of
Hawaii, University of
Houston, University of
Howard University
Idaho, University of
Illinois Institute of Technology
Illinois, University of
Indiana University
Iowa State University
Iowa, University of
Johns Hopkins University
Kansas State University
* Kansas, University of
Kent State University
Kentucky, University of
Lehigh University
Louisiana State University
Louisville, University of
Lowell Technological Institute
Maine, University of
Marquette University
Maryland, University of
Massachusetts Institute of Technology
Massachusetts, University of
Miami, University of
Michigan State University
Michigan Technological University
Michigan, University of
Minnesota, University of
Mississippi State University
Mississippi, University of
Missouri, University of
Missouri, University of, at Rolla
Montana State University
Montana, University of
Nebraska, University of
Nevada, University of
New Hampshire, University of
New Mexico State University
New Mexico, University of
New York, The City University of
New York, State University of, at Buffalo
New York, State University of, at Stony Brook
North Carolina State of the University of North Carolina
North Carolina, University of
North Dakota State University
North Dakota, University of
Northeastern University
Northwestern University
Notre Dame, University of

Ohio State University
Ohio University
Oklahoma State University
Oklahoma, University of
Oregon State University
Pennsylvania State University
Pennsylvania, University of
** Pittsburgh, University of
Princeton University
* Purdue University
Rensselaer Polytechnic Institute
Rhode Island, University of
Rice University
Rochester, University of
Rutgers—The State University
St. Louis University
South Carolina, University of
South Dakota, University of
** Southern California, University of
Southern Illinois University
Southern Methodist University
Southern Mississippi, University of
* Stanford University
Stevens Institute of Technology
Syracuse University
Temple University
Tennessee, University of
Texas A&M University
Texas Christian University
Texas Technological College
Texas, University of
Toledo, University of
Tufts University
Tulane University
Utah State University
Utah, University of
Vanderbilt University
Vermont, University of
Villanova University
Virginia Polytechnic Institute
Virginia, University of
Washington State University
Washington University (St. Louis)
Washington, University of
Wayne State University
West Virginia University
Western Reserve University
William and Mary, College of
Wisconsin, University of
Worcester Polytechnic Institute
Wyoming, University of
Yale University
Yeshiva University

* Institutions receiving training grants specifically for engineering design.
** Institutions receiving training grants specifically for public administration.

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