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Twentieth SEMIANNUAL REPORT TO CONGRESS

JULY 1 - DECEMBER 31, 1968

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546

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THE PRESIDENT
The White House

OCTOBER, 3, 1969

DEAR MR. PRESIDENT:

I am pleased to submit to you this Twentieth Semiannual Report of the National Aeronautics and Space Administration for transmittal to Congress in accordance with section 206(a) of the National Aeronautics and Space Act of 1958. The Report covers the period July 1 through December 31, 1968.

Within this time, the space program marked its tenth anniversary. How far we have come since October 1958 is revealed by a comparison: NASA's First Semiannual Report highlighted the launching of three Pioneer space probes, the largest weighing 39 pounds and traveling about 70,000 miles into space. The Twentieth features the manned Apollo flights—precise exercises in orbiting the Earth (Apollo 7) and the Moon (Apollo 8) by three-man crews in spacecraft weighing about 13,000 pounds at launch. These flights, and the more recent flights of Apollo 9, Apollo 10, and Apollo 11 which tested the Lunar Module in earth orbit, next in lunar orbit, and then in landing on the moon, are accomplishments of which the Nation can be justifiably proud.

We can also view with considerable satisfaction what we have achieved with our scientific and applications satellites during this period. The record number of satellites launched included an Orbiting Astronomical Observatory which is giving us a new view of the universe, a Radio Astronomy Explorer, a Pioneer spacecraft placed in a solar orbit, and a pair of Explorers launched together. The two ESSA spacecraft, launched for the Environmental Science Services Administration, laid the foundation for an operational weather satellite network, and INTELSAT III, launched for the Communications Satellite Corporation, is a large-capacity communications satellite designed to last five years.

In aeronautics research, satisfying results were achieved in the search for practical methods of dissipating warm fog—a frequent cause of airport delays and flight cancellations. Studies of jet aircraft noise pointed to several ways of alleviating this problem, and work on V/STOL aircraft moved ahead as various engine problems, aircraft configurations, and instrument displays were investigated. NASA also contributed to the national supersonic transport program by assigning personnel to help evaluate the proposed design, by conducting certain wind tunnel tests, and by using the XB–70 to collect related data.

These and the other activities described in the following pages are firm evidence that we are progressing in an orderly manner toward our goal of a manned lunar landing and return within this decade. They also show that we are committed to maintaining a strong, well balanced program in space and aeronautics which will enable the Nation to advance effectively in each of the areas of space endeavor during the next decade.

Respectfully yours,

T. O. PAINE,
Administrator.

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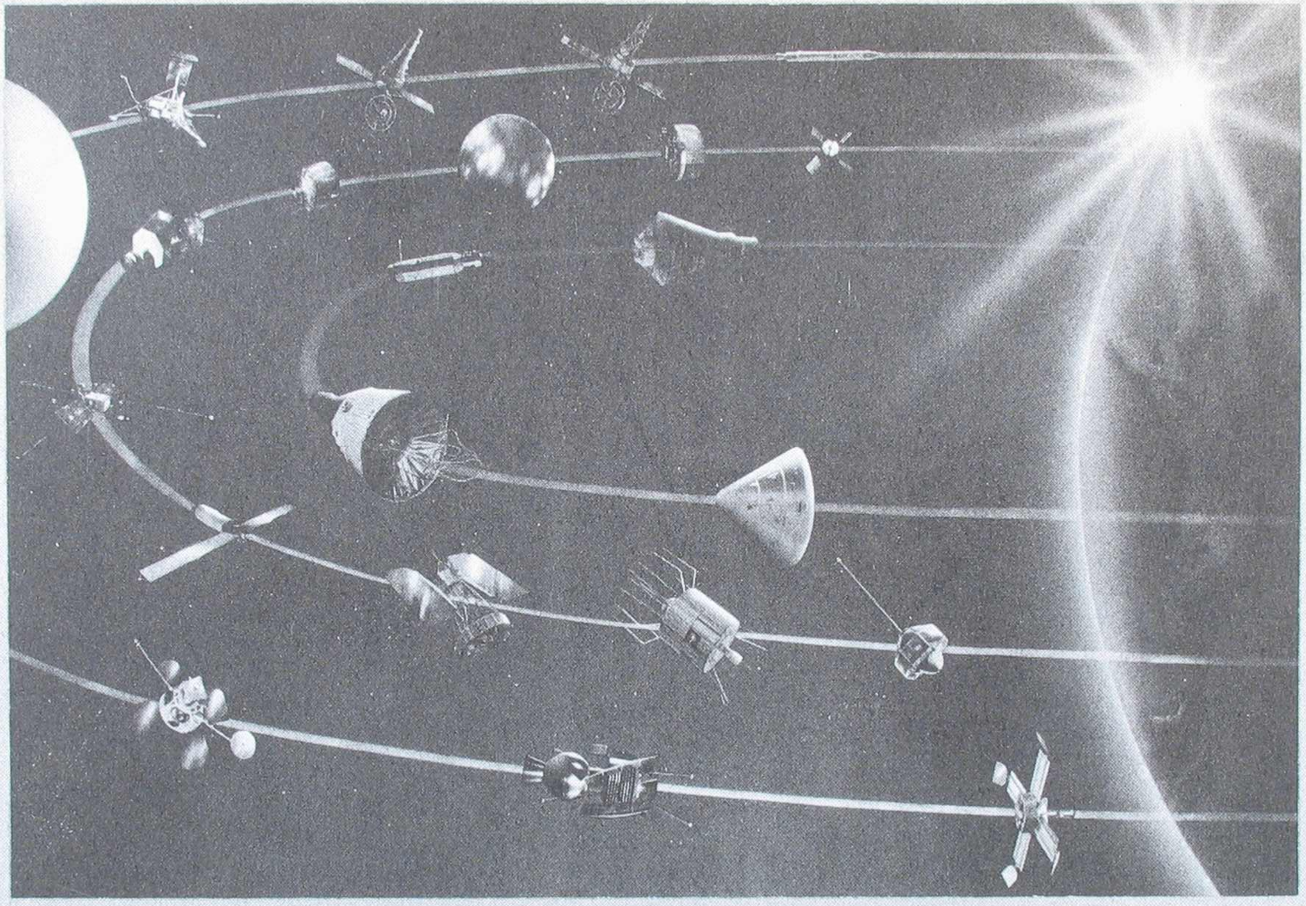


HIGHLIGHTS 1958 - 1968

SELECTED HIGHLIGHTS

1958

The National Aeronautics and Space Administration became an officially operating agency of the U.S. Government on October 1.

* *

October—Factory rollout of the X–15 No. 1 research airplane.

* *

October—NASA initiated the Nation's first manned space flight project—Project Mercury.

* *

October 11—NASA launched its first spacecraft, Pioneer I, a deep space probe which reached an altitude of over 70,000 miles. It sent back radiation, magnetic field, and micrometeoroid data during its 43-hour lifetime.

* *

1959

In January, selection of the first astronauts began. In April, the seven men chosen reported to the Space Task Group, Langley, Va. Those selected were Alan B. Shepard, Jr. and Walter M. Schirra, Jr., Navy lieutenant commanders; M. Scott Carpenter, a Navy lieutenant; John H. Glenn, Jr., a Marine lieutenant colonel; and Virgil I. Grissom, L. Gordon Cooper, Jr., and Donald K. Slayton, Air Force captains.

* *

June—First flight of an X–15 aircraft.

* *

August—Explorer VI, the "paddle wheel" satellite was launched and transmitted the first TV pictures from space.

* *

September—A boilerplate Mercury capsule was successfully tested in a suborbital flight.

* *

1960

April—TIROS I meteorological satellite orbited. Supplied the first global cloud cover pictures.

* *

August—Echo I, a 100-foot balloon, was placed in orbit and inflated to become a passive communications satellite. It proved that radio microwaves reflected from a man-made satellite could be used for communications between widely separated areas on earth.

* *

1961

May—Astronaut Shepard made the first manned suborbital flight in the Mercury capsule. Duration—15 minutes.

* *

May—President John F. Kennedy proposed a National goal of landing a man on the moon and returning him safely to earth before this decade is out. Congress endorsed the President's proposal.

* *

July—The second successful suborbital flight in Project Mercury was made by Astronaut Grissom. Duration: 15 minutes.

* *

1962

February—John Glenn made a three-orbit flight in the Mercury spacecraft *Friendship 7*—the first U.S. manned orbital flight.

* *

April—Ariel I, the first international satellite, was launched for the United Kingdom. Purpose: to investigate solar effects in the ionosphere.

* *

May—Astronaut Carpenter completed three orbits in the Project Mercury spacecraft, *Aurora 7*. The flight lasted 4 hours, 56 minutes.

* *

July—Telstar I, the first privately built (American Telephone and Telegraph Company) satellite launched by NASA, relayed the first telecast from Europe to the U.S.

* *

August—Marineer II was launched on a trajectory to the planet Venus and passed within 21,000 miles of the planet in December, reporting a surface temperature of about 800°F.

* *

September—NASA launched the Canadian geophysical satellite Alouette I to investigate electronic densities in the ionosphere. Second international satellite.

* *

October—Project Mercury spacecraft, *Sigma 7*, manned by astronaut Schirra, completed a six-orbit mission lasting 9 hours 13 minutes.

* *

December—The Relay I active communications satellite was launched into a low orbit to test its ability to transmit wideband TV and telephone signals. It successfully transmitted signals between the U.S. and European countries.

* *

1963

May—Astronaut Cooper completed 22 orbits in the Mercury spacecraft, *Faith 7*. The flight lasted 34 hours 20 minutes. The spacecraft was manually controlled during the last few orbits and retrofire was also manual.

* *

July—Syncom II became the first operational satellite in a synchronous orbit. It demonstrated that a communications satellite can be controlled in a synchronous orbit and maneuvered to a preselected station.

* *

December—TIROS VIII, a meteorological satellite, carried automatic picture transmission equipment enabling inexpensive ground stations to read out in real time local cloud pictures for weather forecasting.

* *

1964

January—Echo II, a large rigid reflecting sphere, was launched for use as a passive communications satellite.

* *

March—Ariel II, the third international satellite, was launched by NASA for the United Kingdom. It transmitted data on radio frequency radiation from space, on ozone in the ionosphere, and on micrometeoroids.

* *

July—Ranger VII was launched on a lunar trajectory and successfully accomplished its mission by transmitting over 4,000 TV pictures of the lunar surface in the 17 minutes before impact.

* *

August—Syncom III was launched into a truly synchronous (stationary) orbit. It has been used experimentally and operationally, relaying TV coverage of the 1964 Olympic games from Japan to the U.S.

* *

August—Nimbus I, a sophisticated meteorological satellite launched into a near polar orbit, carried a system which kept its sensors pointed toward the earth at all times. It sent back the first night time cloud cover data.

* *

November—Mariner IV was launched on an interplanetary exploration mission, including a Mars fly-by. On the way, it transmitted data on the interplanetary environment. It passed within about 6,000 miles of Mars, sending back 22 remarkably clear TV pictures of the surface of the planet.

* *

December—A NASA-trained Italian team launched San Marco I, an Italian designed atmospheric physics satellite.

* *

1965

January—TIROS IX, the first of this series in the "cartwheel" configuration, was launched into an elliptical orbit. This meteorological satellite provided global daylight cloud cover data once a day.

* *

March—Ranger IX, the final mission of this series, landed on the moon less than 3 miles from its target area. It sent back over 5,800 high resolution pictures of the lunar surface. Live pictures of the surface of the moon were televised to home viewers as the spacecraft approached the moon.

* *

March—The Nation's first two-man mission, Gemini III, was a 3-orbit flight lasting 4 hours 53 minutes. Astronauts Grissom and John W. Young flew the first manned mission in the second phase of the manned space program.

* *

April—NASA launched Early Bird I (INTELSTAT I) for the Communications Satellite Corporation, the first commercial communications satellite linking countries across the Atlantic.

* *

June—Gemini IV, June 3-7, was the Nation's longest manned flight to date. Astronauts James A. McDivitt and Edward H. White completed 62 orbits, lasting 97 hours 56 minutes. Astronaut White carried out a 22-minute space walk in the first extravehicular activity by U.S. spacemen.

* *

August—Gemini V, manned by Astronauts Cooper and Charles Conrad, Jr., remained in orbit for 8 days, demonstrating the physiological feasibility of the lunar mission.

* *

December—Gemini VII, crewed by Astronauts Frank Borman and James A. Lovell, Jr., travelled over 5 million miles in 330 hours, 35 minutes (Dec. 4-18), and served as target for rendevous with Gemini VI–A (Dec. 15-16) manned by Astronauts Schirra and Thomas P. Stafford. The two spacecraft accomplished the first successful rendezvous when Gemini VI–A maneuvered to within 120 feet of Gemini VII; station keeping was maintained for over 5 hours at distances varying from 1 foot to 300 feet.

* *

February—The ESSA I and ESSA II meteorological satellites were launched to open the national operational weather satellite system. The two craft transmit hundreds of pictures daily which are received by local Automatic Picture Transmission stations.

* *

March—Gemini VIII, manned by Astronauts Neil A. Armstrong and David R. Scott, completed the second rendezvous and the first docking of the manned space flight program. Landing was the first in the Pacific.

* *

1966

May—Nimbus II, the most sophisticated, completely instrumented weather satellite up to this time, was placed in a near polar orbit. It provided a vast amount of data for accurate weather forecasting.

* *

May—Surveyor I achieved a soft lunar landing on this first engineering test flight. The craft transmitted thousands of high-resolution television pictures of the lunar surface and of parts of the spacecraft.

* *

June—Gemini IX–A, with Astronauts Stafford and Eugene A. Cernan aboard, made rendezvous with an unmanned target vehicle three times, but did not dock. During the 72-hour flight, Astronaut Cernan carried out 2 hours and 5 minutes of extra-vehicular activity.

* *

June—PAGEOS I, a 100-foot, plastic sphere was placed in a 2,600-mile polar orbit for use in precision mapping of the earth's surface. The non-instrumented satellite reflects sunlight and is photographed as an orbiting point of light by ground stations around the world.

* *

July—Gemini X, manned by Astronauts Young and Michael Collins, was another rendezvous mission. During the near-71-hour flight, the astronauts made a dual rendezvous, maneuvered the docked spacecraft, carried on extravehicular activity, and retrieved a micrometeoroid experiment from the Gemini VIII target vehicle.

* *

August—Lunar Orbiter I was placed in a close orbit of the moon and sent back pictures of potential landing sites for Apollo. It also took pictures of the earth from the vicinity of the moon.

* *

September—Gemini XI (Astronauts Conrad and Richard F. Gordon, Jr.) made rendezvous and docked with the target vehicle during its first revolution. Astronaut Gordon completed almost three hours of extravehicular activity, the docked spacecraft were propelled to an 853-mile altitude, and the tethered spacecraft were undocked and rotated. The flight ended in the first computer controlled reentry.

* *

November—Lunar Orbiter II photographed additional landing sites for the Apollo mission as well as areas on the far side of the moon not covered by the first Orbiter.

* *

November—Gemini XII, the final mission of the series, was manned by Astronauts Lovell and Edwin E. Aldrin, Jr. Primary mission objectives—rendezvous and docking and extravehicular activity evaluation—were accomplished. Aldrin spent over 5 hours in EVA; including this flight, Lovell logged a total of over 425 hours in space.

* *

December—ATS–1 was placed in a synchronous circular equatorial orbit at an altitude of about 22,000 miles. Its spin-scan cloud camera photographs almost the entire disc of the earth, providing views of a large area for use in studying weather systems.

* *

1967

February—Lunar Orbiter III obtained additional photographs of landing sites for Surveyor spacecraft and Apollo astronauts. It also transmitted data on meteoroid flux, high energy radiation near the moon, and the moon's gravitational field.

* *

April—Surveyor III made a soft landing on the moon and transmitted over 6,300 pictures (some in color) during a 14-day period. A surface sampler dug a 6-inch trench and otherwise manipulated the soil. Data from it and strain gages enabled the surface bearing strength to be calculated at 3 to 8 pounds per square inch.

May—Lunar Orbiter IV provided detailed pictures of 99 percent of the front surface of the moon as well as photographs of its hidden side.

* *

June—Mariner V was launched on a mission to Venus, which it encountered in October, approaching within 2,600 miles of the surface. It sent back valuable data on the Venusian atmosphere and on the interplanetary environment during increasing solar activity.

* *

August—Lunar Orbiter V, the last in this series of spacecraft, provided detailed photographic coverage of 36 sites of scientific interest and 5 Apollo sites. It also sent back a full view of the earth, as well as scientific data.

* *

September—Surveyor V landed on the moon in the Sea of Tranquillity, then sent back over 18,000 photographs. It also made an analysis of the chemical composition of the surface, finding it to be basaltic in character.

* *

November—Surveyor VI landed in the Central Bay area of the moon. It transmited many thousands of pictures of the surface, photographed stars and the planets Jupiter and Earth, and confirmed the basaltic character of the lunar soil. It also moved to a new location on command from the Earth.

* *

November—Apollo IV was the first unmanned test of the Apollo-Saturn V space vehicle under the "all-up" concept. The 8½-hour earth orbital mission tested the launch vehicle, the spacecraft, and the ground support and control facilities.

* *

1968

January—Surveyor VII, last in the series of soft lunar landers, sent TV pictures, collected data on the chemical composition of the lunar soil, photographed the earth, and carried out star surveys.

* *

January—Apollo V, a lunar module development mission, verified the propulsion system of the lunar module ascent and descent stages, including the ability to restart in space. It was the first flight of the lunar module.

* *

April—Apollo VI was the second mission in the launch vehicle and spacecraft development flight phase. The flight, which lasted about 9 hours, attained all but one (restart of S–IVB in orbit) of its primary objectives.

* *

July—Explorer XXXVIII, the Radio Astronomy Explorer, carried highly advanced instruments into a nearly circular orbit at an altitude of about 3,600 miles. The spacecraft, with X-shaped antenna arms extending a total of 1,500 feet, is studying low frequency radio signals, radiation from the sun, and the plasma.

* *

October—Apollo VII was the first manned Apollo flight. Astronauts Schirra, Donn F. Eisele, and Walter Cunningham spent eleven days in earth orbit, made seven live telecasts, conducted a simulated docking exercise, and used the service propulsion system to carry out 8 planned maneuvers.

* *

October—Final research flight of an X–15 aircraft.

* *

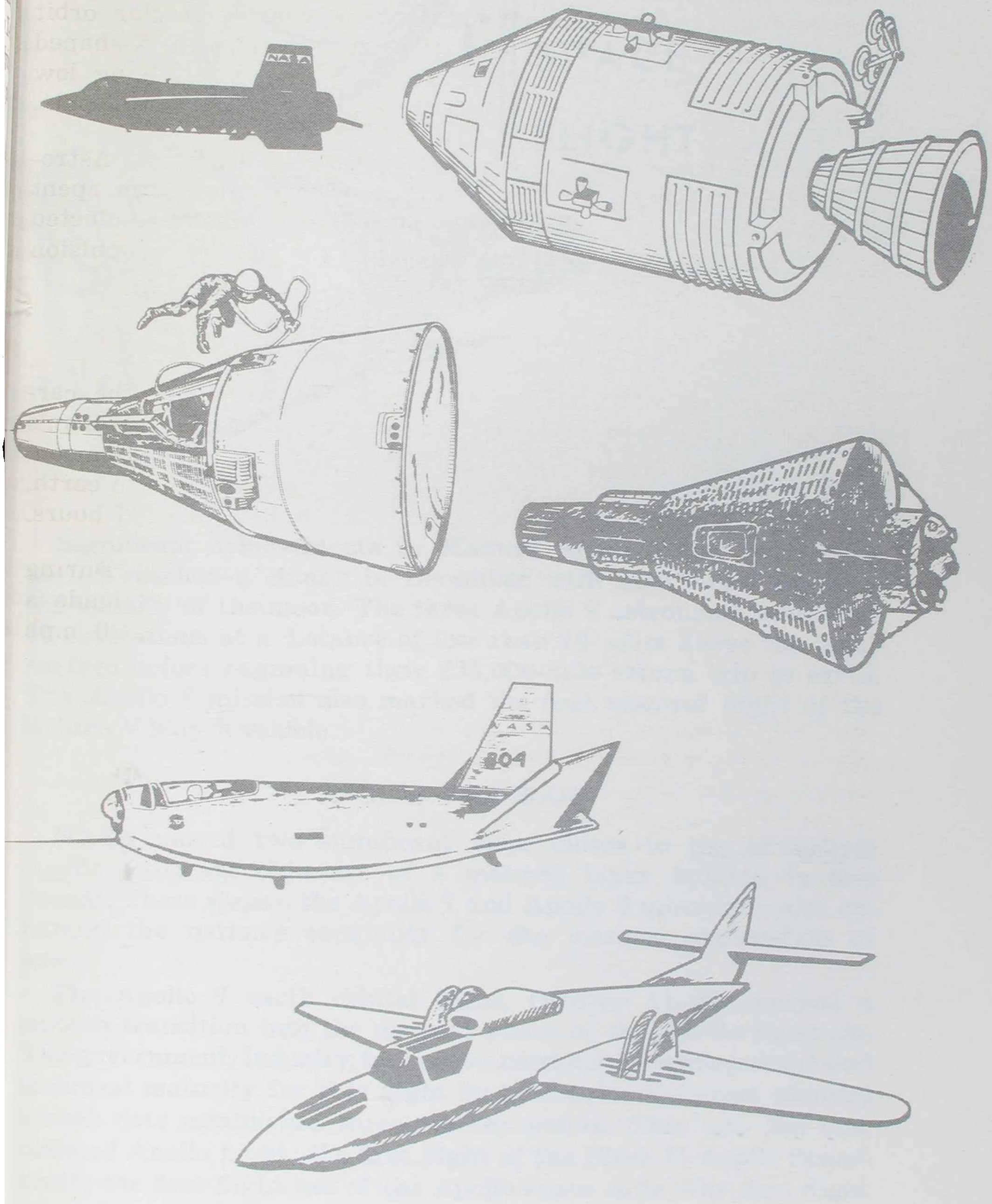
December—Apollo VIII, the first manned Saturn V flight, carried Astronauts Borman, Lovell, and William A. Anders on man's first lunar orbit mission. During 10 revolutions around the moon, the astronauts took photographs, sent TV pictures back to earth, and observed landing site/landmarks. The flight lasted 147 hours.

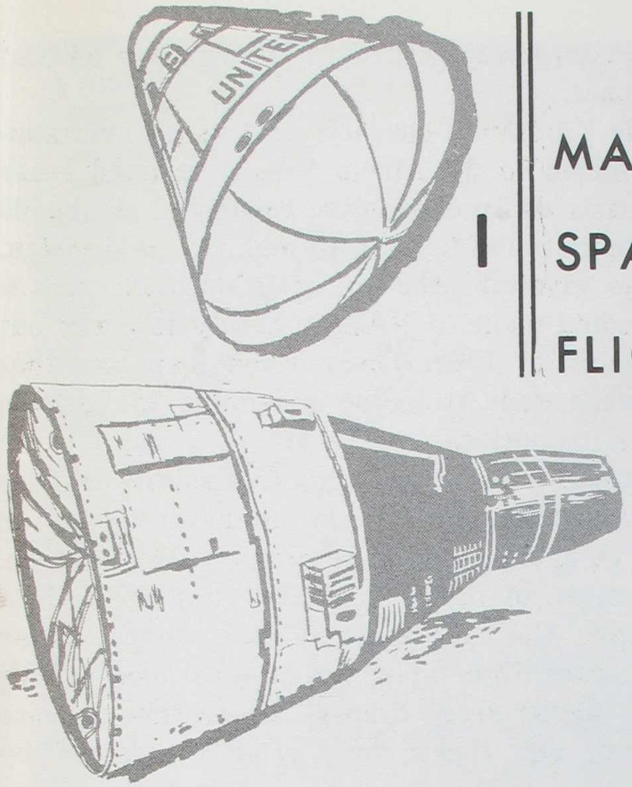
* *

December—The X–15 flight program was terminated. During the nine-year flight program, the three X–15 aircraft made a total of 199 flights, attaining a maximum speed of 4,520 mph and an altitude of 354,200 feet.

* *

ACTIVITIES & ACCOMPLISHMENTS





I MANNED SPACE FLIGHT

Significant achievements in Manned Space Flight during the period reached a climax in December with man's first flight to the vicinity of the moon. The three Apollo 8 astronauts completed 10 revolutions at a distance of less than 70 miles above the lunar surface before beginning their 233,000-mile return trip to earth. The Apollo 8 mission also marked the first manned flight of the Saturn V launch vehicle.

APOLLO PROGRAM

NASA moved two significant steps closer to the immediate Apollo Program objective of a manned lunar landing in this decade. These steps—the Apollo 7 and Apollo 8 missions—also enhanced the nation's capability for the manned exploration of space.

The Apollo 7 earth orbital flight, October 11–22, marked a smooth transition into the manned phase of the Apollo Program. The government/industry team demonstrated its management and technical maturity for this flight by holding to the exact planned launch date established three months before. This was the first manned Apollo flight; the first flight of the Block II Apollo Spacecraft; the first flight use of the Apollo space suits; the first flight with full crew support equipment; and the first U.S. live telecast of man's activities in space.

Following the Apollo 7 mission, characterized as an outstanding success, NASA decided to fly Apollo 8 as a manned lunar orbit mission on the basis of an exhaustive review of all Apollo 6 and 7 technical and operational factors. In making the decision, consideration was also given to the contribution that such a lunar orbital mission could make to NASA's ability to carry out the manned lunar landing in 1969. The mission plan was that Apollo 8 would be open-ended, providing a number of possible abort and alternate mission options.

In the Apollo 8 flight, December 21–27, man escaped the confines of his planet for the first time. He flew to another body in the solar system (the moon), orbited it, and returned safely to earth. There were also a number of other significant firsts: the first manned Saturn V flight; the first manned flight to the lunar vicinity; and the first space flight in which man escaped earth's gravity. This flight also achieved the deepest penetration of space by a manned spacecraft and the highest velocity attained by man—36,221 feet per second. The flight showed that the spacecraft could function and support man in the hostile environment of space 233,000 miles from earth; it demonstrated the accuracy of the guidance and navigation systems; it verified the ability of the spacecraft to maneuver and change course; and it confirmed the ability of the spacecraft's heat shield and structure to withstand the forces and heat at the high speed of earth re-entry from lunar distance. (Fig 1–1)

NASA must accomplish two more major flight development phases in the mainline Apollo Flight Mission Sequence before undertaking the lunar landing mission: the command/service module—lunar module (CSM–LM) Operations phase, and the Lunar Mission Development phase. The former is expected to demonstrate LM systems capability and CSM–LM operations in a near earth orbit. It must test all primary and many backup LM subsystems in actual flight, demonstrate the Apollo rendezvous capability, and show that the support facilities can function reliably and accurately during a mission using the entire Apollo space vehicle. The Lunar Mission Development flight phase will carry out or simulate all portions of the lunar landing mission except the actual landing.

Apollo 9 is scheduled as a CSM–LM Operations mission, and Apollo 10 as a Lunar Mission Development flight. Following these flights, the first lunar landing mission will demonstrate the lunar

Figure 1–1. Earth, as seen from Apollo 8.

landing capability (with some deployment of experiments), and the second lunar landing mission will begin to exploit that capability, including deployment of the Apollo Lunar Surface Experiment Package.

Apollo 7 Mission

The Apollo 7 space vehicle was launched from the Kennedy Space Center (KSC), at 11:02:45 a.m. EDT on October 11, carrying astronauts Walter M. Schirra, Donn F. Eisele, and Walter Cunningham. Following a normal boost phase, the spacecraft/S–IVB combination was inserted into a 140 by 176 mile orbit. Before the CSM separated from the S–IVB, the crew manually controlled the combination. After separation, the crew conducted a transposition and simulated docking exercise. (Fig. 1–2)

After completing these exercises, the crew used the reaction control system (RCS) to perform two phasing maneuvers for rendezvous. They performed the first service propulsion manuever to begin the rendezvous sequence over Carnarvon, Australia, during

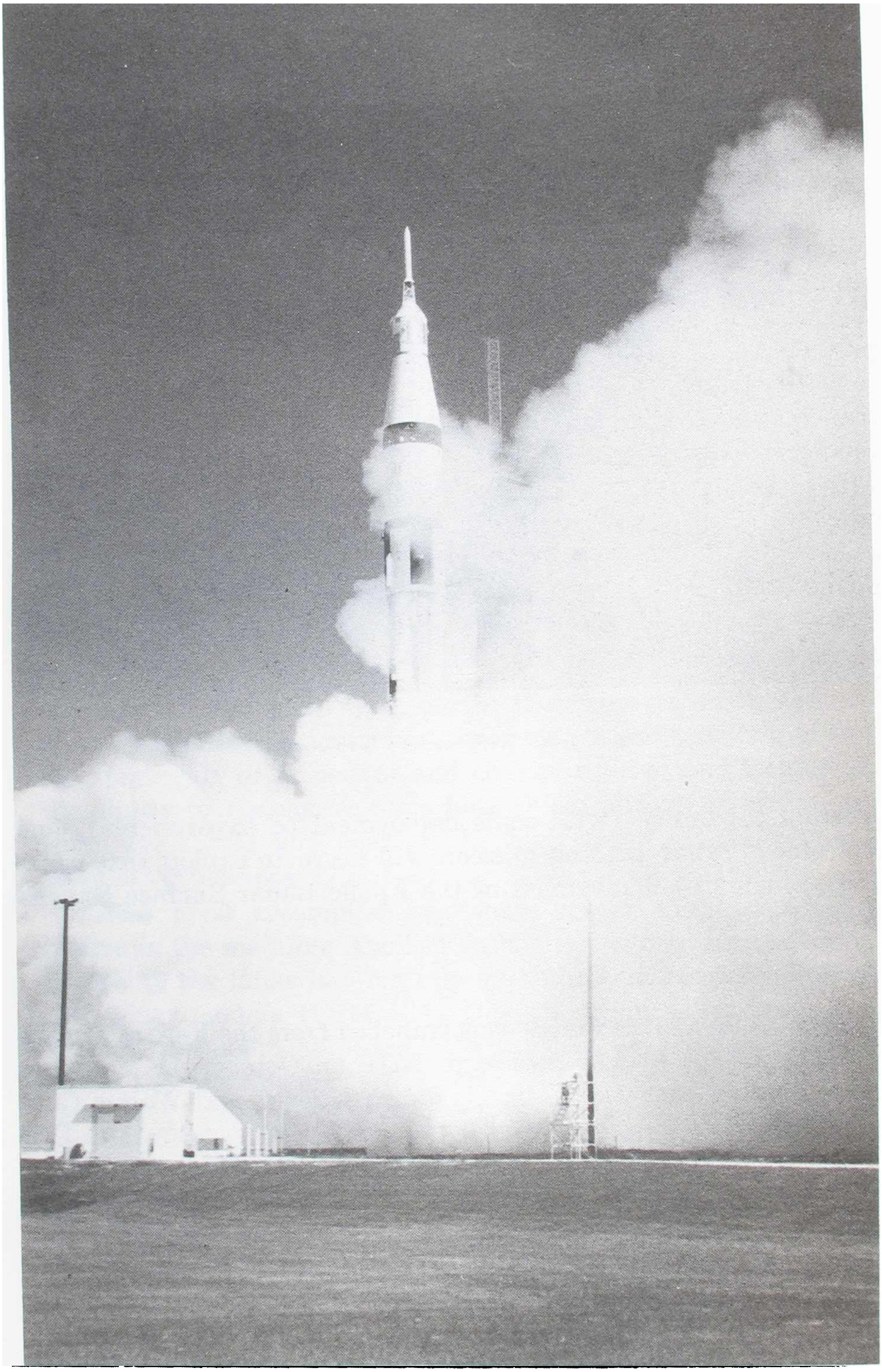


Figure 1–2. Lift-off of Apollo 7.

the 17th revolution and the second maneuver one revolution later to establish the necessary catch-up rate. They reported station-keeping with the S–IVB at 3:00:00 hours, ground elapsed time (GET). A final separation maneuver from the S–IVB was performed during the 19th revolution.

During the 10.8-day flight, the crew used the Service Propulsion System (SPS) to conduct eight planned maneuvers. All major test objectives were achieved. Almost without exception, spacecraft systems operated as intended. Temperatures remained within acceptable limits and behaved essentially as predicted, although fuel cell No. 2 condensor exit temperature ran higher than predicted.

Communications quality was good, and live television was transmitted to ground stations on seven occasions. A test of the rendezvous radar system was completed in support of later flights with the lunar module. Manual operation of the spacecraft by the crew was good. Even though they were somewhat hampered by head colds and congestion, the astronauts satisfactorily performed all flight plan functions and photographic experiments.

The deorbit maneuver (eighth service propulsion maneuver) occurred during the 163rd revolution over Hawaii 10 days and 19 hours after lift-off. The Command Module (CM) splashed down approximately 30 minutes later in the Atlantic Ocean southeast of Bermuda, landing within one mile of the guidance system target point. The crew was picked up by helicopter, and both the spacecraft and crew were taken aboard the prime recovery ship, the USS *Essex*.

Launch Vehicle.—Engineering evaluation of the launch vehicle performance indicated that it achieved all primary and secondary mission objectives and that no significant anomalies occurred. All launch vehicle ground support equipment (GSE) performed satisfactorily, and both propulsive stages and the instrument unit (IU) performed well within expected tolerances.

Spacecraft.—The Apollo spacecraft performed without major anomalies, and the few minor discrepancies did not adversely affect mission performance. (Fig. 1–3)

Structures.—Structural loads were within predicted values for all phases of flight. The peak ground winds just before lift-off were within 1 knot of the structural limit; however, the measured launch vehicle strain data indicated that only 50 percent of the limit loads were encountered.

Propulsion.—The spacecraft propulsion systems operated as planned. The eight firings of the large 20,000 lb.-thrust SPS

Figure 1–3. Apollo 7 spacecraft being brought aboard USS Essex.

engine and the many firings of the 100 lb.-thrust RCS engine were satisfactory in all respects.

Guidance and Control.—Guidance and control system performance was satisfactory throughout the mission. The inertial measurement unit was aligned optically, and backup alignment methods were demonstrated for it and for the stabilization and control system attitude reference. Data were obtained on star visibility, landmark tracking, star/horizon sightings, and optics utilization. The guidance and navigation system, using optical tracking data, supported the rendezvous with the S–IVB. All significant attitude control modes in both the prime and the backup system were tested and performed satisfactorily. Thrust vector control of the service propulsion engine was demonstrated, using both the guidance and navigation and the stabilization and control systems. The mid-maneuver manual takeover techniques were also successfully demonstrated.

Electrical Power System.—The electrical power system maintained the AC and DC voltages within nominal limits except for two AC bus 1 failure indications and one AC bus 1 and 2 failure indication reported by the crew early in the mission. The onboard meter verified the loss of voltage, and the voltage was restored to normal by resetting the AC bus sensors. The failures occurred when the cryogenic oxygen tank fans and heaters simultaneously cycled *off* in the automatic mode. An AC bus can be automatically disconnected by an overvoltage being detected by the AC overload sensing unit. After a procedural change was made to prevent the fans in both tanks from cycling simultaneously, the problem did not recur for the remaining 200 hours of flight. After analyzing the problem, program officials decided not to make a hardware change but to revise procedures for future missions.

Fuel Cells.—All power requirements imposed on the three fuel cells were satisfied. Before the fifth service propulsion maneuver, the condenser exit temperature of fuel cell 2 increased from 160° to 180°F (nominal is from 155° to 165°F). The electrical load was removed from this fuel cell for approximately 54 minutes, permitting it to cool. Subsequently, it performed satisfactorily during the maneuver. Four days later, the electrical load was again removed from fuel cell 2 for a short time as a precautionary measure to make certain that it performed properly during the deorbit maneuver. (Fig 1–4)

Batteries.—The voltage and current delivered by the entry batteries and pyrotechnic batteries were within the range of normal battery performance throughout the mission. However, the charge rates on batteries A and B were much lower than expected. Ground tests performed during and after the flight showed that two factors contributed to this condition: line impedance between the battery and charger, and the particular characteristics of the battery and charger system under the flight conditions. When the CM separated from the service module (SM), the main bus voltage unexpectedly dropped to approximately 25.0 volts but then gradually increased to a normal level before blackout.

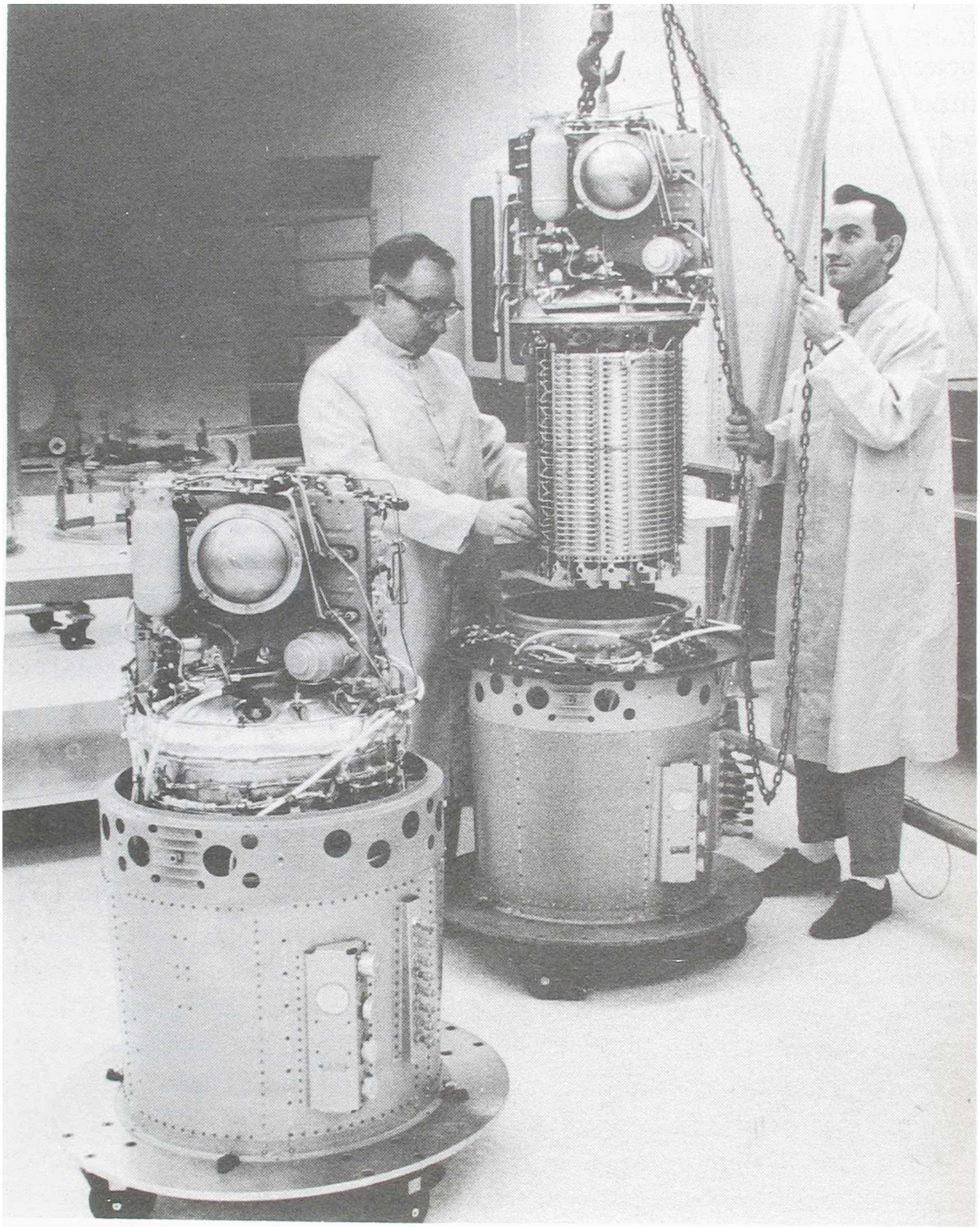


Figure 1–4. Power pack for Apollo fuel cell.

Communications.—The communications system (voice, telemetry, earth-to-spacecraft link, television, and tracking) satisfactorily supported the mission. The VHF and S-band voice links provided good communications. Astronauts operated the onboard television equipment on seven occasions with good picture quality. Overall telemetry performance was satisfactory. A test of the rendezvous radar transponder was successful, and approximately 47 seconds of data were obtained. The ground radar acquired and locked on the spacecraft transponder at a range of 448 miles and tracked to a range of 477 miles. This was the first in-flight verification of the capability of the LM rendezvous radar to lock on and track the CSM. (Fig. 1–5)

Environmental Control System.—The environmental control system (ECS) performed satisfactorily. During pre-launch operations, the cabin was purged to an atmosphere of 60 percent oxygen and 40 percent nitrogen. The crew was isolated from the cabin by the suit circuit, which contained 100 percent oxygen. Shortly after liftoff, the cabin atmosphere was gradually enriched to pure oxygen at a pressure of 5.9 psi. Cabin leakage was estimated to have been 0.1 lb/hr, as expected.

Earth Landing System.—The Earth Landing System (ELS) also performed satisfactorily. The crew reported that all parachutes disreefed and deployed properly. After landing, the spacecraft assumed a stable II (apex-down) attitude for 8 minutes, at which time the uprighting system was activated; 4½ minutes later,

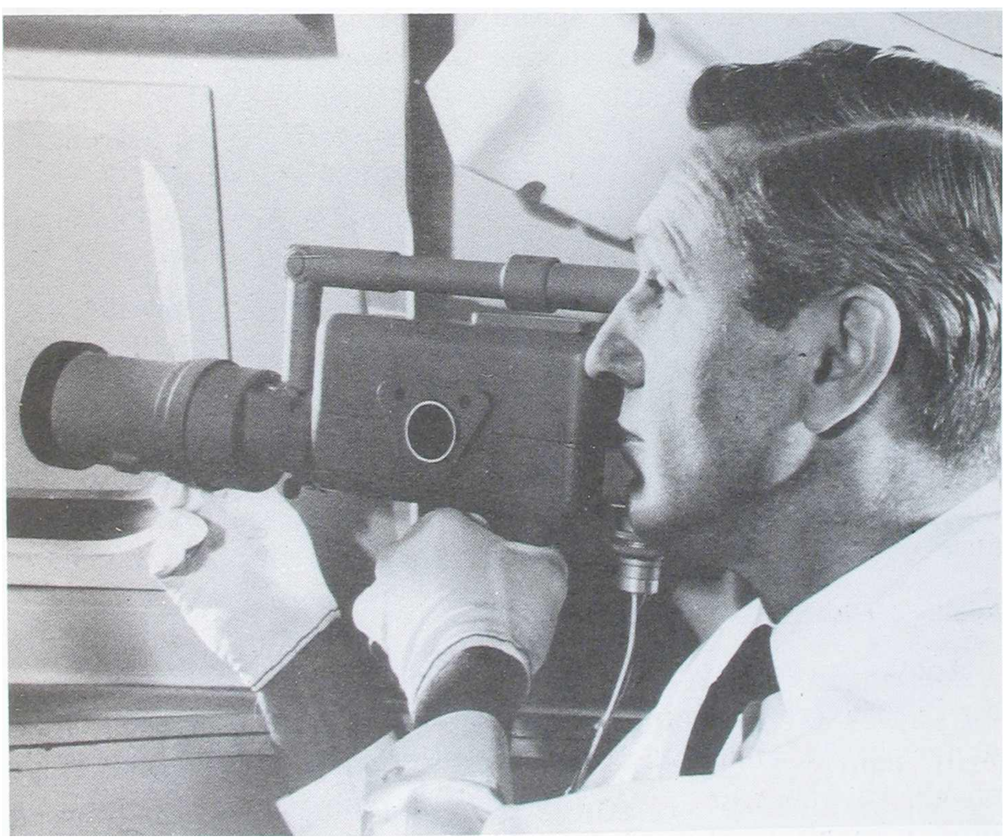


Figure 1–5. Television Camera used aboard Apollo 7.

the spacecraft returned to the stable I (apex-up) attitude. Operation of the recovery aids was interrupted while the spacecraft was in the stable II attitude. Communications were reestablished, and the flashing light was activated after the spacecraft was uprighted.

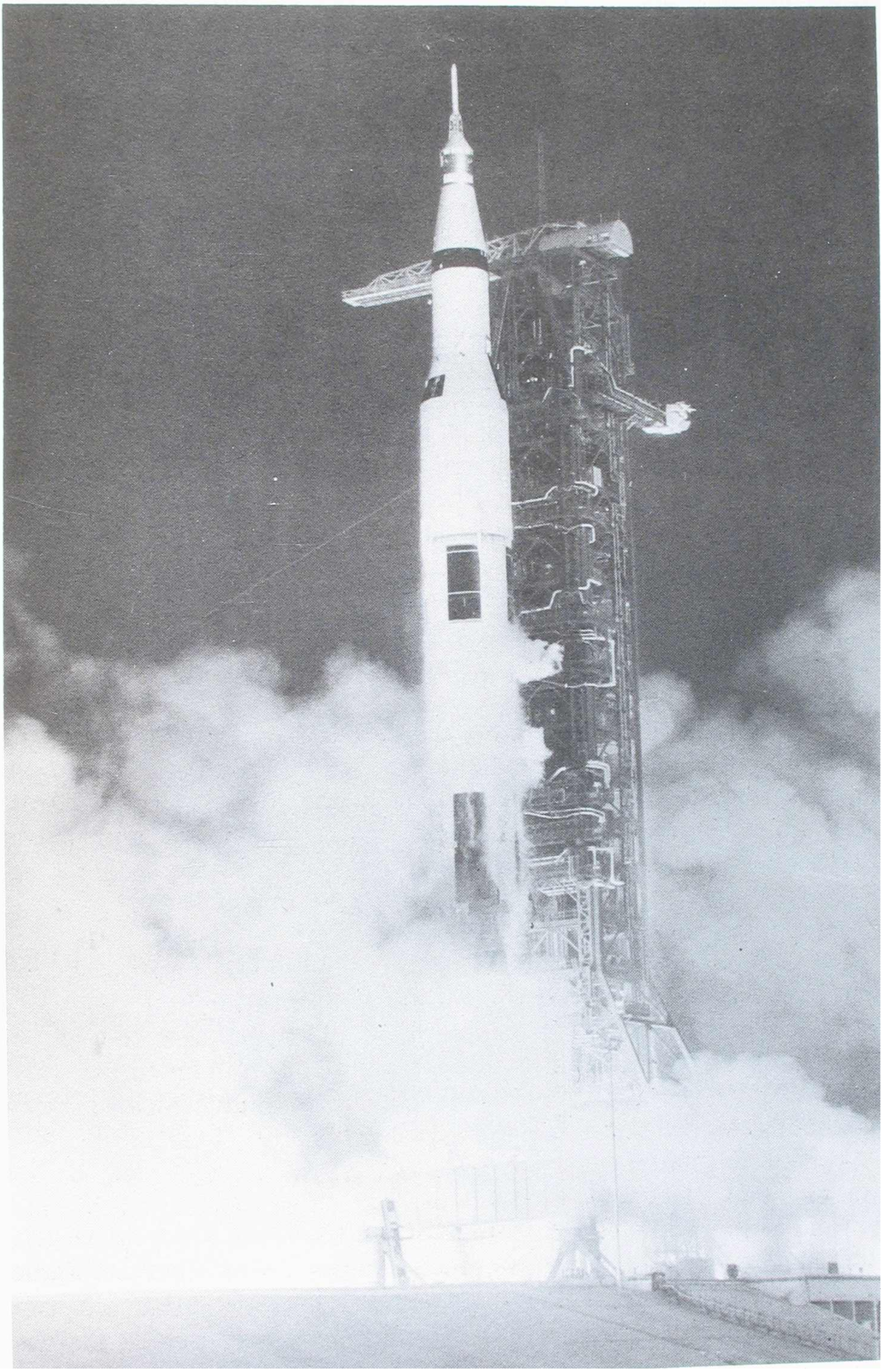


Figure 1–6. Lift-off of Apollo 8.

tion maneuver was initiated 2 hours and 50 minutes after launch by reigniting the S–IVB engine for a five-minute burn. (Fig. 1–6)

The spacecraft separated from the S–IVB about 3 hours and 21 minutes after launch, with separation maneuvers being performed by the Service Module RCS. The first mid-course correction was made approximately eleven hours into the mission. The translunar coast phase was devoted to navigation sightings, two television transmissions, and various systems checks. The second midcourse correction was made at about 61 hours GET.

The 246.5-second duration lunar orbit insertion maneuver was performed at approximately 69 hours GET; the initial lunar orbit was about 193 by 69 miles. About 4½ hours later, the astronauts conducted a maneuver to circularize the orbit. The coast phase between maneuvers was devoted to orbit navigation and ground track determination. The astronauts completed ten revolutions during the 20 hours, 11 minutes they spent in lunar orbit.

The lunar orbit coast phase involved numerous landing-site/landmark sightings, lunar photography, two televisions transmissions, and preparation for transearth injection. The transearth injection maneuver, 203 seconds in duration, was conducted at about 90 hours into the mission, using the Service Propulsion System.

During both translunar and transearth coast phases, passive thermal control maneuvers of about one revolution per hour were effected when possible to keep the spacecraft temperatures within safe limits. During the transearth coast period the astronauts made a number of star/horizon navigation sightings, using both the earth and moon horizons. They also made two additional television transmissions.

CM/SM separation occurred at 146:29:00 GET, and the spacecraft reached the entry altitude (400,000 feet) about 17 minutes later. Following normal deployment of all parachutes, the spacecraft landed safely in the Pacific Ocean, and it and the crew were recovered by the USS *Yorktown.* The total flight duration was 146 hours 59 minutes 49 seconds.

Almost without exception, spacecraft systems operated as intended, and the crew satisfactorily performed all flight-plan functions and achieved all photographic objectives.

Launch Vehicle.—Early engineering evaluation of the Saturn V (SA–503) launch vehicle (Fig 1–7) indicated that all test and mission objectives were met and that all systems and subsystems apparently performed normally. Engineers were continuing to evaluate data to determine detailed performance. The S–IC

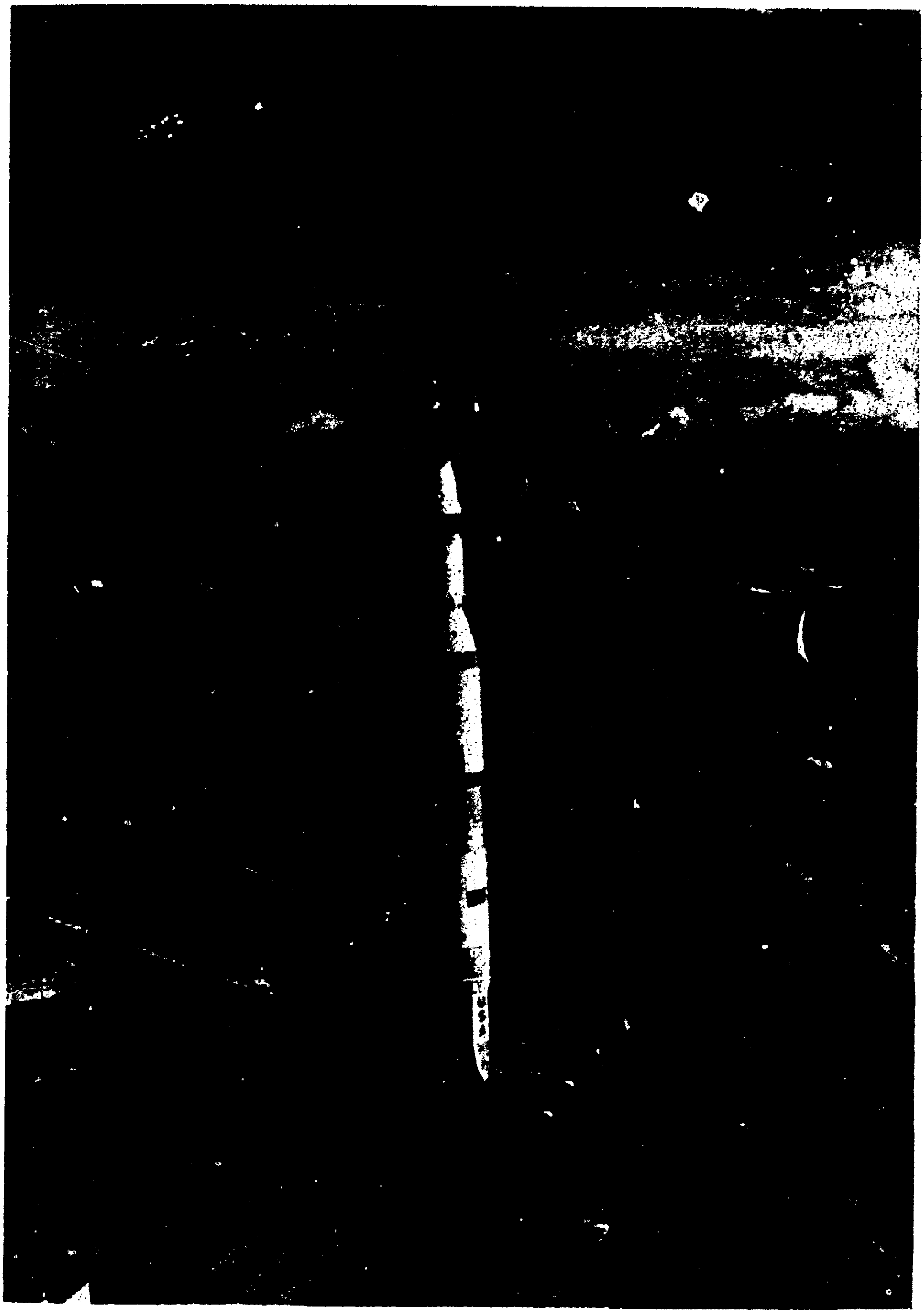


Figure 1–7. Roll-out of Saturn 503 from VAB.

pogo suppression system performed as expected and indications are that no pogo effects occurred.

While the overall propulsion system performed about as expected, near the end of S–II stage burn certain oscillations in engine number 5 were noted. Oscillations were also noted in liquid hydrogen pump inlet pressures on the other four engines even though no chamber pressure oscillations were evident. These anomalies are being studied, and a ground test program is under way.

Spacecraft.—Spacecraft structural and mechanical systems performed satisfactorily except that the spacecraft windows fogged. The hatch (center) window was completely fogged after about 6 hours. The two side windows were also fogged but to a lesser degree. The rendezvous windows remained usable throughout the flight. This fogging was consistent with what was expected as a result of the Apollo 7 analysis of window fogging on the inner surface of the outer heat-shield pane. The fogging results from vaporized oil given off by the compound which seals insulation around the window area. A cure has been developed and will be used on all windows of Apollo 9 and subsequent spacecraft.

Temperature measurements indicated that both passive and active thermal control elements performed satisfactorily. Passive thermal control during the translunar and transearth coast periods stabilized spacecraft propellant temperatures within the expected normal range. Tank temperatures were maintained within safe limits by varying spacecraft orientation. All temperatures were within predicted limits during lunar orbit operations.

Communications.—The overall performance of the spacecraft-to-network communication system was satisfactory. Communications systems management, including antenna switching during the mission, was very good.

The data quality of both high- and low-bit-rate telemetry was good. High-bit-rate telemetry was received through the 85-foot antennas at slant ranges of up to 184,000 miles while the spacecraft was transmitting on omni antennas. The voice quality, both normal and backup, was excellent throughout the mission. The Manned Space Flight Network (MSFN) sites reported receipt of good-quality telemetry data during data storage equipment dumps.

Communications were satisfactory during entry until blackout. Air-to-ground voice contact was re-established at approximately 146:52 GET through the Apollo Range Instrumentation Aircraft. The USS *Yorktown* established voice contact during para-

Figure 1–8. Photo of lunar surface, using long focal-length lens.

chute descent. Post-landing void communications were momentarily interrupted when the spacecraft was in an apex-down flotation altitude; they were resumed when the spacecraft was turned right side up.

Six television transmissions were made during the flight. For the first telecast, the 100 mm telephoto lens was used to view the earth. Because of camera motion and the higher than expected light intensity of the earth, the pictures were of poor quality. On later telecasts of the earth, the telephoto lens was used with a red filter and was satisfactory. Excellent views of the lunar surface were taken in lunar orbit using the 9 mm extra-wide-angle lens and suitable filters. (Fig. 1–8)

Guidance and Control.—Performance of the guidance and control system was extraordinary. All monitoring functions and navigation comparisons required during ascent, earth orbit, and translunar injection were nearly perfect. Platform alignments were performed during all coast phases with excellent results. Onboard midcourse navigation techniques were thoroughly exercised. Star/horizon measurements were made during translunar and transearth coast, with very close agreement with ground tracking. Entry guidance and navigation were excellent.

Service Propulsion System.—The astronauts used the SPS to carry out four maneuvers; the longest of these was the 246.5 second lunar orbit insertion maneuver. A momentary drop in chamber pressure early in the first service propulsion maneuver was attributed to the presence of a small helium bubble in the oxidizer feed line. This bubble is thought to have resulted from an inadequate engine-oxidizer bleed during preflight servicing. The chamber pressure was satisfactory throughout the remainder of the burn and for the three subsequent maneuvers.

Environmental Control System.—This system performed satisfactorily. The radiators effectively rejected the spacecraft heat loads during the translunar and transearth coasts maintaining water/glycol temperatures below the evaporator turn-on level. Evaporator dryout occurred several times but did not impose any restraints on the mission. The primary evaporator was used in the automatic mode during lunar orbit. The evaporator was reserviced at the end of the first lunar orbit and operated satisfactorily until dryout recurred during the fourth lunar orbit. It was once more reserviced and operated satisfactorily for the remainder of lunar orbital flight. Primary evaporator dryout occurred again during entry; however, the crew activated the secondary coolant loop, which operated properly throughout entry and maintained normal cabin temperatures near 61°F.

Flight Crew.—The Apollo 8 mission essentially followed the normal flight plan. However, the astronauts did have to spend more time than planned keeping the S–IVB in sight since it did not move away from the spacecraft as fast as predicted. Also, because of the heavy work load in lunar orbit, the orbital activities after the eighth revolution were sharply reduced to allow additional crew rest. Normal activities were resumed when it came time to prepare for the transearth injection, and then the flight plan was again modified to allow for more rest. About 100 hours into the mission, the astronauts returned to the normal flight plan with only minor rescheduling of rest and meal periods. Despite the long duty hours, crew performance was good throughout the mission, and the astronauts made many valuable observations of the lunar surface and its environment.

Entry and landing took place in darkness, with no apparent problems. The spacecraft landed apex down, about 5200 yards from USS *Yorktown,* and the astronauts used on-board equipment to put the spacecraft in an upright position. (Fig. 1–9) The deployment of swimmers was delayed until daylight as decided previously. As a consequence, crew transfer to the prime recovery ship by helicopter occurred about 80 minutes after landing.

Apollo 9 Mission Summary

The Apollo 9 mission, scheduled for the first quarter of 1969, will use the SA–504 Saturn V launch vehicle, CSM 104, and LM–3. The launch vehicle and spacecraft will differ slightly from the final space vehicle configuration; R&D instrumentation will be flown in all three stages and in the spacecraft. This will be the third manned flight of the command and service module. the

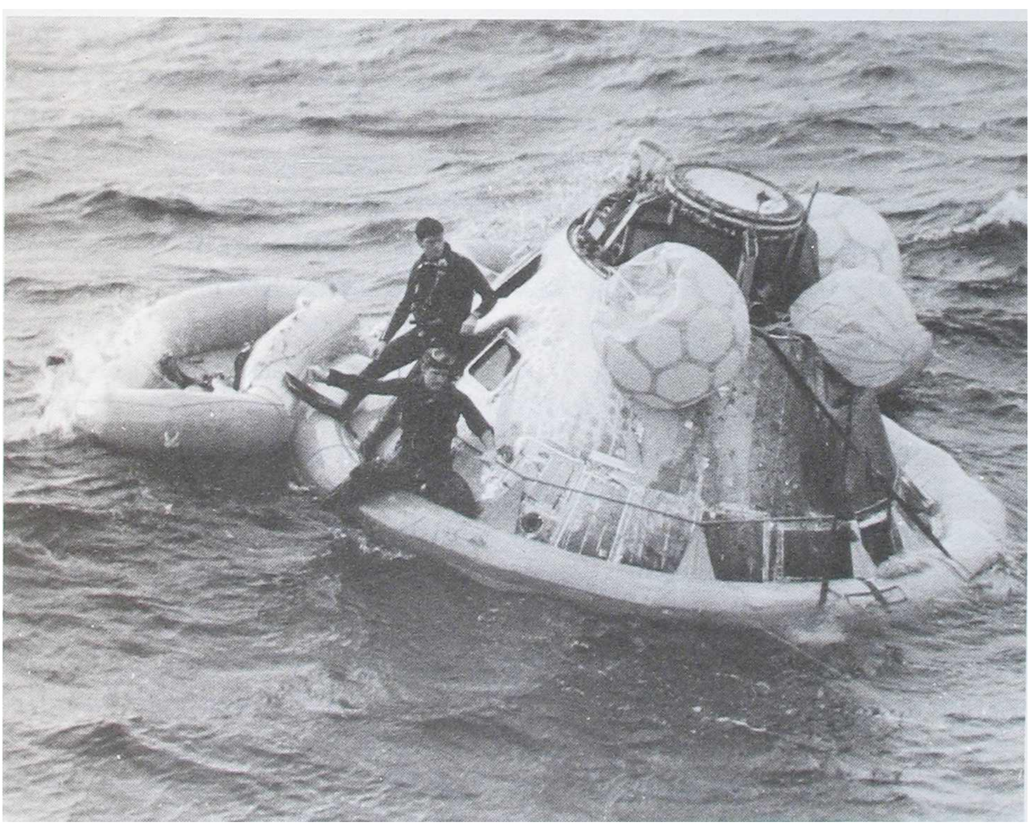


Figure 1–9. Apollo 8 with on-board uprighting equipment deployed.

second manned flight of the Saturn V launch vehicle, and the first manned flight of the lunar module.

This mission is expected to demonstrate crew/space vehicle mission support facilities performance with the CSM and LM in earth orbit; to demonstrate LM/crew performance; and to demonstrate performance of normal and selected backup lunar orbit rendezvous mission activities. These activities are to include transposition, docking, and LM withdrawal; intravehicular and extravehicular crew transfer; docked SPS and descent propulsion system (DPS) burns; and LM active rendezvous and docking.

This mission is to be open ended, lasting up to 11 days. The launch vehicle will place the manned spacecraft in a circular earth orbit. The CSM will separate from the launch vehicle, turn around, dock with the LM which will still be attached to the S–IVB. When docking is complete, the entire Apollo spacecraft will be spring-ejected from the S–IVB. Then the spacecraft will move away from the S–IVB so that the crew can observe two restarts of the S–IVB, the second boosting the stage into a solar orbit. The lunar module descent stage engine and the service module engine will each be burned while the spacecraft and lunar module are docked. While the CSM/LM is in orbit, the crew will transfer through the docking tunnel to power up the LM. Staging (separation of LM ascent and descent stages) will be performed with the LM manned and separated from the CSM by approximately 100 miles. LM active redezvous with the CSM will be performed with the ascent stage. CSM and LM orbits throughout the mission will not exceed 345 miles altitude.

Apollo 10 Mission Summary

Apollo 10 will use the SA–505 Saturn V launch vehicle, the CSM–106, and the LM–4. A test (non-operational) Lunar Surface Experiments Package (ALSEP) will be carried. The primary objectives of this mission will be to demonstrate crew, space vehicle, and mission support performance during a manned lunar mission with CSM and LM; and to evaluate LM performance in the cislunar and lunar environment.

Apollo 11 Mission Summary

The primary objective of the Apollo 11 mission will be a manned lunar landing and return. The flight will be configured with the SA–506 Saturn V launch vehicle, the 107 command and service module, and lunar module 5. The Saturn V launch vehicle and the Apollo spacecraft will be the final spacecraft configuration. Two astronauts will descend to the lunar surface, collect a contingency lunar soil sample and shortly afterward a larger lunar soil sample. They will deploy three experiments—a solar powered seismometer to measure moonquakes, a glass mirror to reflect the light of ruby lasers in earth based telescopes and to measure the distance of the moon more accurately, and an aluminum foil which will absorb particles from the solar wind for analysis on earth. The time on the lunar surface is open-ended with the normal plan providing for an exploration period of up to three hours. The astronauts are to remain within 300 feet of the LM.

Development and Test

The flights of Apollo 7 and 8 proved the Apollo space vehicle and supporting systems, and the Apollo 7 flight completed the Apollo requirements for Saturn IB launch vehicles. Subsequently, NASA began phasing down the entire Saturn IB Project in support of Apollo. The IB program will be maintained at the minimum sustaining level that will allow reactivation when required for the Apollo Applications Program. During the last half of 1968, major ground test activities were aimed at certifying systems for manned flight, and at producing and verifying flight hardware.

Command and Service Modules.—The planned ground tests and flight activities of the CSM for the latter half of 1968 were carried out. The pogo oscillation experienced in the April launch of Apollo 6 resulted in higher than anticipated structural loads on the spacecraft and adapter. In June, NASA began a space vehicle static and dynamic structural test program, completing it in October. Analyses of the test results confirmed that the spacecraft and adapter could withstand the higher loads if the oscillation were to occur on vehicles with the pogo fix incorporated.

To show that the Block II CSM could perform satisfactorily, NASA conducted additional unmanned and manned thermal/vacuum tests (ground simulation of a space mission in the vacuum chamber), using a CSM test article. A special hatch test was conducted in July, and the final manned test was completed in September. Only minor anomalies occurred during the complete series of thermal/vacuum tests, and the CSM was approved for the Apollo 7 and 8 missions.

In spacecraft structural testing, the parachute loads test, forward tunnel and hatch test, end boost loads test, abort loads test, CSM/LM docked mode dynamic and structural loads tests, and numerous component tests were completed. The test of the probe and drogue for CSM/LM docking was nearing completion at the close of 1968.

The service propulsion system underwent an exhaustive series of tests to verify its performance during all mission phases. The Apollo 7 mission confirmed the reliability of the SPS, and on the Apollo 8 mission, it again performed flawlessly.

Increased weight of the command module made it necessary to redesign the main and drogue parachute and risers and to requalify the earth landing system. In a test program using a boilerplate drop test vehicle, the parachute qualification was completed in July, and the final qualification drop of the drogue/riser in September. This drop removed the ELS constraint to the launch of Apollo 7.

In a test program to assure the safety of the astronauts in a land or water landing of the command module, over a dozen tests were conducted at KSC and the Manned Spacecraft Center (MSC) to simulate various land impact and water landing conditions that might be experienced. The tests were completed satisfactorily and the Block II command module structure and the redesigned crew couch struts were certified as acceptable for manned operations. The first CSM approved was flown on the Apollo 8 flight, and as the period closed, those for the Apollo 9 and 10 missions were being checked out at KSC.

Lunar Module.—The Lunar Module ground test program continued to move forward as most qualification tests were completed. There remain only a series of propulsion tests required to certify the LM ready for lunar missions, and applying only to the Apollo 10 and 11 lunar modules. The completed tests removed all constraints on the man rating of the LM for Apollo 9.

The ground tests to assess the flammability and propagation characteristics of the naw materials in the Apollo 9–LM–configured test articles cabin were completed in September. In the tests, numerous attempts were made to ignite materials in the LM cabin under various cabin pressures and oxygen content conditions. At the cabin conditions for flight operations, the only fires were caused by extreme ignition situations, and they were slow to build up and controllable, offering no limitation on safe manned operations.

The descent propulsion system tests conducted to select and to qualify an engine injector were satisfactorily concluded in September, lifting the restriction on the flight of the Apollo 9 LM. Ascent propulsion system tests on the Apollo 11 LM, the first potential lunar landing mission vehicle, are to be completed early in 1969.

The lunar module for Apollo 10, the second scheduled manned flight vehicle, was delivered in October and was in prelaunch checkout at KSC at the close of the period. (Fig. 1–10)

The LM flight test program was delayed when NASA decided to withdraw the designated LM from the Apollo 8 mission because a series of technical problems delayed checkout of the LM at KSC. The problems were resolved, and the LM completed all KSC individual and combined systems checkout operations. It was mated with the Apollo 9 CSM and launch vehicle, and the space vehicle was ready for transfer to the launch pad for a scheduled launch early in 1969.

ALSEP.—The first and second flight units of the Apollo Lunar Surface Experiments Package were accepted from the manufacturer. The astronauts successfully deployed the ALSEP during a mission simulation. (Fig. 1–11) After extensive review and evaluation, NASA decided to have the astronauts conduct only one excursion on the lunar surface during the first lunar landing. Since the full ALSEP would be deployed on a second excursion, both it and the field geology investigation will be deferred to the second lunar landing mission.

NASA decided on the delay because of the significant difference between orbital operations and the first lunar landing. The descent, landing, extravehicular activity (EVA), and ascent from the lunar surface are new operations in a new environment. Gemini EVA experience showed that a methodical increase in task complexity was necessary in order to understand and operate in the zero g space environment. The 1/6 g lunar surface environment will be a new experience, one that cannot be completely simulated on earth. For example, sufficient metabolic data is simply not available to predict, with high confidence, rates in a 1/6 g environment. Only educated assessments can be made of the difficulties the astronaut will have in maneuvering on the surface or the time it will take him to accomplish assigned tasks. As a consequence, a prime objective of the first mission EVA will be to assess the capabilities and limitations of the astronauts in the lunar environment.

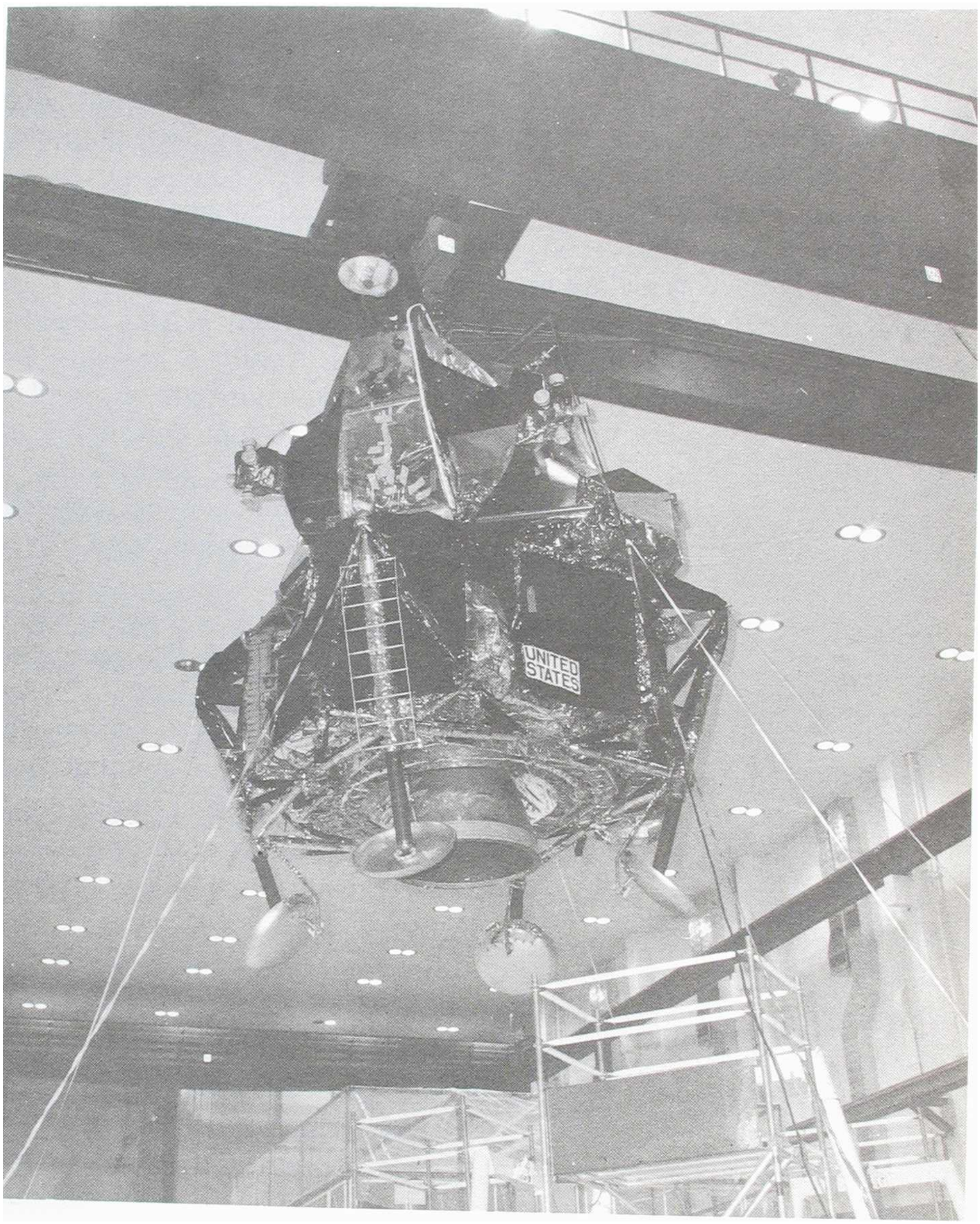


Figure 1–10. Lunar Module 4 for use with Apollo 10.

To obtain maximum scientific benefits from the first lunar mission, and in keeping with a curtailed EVA, the astronauts will carry out three self-contained, lightweight, and easily deployed, alternative experiments requiring minimum effort (p. 31). Plans still call for the astronauts to collect lunar samples and photograph the site from which the samples are obtained.

Figure 1–11. Simulated deployment of ALSEP.

In addition, the astronauts will try to photograph the fine texture of the undisturbed lunar material. For this purpose, a close-up stereo camera is under development and may be ready for the first lunar landing mission.

The lunar samples, together with the astronauts and their spacecraft, will be brought back to the Lunar Receiving Laboratory (Houston) for a period of precautionary quarantine and other processing. Then the samples will be distributed to more than 135 investigators throughout the world. The data from their analyses and from the surface experiments will provide the first direct knowledge of the moon and its interaction with its environment.

Launch Vehicles.—One Saturn V was launched (Apollo 8), and prelaunch preparations were underway on two others, which were delivered to KSC during this period. Saturn V launch vehicle ground test activities continued to concentrate on the problems identified by the flight of Apollo 6 in April 1968. The effort consisted of space vehicle vibration studies to determine allowable POGO induced oscillation; static and dynamic tests of the coupling effect on spacecraft/spacecraft LM adapter (SLA) resulting from such oscillations; and the resulting corrective action and modifications. Additionally, the structural qualification tests of the S–II stage lightweight structure were completed.

The modifications to resolve the three technical problems experienced by Apollo 6 were flown on Apollo 8. They consisted of the pogo fix (injecting helium gas into a cavity in an existing prevalve at the lower end of the LOX feedline of the four outboard F–1 engines of the S–IC stage); redesigned fuel lines for the J–2 engine augmented spark igniter; and SLA structural corrections. (The last two modifications were also flown on Apollo 7.) Apollo 8 experienced no pogo during launch. While one flight without pogo is not absolute proof that it will not recur, it does provide added assurance that the F–1 engine fix is effective. The solutions to the J–2 Engine and SLA problems proved satisfactory on Apollo 7 and 8.

The first Saturn V launch vehicle with the lightweight S–II structure design is scheduled for launch in early 1969. The dry weight of this S–II stage and of subsequent S–II's is approximately 2200 pounds less than previous ones.

The S–IC–6 first stage completed acceptance tests in August, was shipped to Michoud, completed post static checkout in December, and is scheduled to arrive at KSC in February 1969. S–IC–7 was delivered to Mississippi Test Facility (MTF) where acceptance tests were completed in November. It was subjected to a long duration static firing to test the accumulator fix for the pogo problem. The stage was returned to Michoud for post static checkout and preparation for delivery to KSC. S–IC–8 was removed from storage, given a factory checkout, and sent to MTF for acceptance test. S–IC–9 completed factory assembly and checkout and was being readied for acceptance test. Stages S–IC–10 through 15 were being assembled at the factory.

Modifications, cryogenic proof pressure tests, and static firing were completed for the S–II–5 stage at MTF, and the stage was delivered to KSC in November. S–II–6 completed the same final acceptance tests and was in post static checkout for delivery to KSC at period's end. S–II–7 was delivered to MTF in November for the required acceptance testing. The remaining S–II stages—S–II–8 through 15—were in various stages of assembly and checkout.

The S–IVB–506 and 507 stages underwent acceptance tests and were placed in storage awaiting delivery to KSC. S–IVB–508 remained in storage. S–IVB–509 was assembled, subjected to factory checkout, and placed in storage. The remaining three stages were in various stages of assembly.

Instrument Unit S–IU–505 completed retrofit and retest and was delivered to KSC in December. S–IU–506 and 507 were being retrofitted and retested, with delivery scheduled for early 1969, and 508 was in component assembly. Structural fabrication of units 509 and 510 was begun.

Quality and Reliability Assurance

The Apollo Quality and Reliability Assurance (Q&RA) effort concentrated on the readiness of hardware for the Apollo 7 and 8 missions. Q&RA teams reviewed more than 7000 nonconformances and corrective actions on Apollo hardware. They analyzed the criticality of 924 space vehicle single failure points and evaluated equipment certifications. Critical hardware items, which required verification prior to launch, were identified and reported to the Apollo Program Director and to the manned space flight centers. Each of the identified items was effectively cleared prior to launch. As a result, the assessed levels of quality and reliability were confirmed by the successful performance of the prescribed missions.

Apollo Q&RA also performed risk analyses for alternate Apollo 8 mission plans. These analyses concentrated on evaluating the life science aspects of extending the usage of hardware with a demonstrated earth orbit capability to the requirements of a lunar mission. Program Management used the results of these analyses in selecting the Lunar Orbit mission and in developing and refining mission operation improvements. These improvements included, among others, providing for on-board emergency manual navigational aids; additional planning for crew safety; and testing the S–Band communications and other selected systems.

APOLLO APPLICATIONS

The Apollo Applications Program (AAP) efforts progressed into the phase of final hardware and software development. The AAP objectives remain essentially those described in the *18th Semiannual Report* (p. 29), except that the specific objective of extended lunar exploration, using Saturn V launch vehicles, was transferred from AAP to the newly formed Apollo Lunar Exploration Office. The Apollo Applications Program is designed to capitalize on the Apollo-developed capabilities and resources to accomplish additional scientific, technical, and medical investigations.

Missions

Because of financial limitations, NASA developed a "core program" with a limited number of Saturn IB launches planned and dropped the Saturn V Workshop from the list of planned missions. However, the flexibility remains to expand technical efforts beyond the "core program" at a later time.

The AAP missions are the Saturn I Workshop (launch of two Saturn IB vehicles); the Workshop revisit (single launch); the solar astronomy mission (launch of two Saturn IB vehicles); and the backup Saturn I Workshop or backup solar astronomy mission. These missions are described in detail in the *19th Semiannual Report* (p. 22), and therefore only summarized here. (Fig. 1–12)

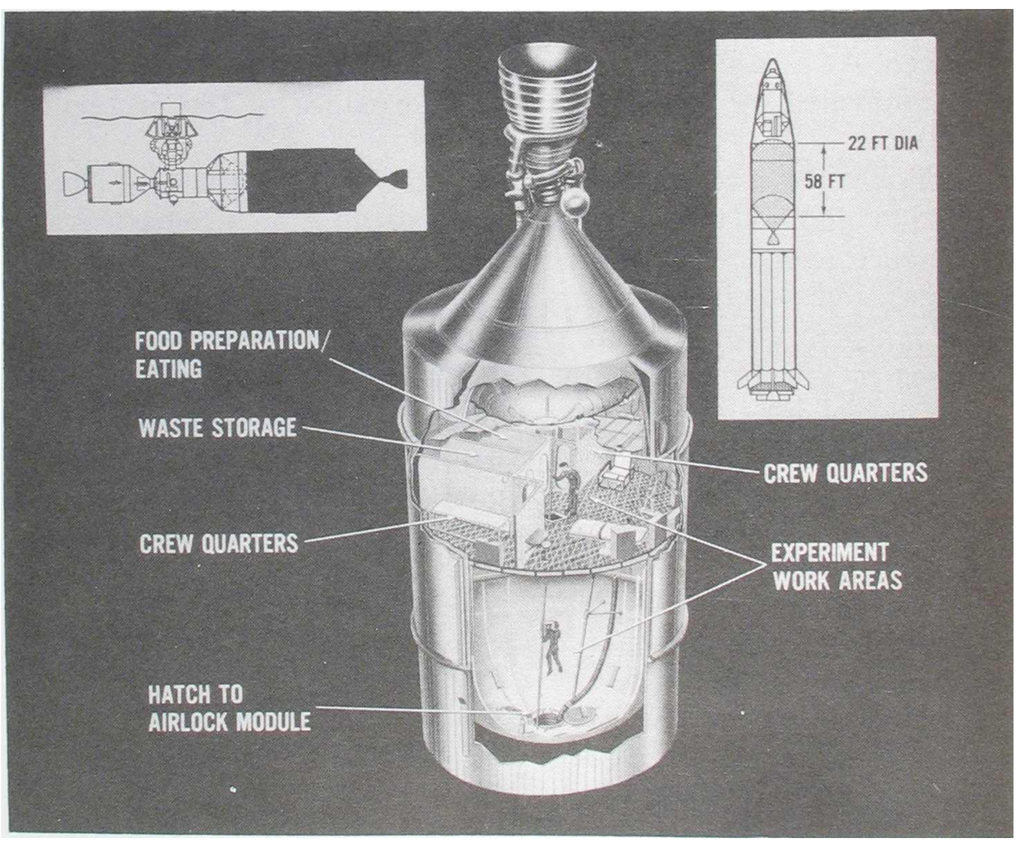


Figure 1–12. Concept of Saturn I Workshop.

The Saturn I Workshop mission calls for the launch first of an unmanned Saturn IB with an S–IVB stage modified for use as living and working quarters, an airlock module, and a docking adapter. Then the manned Apollo CSM will be launched and will rendezvous and dock with the S–IVB stage. This mission is open-ended with consumables on board sufficient for 28 days.

In the Workshop revisit mission, a single Saturn IB launches a three-man CSM to rendezvous and dock with the Saturn I Workshop remaining in orbit from the previous mission. Planned to last up to 56 days, the flight will test the ability of men and equipment to function for long periods in space.

The solar astronomy mission consists of two flights: the first, a Saturn IB launch of a three-man CSM with consumables for a 56-day stay; the second, a Saturn IB launch of the unmanned Apollo Telescope Mount (ATM) with its payload of solar instruments. Both will rendezvous and dock with the Workshop in orbit from the first mission. (Fig. 1–13)

Hardware is planned to be available to permit backup missions in the event of the failure of any of the flights that support the Saturn I Workshop mission or the solar astronomy mission. Backup hardware includes a Saturn I Workshop, including the associated airlock module and multiple docking adapter; a lunar module and Apollo Telescope Mount; one additional CSM; and two additional Saturn IB launch vehicles.

The schedule for the AAP missions has changed since the last report. The Saturn I Workshop mission slipped from a launch readiness in late 1970 to the last half of 1971; the solar astronomy mission slipped from 1971 to 1972.

AAP Management

The Apollo Applications hardware responsibility was realigned between Manned Spacecraft Center and Marshall Space Flight Center (MSFC) in order to make best use of available facilities and manpower. MSFC was assigned responsibility for modifying the lunar module ascent stage and for developing the airlock. Thus, MSFC has been assigned the following flight hardware: Saturn IB; lunar module ascent stage modification; workshop, airlock, and Multiple Docking Adapter (MDA); payload enclosure for workshop and Apollo Telescope Mount launches; Apollo Telescope Mount; and assigned experiments. MSC is responsible for the CSM and its required modification; for SLA; for manned launches; for crew systems; for medical equipment; for food; and for assigned experiments.

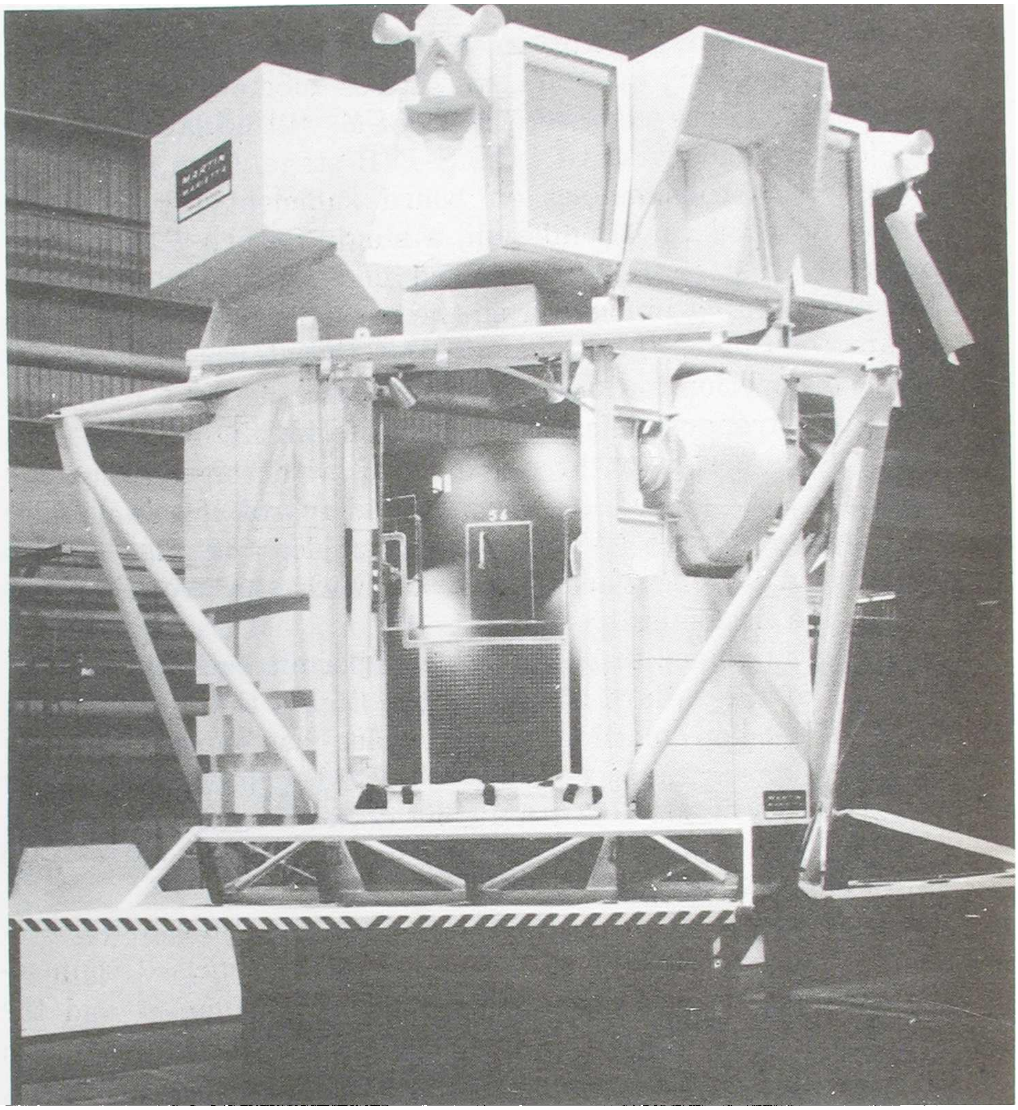


Figure 1–13. The Apollo Telescope Mount.

Hardware

For the Apollo Applications Program, NASA continued to develop and modify major flight hardware, and to design, fabricate, and update test articles.

Saturn I Workshop.—The basic module for the Workshop is an S–IVB stage modified to provide living and working quarters for three men for up to eight weeks. Included is an airlock for crew transfer from the CSM to the Workshop without extravehicular activity. The Workshop also has a Multiple Docking Adapter which will allow more than one space vehicle to dock with it. (Fig 1–14)

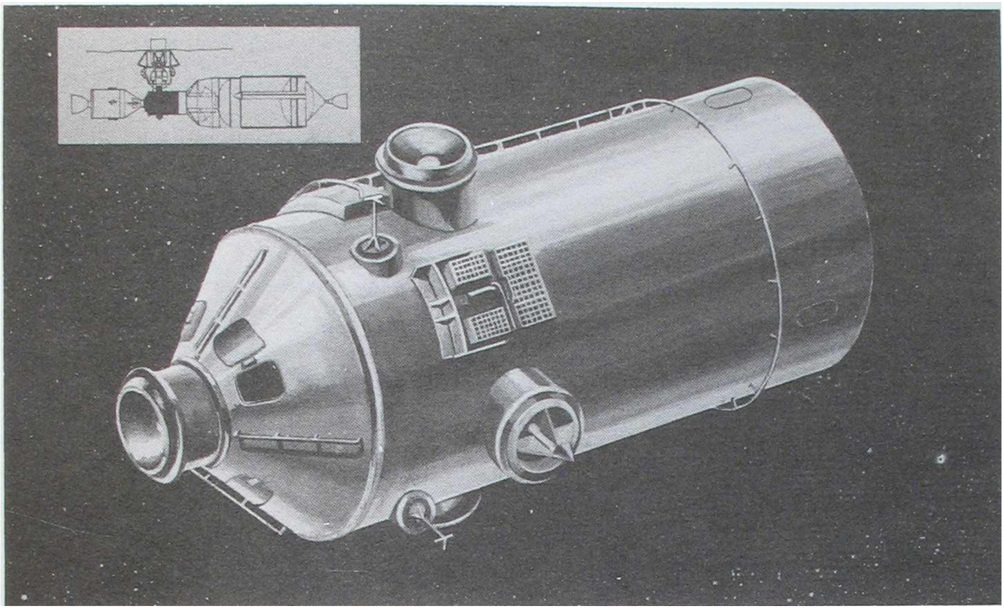


Figure 1–14. Multiple Docking Adapter.

Modifications to the basic S–IVB stage to convert it into the Workshop were underway at the contractor's facility at Huntington Beach, California. During this period, the contractor continued designing, defining, procuring, and fabricating test articles, and began certain development tests.

Airlock Module.—The design of the Airlock Module was nearly complete. This module, which will provide a pressurized connecting passageway between the Multiple Docking Adapter and the Workshop, is composed of a structural section and a tunnel with a forward compartment, an airlock, and an aft compartment. It incorporates an electrical power system for the entire cluster, a central environmental control system, and the central control and display station for cluster operations. (Fig. 1–15)

Multiple Docking Adapter.—The MDA is being developed and fabricated in-house at the MSFC. It will provide parts for the CSM, the LM, and the ATM spacecraft to dock with the orbital workshop cluster assembly. The Adapter will also provide the interface connections necessary to allow these modules to function as an integral part of the cluster. The MDA is to have a pressurized passageway between the Airlock Module and the docked modules for astronaut and equipment transfer. In addition, it will provide space for storing experiments and equipment during launch. A command station, adjacent to a viewing

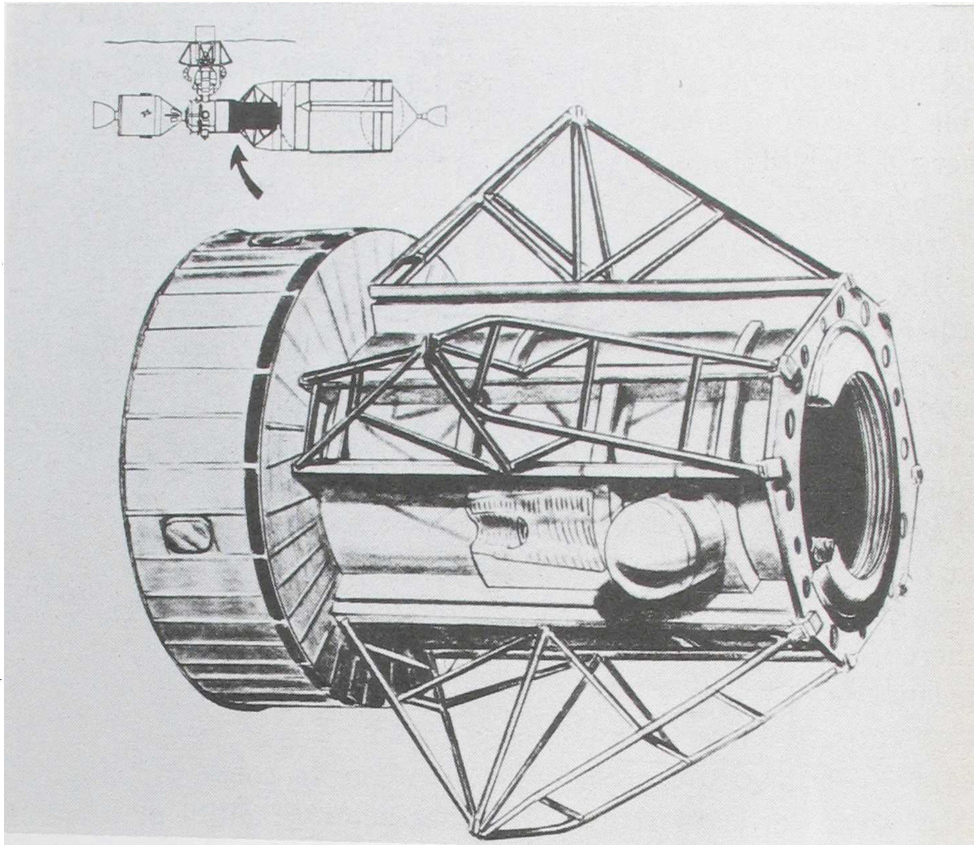


Figure 1—15. Concept of Airlock Module.

window in the MDA, will permit astronauts to observe the unmanned rendezvous and docking of the LM and the ATM.

Activity at MSFC concentrated on designing, defining, planning tests, and fabricating an engineering mock-up. Work was also underway on a structural test article. Final design of the flight unit was continuing; meanwhile, the engineering mock-up design was being updated and hardware fabricated.

Apollo Telescope Mount.—At MSFC, which is responsible for major subsystem development of the ATM, work was progressing rapidly. Preliminary design reviews of the ATM subsystems, for which an updated ATM mockup was available, took place in October. Critical design reviews of certain elements of the ATM subsystems (control moment gyros and fine sun sensor) were held preparatory to giving the go-ahead on the ATM system prototype and flight hardware. The ATM neutral buoyancy and one-gravity mockups were modified to the latest configuration and were ready to support design verification testing. Fabrication of the structural test unit of the ATM rack was eighty percent complete as the period ended.

Unit prototype and test hardware are rapidly becoming available for many of the ATM subsystems. Control moment gyros were delivered to MSFC to be tested, evaluated, and included in the pointing control subsystem simulator. The prototype unit of the fine sun sensor, used for accurately locating the center of the sun, was also furnished to MSFC. The basic pointing control simulator was delivered and installed in MSFC facilities Preliminary thermal vacuum testing was conducted on quarter segments of the ATM structural rack and experiment support spar. Additionally, all of the modular solar cell flight units were supplied and tested for integration into the ATM solar panels.

Lunar Module.—The ascent stage of an Apollo Lunar Module is to be modified by the LM contractor. This stage contains the crew quarters and provides a pressurized compartment in which the crew can control operations of the ATM and its various experiments. The descent stage will be replaced by the ATM structural rack with associated power, pointing equipment, and solar experiments.

A definitive contract for preliminary design review effort was issued to the LM contractor in August, and the review was completed in October. It was a critique of design and program documentation, providing a basis for continued design and development of the LM. (Fig. 1–16)

Command and Service Module.—The Apollo spacecraft, designed to provide a 14-day operational capability, will be modified by the AAP to support flight missions lasting 28 and 56 days. The preliminary requirements review, held at the contractor's facility in August, summarized the configuration, mission, and systems requirements, aiming for a preliminary design review scheduled early in 1969. NASA established a program to validate the new, existing, and modified hardware. The resulting verification test plans will be reviewed at the preliminary design review. A definitive contract was negotiated for this review to provide planning and analysis required for the hardware and test programs. Long lead procurement items required for CSM modifications were identified.

Launch Vehicles.—Launch vehicle procurement, directed by MSFC, will use the same contractors that produce the stages and engines for the Apollo vehicles. Initial AAP missions will use Saturn IB launch vehicles procured by the Apollo Program. In addition, two Saturn IB's are required in the event a repeat work-

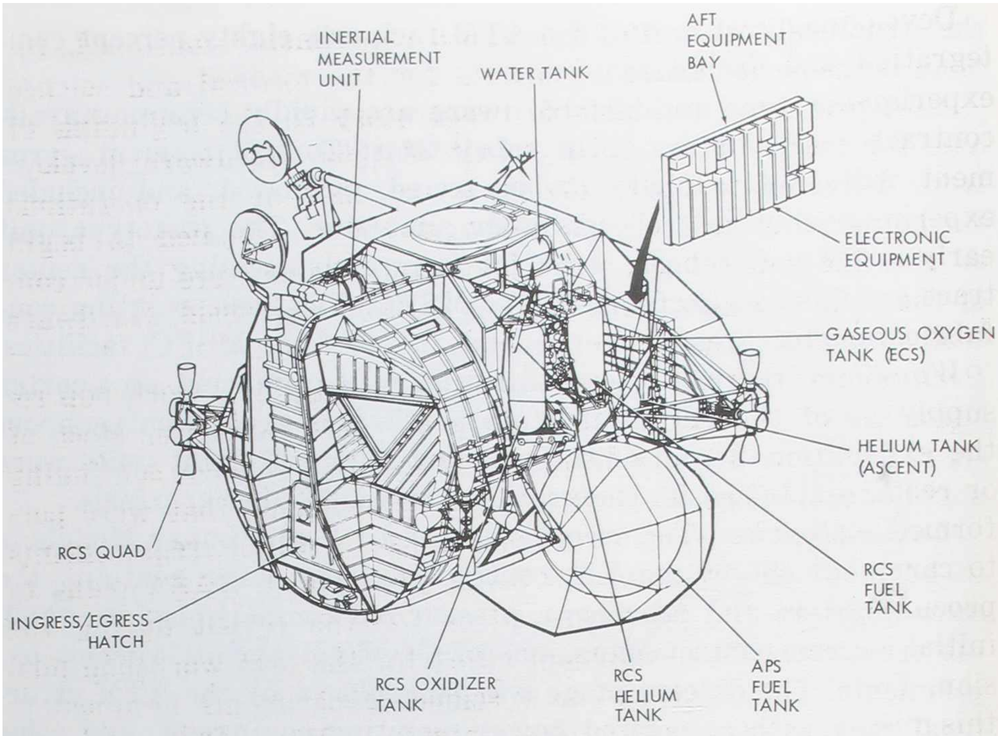


Figure 1–16. Line drawing of the LM Ascent Stage.

shop or solar astronomy mission is required. The assembly of the two S–IB stages, 213 and 214, was continuing, as was the manufacturing of long-lead hardware for the S–IVB stages.

Experiments

The experiment payloads for the AAP missions were defined in more detail. Forty-nine experiments, grouped in five major categories, are assigned as follows:

Workshop Mission (AAP–1/AAP–2)	Revisit Mission (AAP–3A)	ATM Mission (AAP–3/AAP–4)
Medical and Behavior (14) Operations (9) Technology (9) Science (7)	Science (2) Repeat Experiments Medical and others	ATM (5) Science (2) Technology (1) Repeat Medical Experiments

Saturn IB Workshop.—This mission schedule requires the Workshop experiments to be completely developed by June, 1970, and the flight hardware to be installed in the space vehicle by the following December.

Development work on all assigned experiments continued. Integration and design requirements for the medical and science experiments were established, preparatory to the beginning of contract work during the first half of 1969. Hardware development work was already underway on half of the operations experiments, with work on the remainder scheduled to begin early in 1969. All of the technology experiments were under contract and most preliminary design reviews were held. Hardware fabrication was in process.

Workshop Revisit.—This mission is essentially a workshop resupply mission to achieve 56 days of space exposure. Most of the experiment activity in this mission will involve continuing or redoing medical or other selected experiments that were performed on the previous Workshop mission. Flight requirements to carry out this mission are being determined. NASA plans to procure all of the hardware items for the revisit during the initial experiment development effort for the first workshop mission. Development of two new science experiments assigned to this mission should begin, under contract, in March 1969.

ATM Solar Astronomy.—Five experiments plus a pointing telescope are being developed for flight on ATM: High Altitude Observatory; American Science and Engineering; Harvard College Observatory; Goddard Space Flight Center; Naval Research Laboratory; and the H-alpha Telescope, Perkin-Elmer. Critical design reviews were held on all experiments except the Harvard College Observatory and the H-alpha Telescope.

Operations

Operational mission planning activities continued in the several panels and planning groups, with emphasis on refining plans for the first five missions. Baseline reference missions were established for the first three missions; preliminary plans were identified for the backup missions. Factors and topics considered included pre-launch, orbital, and non-orbital operations; experiment operational compatibility; planning of flight crew activities and compatability with the systems; orbital assembly; operational compatibility of hardware.

Preliminary operational program and mission support requirements were identified, published, and discussed with support agencies (Air Force Eastern Test Range and Navy Recovery Forces). Preliminary support plans from these agencies were reviewed, and new facility support requirements were identified.

Launch area facility reviews were conducted to determine changed or new requirements for Apollo Applications. Following the reviews, NASA made plans to transfer management of Launch Complexes 34 and 37 from Apollo to Apollo Applications, and for subsequent phase down or temporary deactivation with any necessary modifications. The Agency also started studies relating to the co-use (with Apollo) of Launch Complex 39.

ADVANCED MANNED MISSIONS

The Advanced Manned Missions program office is responsible for overall systems engineering, planning, and definition of all advanced manned space flight mission studies and projects beyond those encompassed by AAP. It is also responsible for technical feasibility studies of major alternatives or additions to approved manned space flight mission projects. During the period, this office continued to study all aspects of potential future manned space flight systems and missions. Major attention was focused on space station and space shuttle concepts.

Following studies of possible earth orbital space station missions and of launch vehicles which might be used in conducting such missions, NASA decided to initiate steps to develop a space station in earth orbit, following the Apollo Applications Program. Concurrently, NASA issued a document to formalize all new program planning and implementation into four distinct phases: preliminary analysis, definition, design, and development.

A preliminary analysis report summarizing the results of all the advanced studies and supporting activities concluded that a space station would enable the Nation to achieve a wide variety of goals. It also recommended that such a station should be modular in configuration and developed through a program which had the flexibility to adapt to changes in funding and technical activity.

Based on this report, NASA began to plan a program which would support the requirements of all of its elements. Funds originally programmed in the Apollo Applications Program for an advanced workshop were redirected for use in the more advanced Space Station Program. These funds, combined with the Advanced Studies funds for FY 1969, formed a total program to carry out basic studies of preferred Space Station Programs, to define the more practical ones, and to proceed into the design and development of the one that was most promising.

Experiment definition as well as supporting research and technology activities were also redirected to describe experiments and advanced hardware for the station. All planning was focused on an initial launch of the station in about 1975.

As the program began to take shape, NASA determined that certain specific guidelines were to be established. Such guidelines would be necessary because the systems that were being considered covered a wide range, from configurations using variations of existing Gemini and Apollo hardware and existing launch vehicles to entirely new spacecraft and launch vehicles.

Also, during this period, proposals for several promising space shuttle concepts were submitted to NASA as a result of the search for a low-cost transportation system. Several spacecraft configurations were proposed that, while they would stretch technology well beyond Apollo, could be successfully developed and might offer a substantial reduction in the cost of resupplying a space station. (Fig. 1–17)

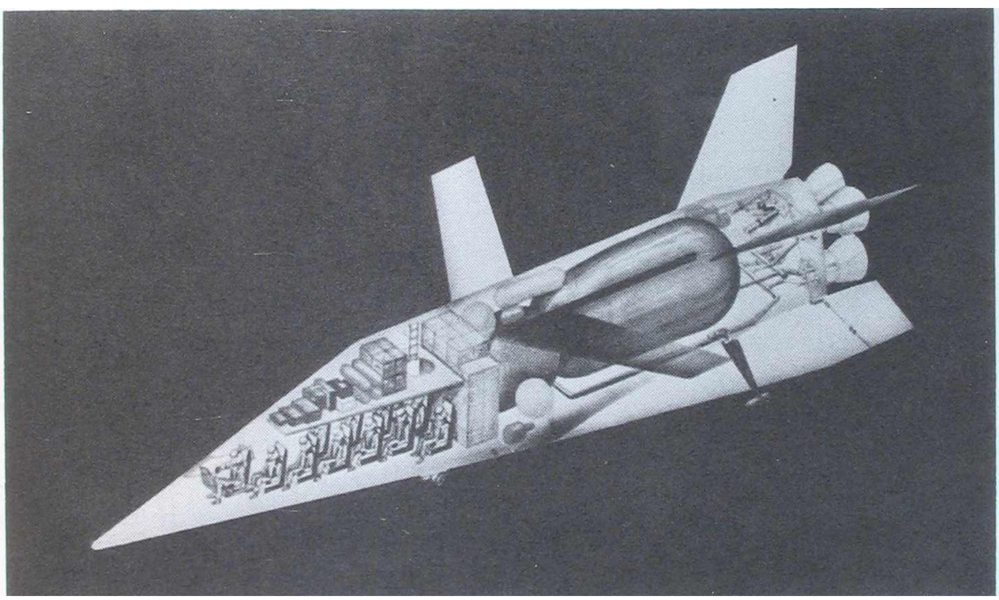


Figure 1–17. Concept of Space Shuttle Reusable Vehicle.

MISSION OPERATIONS

The mission operations activities of the manned space flight program were concerned with flight crew training and support, operations support, mission control systems, launch information systems, operational communications, and the Huntsville Operations Support Center.

Flight Crew Operations

Flight crew training for the first two manned Apollo flights was completed with the successful Apollo 7 and Apollo 8 missions. The crews for Apollo 10 and 11 were identified, and their specific training was underway.

Flight training for the scientist-astronauts selected in 1967 was well along at various Air Force training bases. The difficulty associated with flying jet aircraft caused one of the astronauts in training to resign—leaving nine in the program.

The first two lunar landing training vehicles designed specifically for training entered flight testing. Flights of these vehicles had been suspended after the first vehicle went out of control on its fourteenth flight in December and was lost. (The test pilot, Joseph Algranti, ejected safely.) Before the tests were resumed, changes were incorporated in the second two vehicles based on the report of the accident investigation board. (Fig. 1–18)

Operations Support Requirements

Continued operations support of Apollo was achieved through the Requirements/Support Management System. NASA continued its associate membership on the DOD Inter-Range Documentation Group, and was working closely with it to develop a Unified Documentation System. Plans were underway to adopt the Program Introduction portion of the System for NASA use.

The DOD launch abort recovery forces successfully demonstrated their capability to recover a spacecraft at night during a series of night-time exercises on the coast at Cape Kennedy.

The Support Requirements office sponsored a NASA-wide study, with the intention of consolidating and deleting support requirements wherever possible. The office also began incorporating the management system developed and proved for Apollo support requirements into procedures for follow-on programs.

Mission Control System (MCS)

The Mission Control Center (MCC) at Houston completed pre-mission program development, system testing, and mission simulations; it also provided real-time flight control for Apollo 7 and Apollo 8. Apollo 8, the first lunar orbiting mission, verified the capability of MCC hardware, software, and operational procedures to support the requirements of manned lunar orbiting

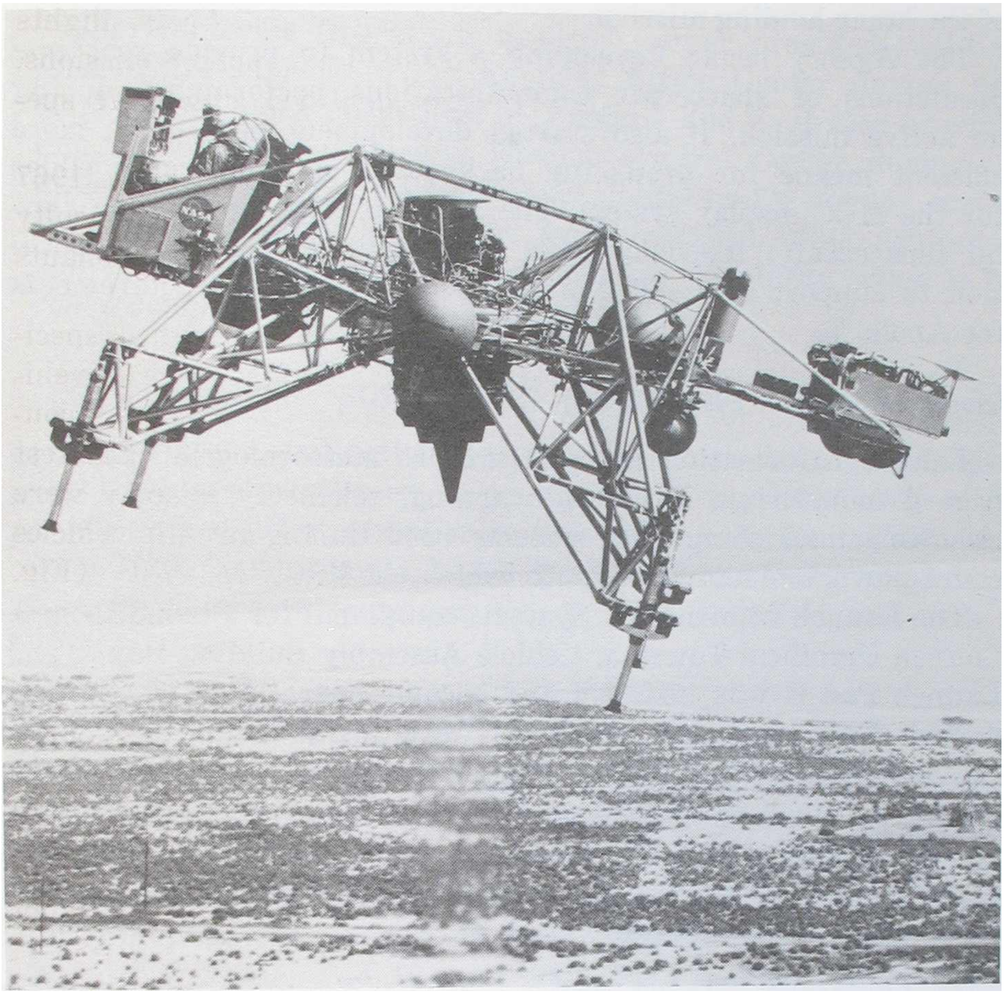


Figure 1—18. Lunar Landing Research Vehicle over Rogers Dry Lake, California.

missions. Considerable progress was also made in mission planning and computer program development for Apollo 9 and 10.

The capacity of the flight controller television data display system for single mission support was increased by approximately 40 percent through provisions for the sharing of display channels between the two MCC mission control areas.

Modest MCC modifications to support future needs were begun when the plans for the ALSEP control room were completed, and the contract was awarded for improved digital television equipment to increase the capacity and improve the quality of the MCC display system.

In the communications system test area, preparations were begun for Lunar Module detailed tests, combined systems tests, and simulation of the total communications system in support of the lunar landing mission.

The Agency began developing a system to provide real-time predictions of spacecraft communications performance during an active mission. It also started development of a much more efficient means for producing background and reference slides for the MCC display system. The MSC-developed prototype digital (spacecraft) television scan converter was placed in operation to support MSC off-line television conversion requirements for Apollo 7.

Launch Information Systems (KSC)

Launch Information Systems are the meteorological, acoustic, hazard monitoring, lightning warning, telemetry, display, data recording, and computing systems used during pre-flight tests, count-down, and launch of space vehicles at KSC.

The Launch Information Systems equipment for Firing Room 3, Launch Umbilical Tower 3, Vehicle Assembly Building Bay 2, and Launch Pad B was installed and became operational during this period. Two hard-copy machines were installed in the Central Instrumentation Facility and were first operational to support the Apollo 8 launch in December. These units provide a paper copy of data displayed on TV monitors upon operator request. The Launch Information Systems were used to support Apollo 7 and 8, and performed successfully.

Operational Communications (KSC)

The major modifications to the operational voice communications systems at Launch Complex 34 and in the Central Instrumentation Facility were completed early in 1968. They were successfully used to support all Apollo 7 prelaunch and launch operations. An expanded operational voice and television recording capability in the KSC Communications Distribution and Switching Center was used to support Apollo 7 and 8. The centralized communications testing and switching capability was first used in support of Apollo 8. (These expansions and improvements in the communications systems had been recommended in the Apollo accident investigation report.)

The high capacity RF multiplexed intercommunications system, provided as part of Launch Complex 39, was used for the first time for a manned operation during the Apollo 8 launch. It performed in a highly satisfactory manner.

Huntsville Operations Support Center (MSFC)

The Huntsville Operations Support Center provided real-time consultative support to the Kennedy Space Center during pre-launch and launch operations of Apollo 7 and 8. It also provided this support to the Houston Mission Control Center during the flight operations. A new 10-channel digital-to-TV display system and new hard-copy equipment were installed. This equipment will provide much improved data display capability when it becomes completely operational in early 1969.

SUPPORTING FACILITIES

Construction and activation of facilities at the manned space flight centers progressed as planned. The key facilities, equipment, and systems essential to the manned lunar missions became fully operational. These facilities, necessary supporting equipment, and systems can also support follow-on missions at a minimal cost.

Kennedy Space Center

At the Kennedy Space Center, successful manned launches from Complex 39 and 34 proved that the facilities were properly designed and constructed to carry out their assigned mission. At Launch Complex 39, the High Bay No. 2 in the Vehicle Assembly Building, the Launch Umbilical Tower No. 3, the Firing Room No. 3, and Pad B were activated. The emergency egress slide wire and spacecraft land landing area at Pad A were completed. (Fig. 1–19) Work was nearing completion on the RF and Radar Checkout Stations in the Vehicle Assembly Building.

In the industrial area, two Automatic Checkout Equipment (ACE) Stations, numbers 5 and 6, located in the Manned Spacecraft Operations Building became operational; they can support three spacecraft in flow at the same time. The Test and Switching Center in the Central Telephone Office was also completed.

The express electrical feeder, serving the ACE Stations from an Air Force generating plant, was under construction in the Industrial Area. Work underway at Complex 39 included the spacecraft land landing area at Pad B, the emergency egress slide wire system, and the liquid nitrogen railroad siding and manifold unloading system. Complexes 34 and 37 were being phased down for their inactive period between the Apollo and

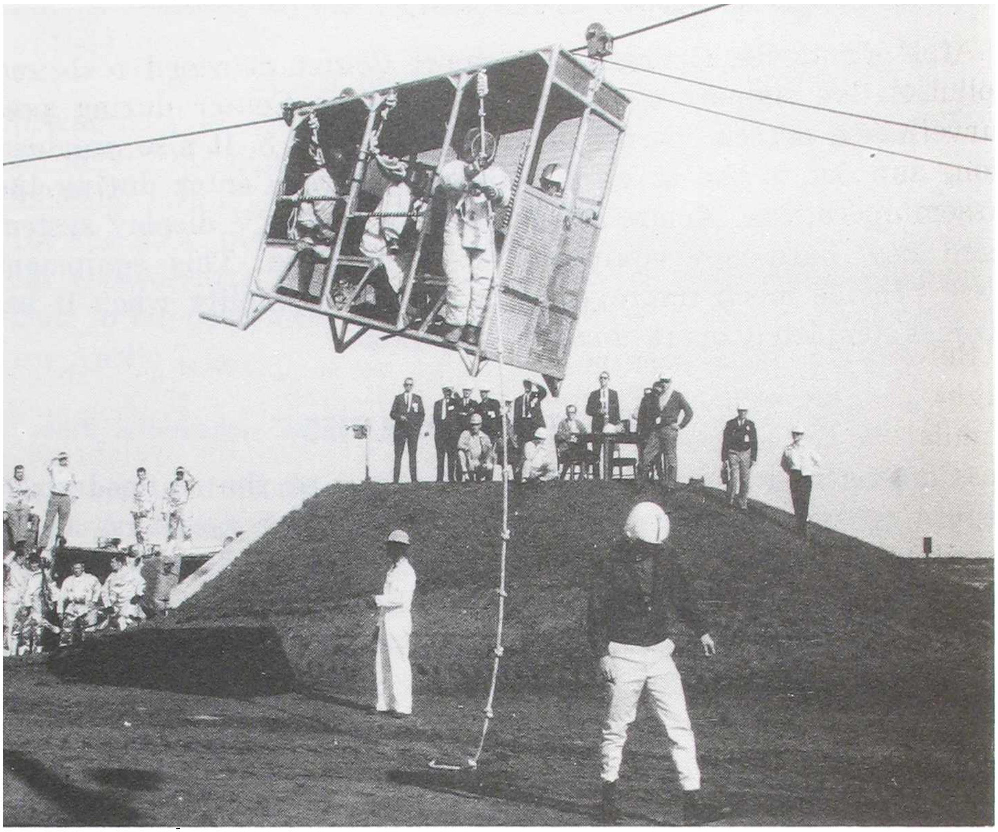


Figure 1–19. Emergency Egress Slide, KSC.

the Apollo Applications Programs. The sandblasting and painting of the umbilical towers and service structures was started.

Manned Spacecraft Center

At the Manned Spacecraft Center, the Atmospheric Reentry Material and Structure Evaluation Facility was completed in October. It provides the means for evaluating the reentry heat shield of the spacecraft and other materials under simulated heating and aerodynamic conditions. The Procedure Development Simulator and associated crew stations within the Flight Crew Training Facility became fully operational in November. In the Lunar Receiving Laboratory, almost all equipment was installed, and limited shake-down tests and practice runs were conducted. Operating procedures for the Laboratory were nearly completed, and partial simulation of the systems began. Full simulation is scheduled during the first quarter of 1969 to demonstrate that the facility is fully operational for its mission in the third quarter of the year.

Marshall Space Flight Center

At Marshall Space Flight Center the construction of the water pollution facility began, and the design for the centralized fire surveillance system was completed. Certain repair, rehabilitation, and improvement efforts were underway at the Michoud Assembly Facility and are to be completed in 1969.

SPACE MEDICINE

Before Apollo 8, the medical experience in manned space flight programs had been limited to ground based experiments simulating the space flight environment (except for weightlessness and combined stresses), and earth orbital flights. With the beginning of the lunar phase of the Apollo program, man ventured out of earth orbit and the gravitational forces of earth into areas where a major unknown factor was considered to be that of potential radiation hazards. For the first time, man encountered the true weightlessness of space and the mobility to move about within his spacecraft, free of the postural restraints he had in either Mercury or Gemini. The two manned Apollo flights flown in this period provided substantial medical information to support the subsequent lunar landing mission and its return to earth.

The 11-day Apollo 7 flight was marred medically by upper respiratory difficulties experienced by the astronauts. These were caused either by pre-existing, undetected viruses or by a reinfection during the flight. Tightened preflight procedures were put into effect to reduce the probability of a recurrence in future flights.

The Apollo 8 lunar orbital flight caused some concern when the astronauts experienced short term nausea. The one crew member who vomited attributed this to a reaction to the medication he had taken to assure sufficient rest. The other two who felt a visceral "awareness" attributed this discomfort to too sudden movement before they were properly adjusted to the weightless environment.

Difficulty in obtaining sufficient rest and sleep for flight crews during manned space missions is not new. However, it becomes more significant, medically, as the number of members in the crew is increased (from two in Gemini to three in Apollo) and as flights become longer and more complex. It was for these reasons that the Apollo 8 astronauts for the first time were permitted to use mild sedation for sleep and rest. In future flights, NASA medical specialists believe this problem can be tackled successfully by further modification of work/rest cycles.

During this period, the roles and missions of aerospace medicine and space biology as they relate to future research, development, and operational activities were under critical review. This review involved identifying, clarifying, and delegating medical and biological support and research responsibilities to the three major program areas. A charter approved for NASA Aerospace Medicine and Space Biology in December provided specific assignments. First, the Office of Space Science and Applications (OSSA) will be responsible for carrying out basic research in space biology, including exobiology and lunar and planetary quarantine. Related experiments to be carried out on manned missions will be defined by OSSA and furnished to the Office of Manned Space Flight (OMSF). OMSF will develop and integrate these experiments into the flight mission.

Second, the Office of Advanced Research and Technology (OART) will provide the broad-based research and development foundation, including the supporting research and technology, and will define related experiments for manned flight. Approved experiments for manned space flight will be developed and integrated by OMSF.

Third, OMSF is responsible for all applied medicine in manned space flights. It is specifically responsible for all medical operational and safety aspects of manned space flight operations. It designs, develops, and tests mainline systems and components of approved manned space flight projects. It provides for a flight experiments program to include ground-based work required to support experiments. And it provides flight hardware, space vehicle integration, and operational support for experiments to be flown on manned space missions. All experiments to be flown in manned space missions, including those defined by OSSA and OART, will be controlled by the Manned Space Flight Experiments Board of OMSF and by the flight program offices.

Two other significant operational procedures were documented during the period. The first involved back contamination and quarantine containment requirements for manned lunar missions. NASA, in cooperation with other Federal agencies, developed general policies to protect the earth's biosphere from lunar sources of contamination. The objectives of back contamination (lunar to earth) quarantine containment are to protect the public health, agriculture, and other living resources against possible hazards from exposure to lunar material. At the same time, every effort will also be made to preserve the integrity of returned lunar materials for scientific experiments and other uses.

The second significant policy involved microbial sampling techniques in the Apollo Program to maintain an inventory of microbial organisms present on, and within, manned space vehicles intended to land on the lunar surface.

MANNED SPACE FLIGHT SAFETY

The manned space flight safety program performed Apollo and AAP risk analysis, reviewed accident reports, began a safety motivation program, and developed safety directives during the period. It also established guidelines, conducted safety appraisals, and helped the newly expanded NASA Safety Office to organize a NASA-wide program.

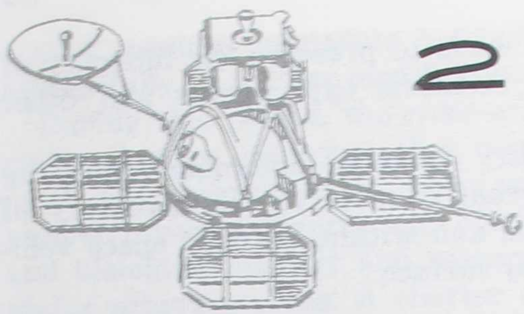
The Apollo Safety Director monitored reviews of Apollo flight planning documents and flight readiness. Additionally, the various systems were reviewed for safety before each flight, and such matters as configuration control, launch preparation, and safety plans were carefully scrutinized.

The manned flight awareness program continued to emphasize craftsmanship and safety motivation throughout MSF activities. In addition, this program gave support to the NASA zero-defects-on-delivery program of the Transportation and Logistics Office.

Safety information was exchanged through meetings, surveys, and publications. Four safety surveys during the period covered contractor safety, radiological and nuclear safety, mission flight planning, and fire safety. A slide wire escape system for the KSC launch site was developed. Meanwhile, all other launch complex safety and egress problems managed and controlled by KSC were carefully examined.

As a part of safety analyses, the risks and hazards of single point failures, redundancy, escape and rescue capabilities, and protective/survival techniques were examined. The objective of these reviews was to make management aware of the risks in the decision-making process.

Projects were started to provide space system emergency and escape studies, to evaluate fatigue and work hours, to show the need for personnel certification for hazardous functions, to study fire protection systems, to establish safety criteria for man-rating manned systems, to develop a system safety requirements document, and to establish accident investigation and reporting guidelines.



2 SCIENTIFIC INVESTIGATIONS IN SPACE

The Orbiting Astronomical Observatory and the Radio Astronomy Explorer were launched to make scientific investigations above the disturbances of earth's atmosphere. A fourth Pioneer spacecraft was launched to join three others. Travelling in widely separated solar orbits, the four will make complementary studies of the interplanetary medium and the sun's activity and their influence on the earth's environment. Astronauts conducted successful tests of the Apollo Lunar Surface Experiments Package in a simulated lunar landing, two Mariner spacecraft were being prepared for Mars flybys in the summer of 1969, and bioscientists derived invaluable data from their analysis of the results of the Biosatellite II biological experiments.

PHYSICS and ASTRONOMY PROGRAMS

Orbiting Observatories

Orbiting Astronomical Observatory II (OAO–II) was launched on December 7 and was operating as planned. This 4400-pound satellite, made up of 328,000 parts and carrying more than 900 pounds of instruments, is the heaviest and most complex automated spacecraft so far orbited by NASA. An octagonal cylinder ten feet high by seven feet across, it has a wing spread of 21 feet with solar cell paddles extended. (Fig. 2–1 and 2–2). OAO–II is in an almost circular orbit at an altitude of about 500 miles—high enough to observe the ultraviolet radiation from space absorbed by the atmosphere.

Star trackers stabilize the Observatory in three axes, pointing the spacecraft's 11 telescopes to within one minute of arc of any selected spot in the sky. After having achieved pointing, they can maintain this direction to within 15 arc seconds for 50 minutes. Two star trackers are enough to stabilize OAO–II, but it uses six to provide redundancy and prevent loss of stabilization

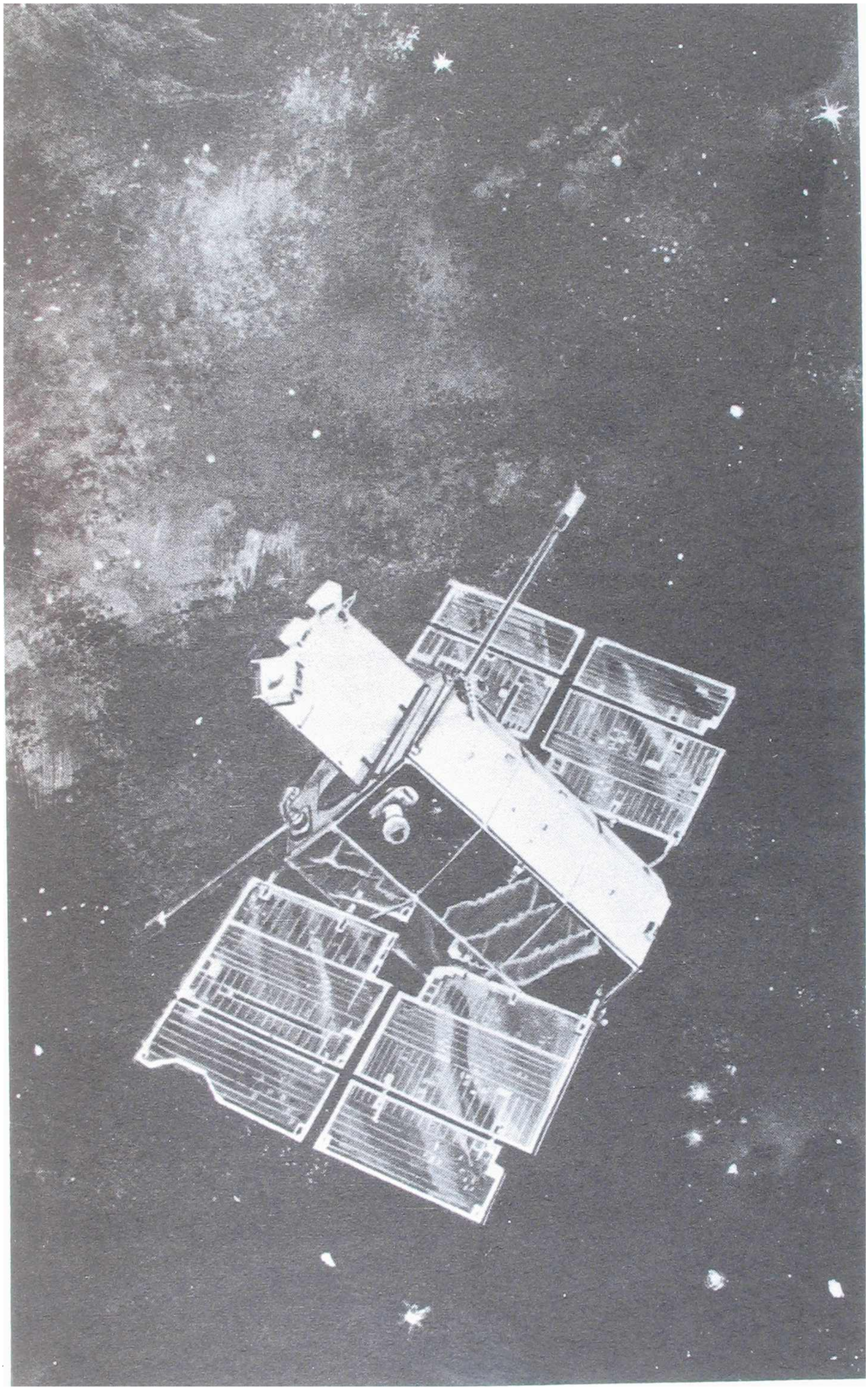


Figure 2–1. Artist's sketch of Orbiting Astronomical Observatory II.

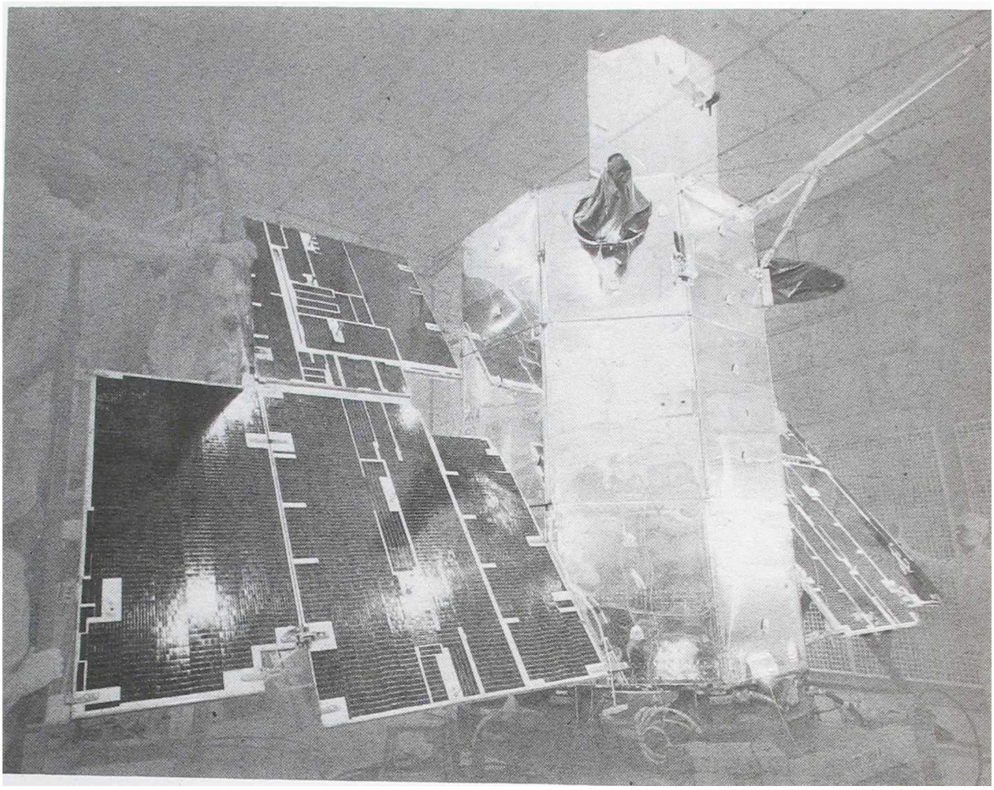


Figure 2–2. OAO–II final qualification tests.

if a reference star passes out of the field of view. Thirty-one of the brighter stars serve as possible reference or guiding points.

In 40 flights, sounding rockets observed ultraviolet radiation for only about 1½ hours. The more sensitive instruments of OAO–II can provide more viewing time (and of fainter stars) in a single day. The satellite carries two instruments that view from opposite ends of the cylinder: a celescope designed at the Smithsonian Astrophysical Observatory to measure the intensities of young "hot stars" in relatively large numbers; another instrument designed at the University of Wisconsin to concentrate on single stars.

The Smithsonian celescope uses four identical high resolution 12.5 inch-reflecting telescopes. Incoming radiation passes through the broad-band filters of these telescopes, producing images on tubes, called *Uvicons*, sensitive to ultraviolet light. These special tubes transmit an image as a television camera does. They convert the optical image into numerical data for transmission to the ground, where the digital data received are then converted into photographs. One to four photographs can be obtained in each revolution of OAO–II—about 700 stars being surveyed daily. A detailed ultraviolet stellar map will be drawn from these observations.

The Wisconsin experiment is planned to obtain detailed photometric measurements of stars and nebulae. It consists of four 8-inch telescopes for stellar measurements, each with its three-color rotating filter photometer, and a 16-inch telescope, operating like the four smaller telescopes, for use with nebulae. In addition, a scanning spectrometer on board will make photometric measurements of unfiltered radiation of different frequencies separated into spectra by the instrument's gratings.

Explorer Spacecraft

Explorer XXXVIII (the Radio Astronomy Explorer) was launched July 4 and slowly maneuvered into a nearly circular orbit at an altitude of 3640 miles—above the denser concentrations of ions in earth's ionosphere. The 415 pound-satellite is a cylinder 31 inches tall with a diameter of 36 inches. It is gravity-gradient stabilized so that two arms of its antenna point away from the earth at all times. (Fig. 2–3)

This spacecraft, featuring an unusual X-shaped or double-V antenna, represents a substantial advance in developing instruments for radio astronomy in space. Each of the four arms of the X-shaped antenna was stored as a flat tape on a reel and extended in stages in response to ground commands. With the arms extended to the full length of 1500 feet, Explorer XXXVIII became the longest artificial satellite ever flown by NASA.

The spacecraft has measured radio signals of low frequencies which usually do not reach the earth. It has also observed radiation from the sun and from Jupiter, and measured the plasma in its environment. Preliminary analyses of data from this Explorer revealed an unexpected number of solar flares—occasionally more than 100 small ones a day. Also surprising was the high intensity of radio emission from the magnetosphere.

Besides the astronomical satellites OAO–II and Explorer XXXVIII, NASA launched an Air Density Explorer (XXXIX) and Injun V (Explorer XL) on a single Scout vehicle on August 8. Explorer XXXIX is a 12 foot-sphere of aluminum foil and plastic —one of several orbited in the space program. Through optical tracking of these spheres ground observers are able to use irregularities noted in their orbits to deduce changes in atmospheric density and temperature at heights of from 400 to 1600 miles.

The Injun V satellite—designed by the State University of

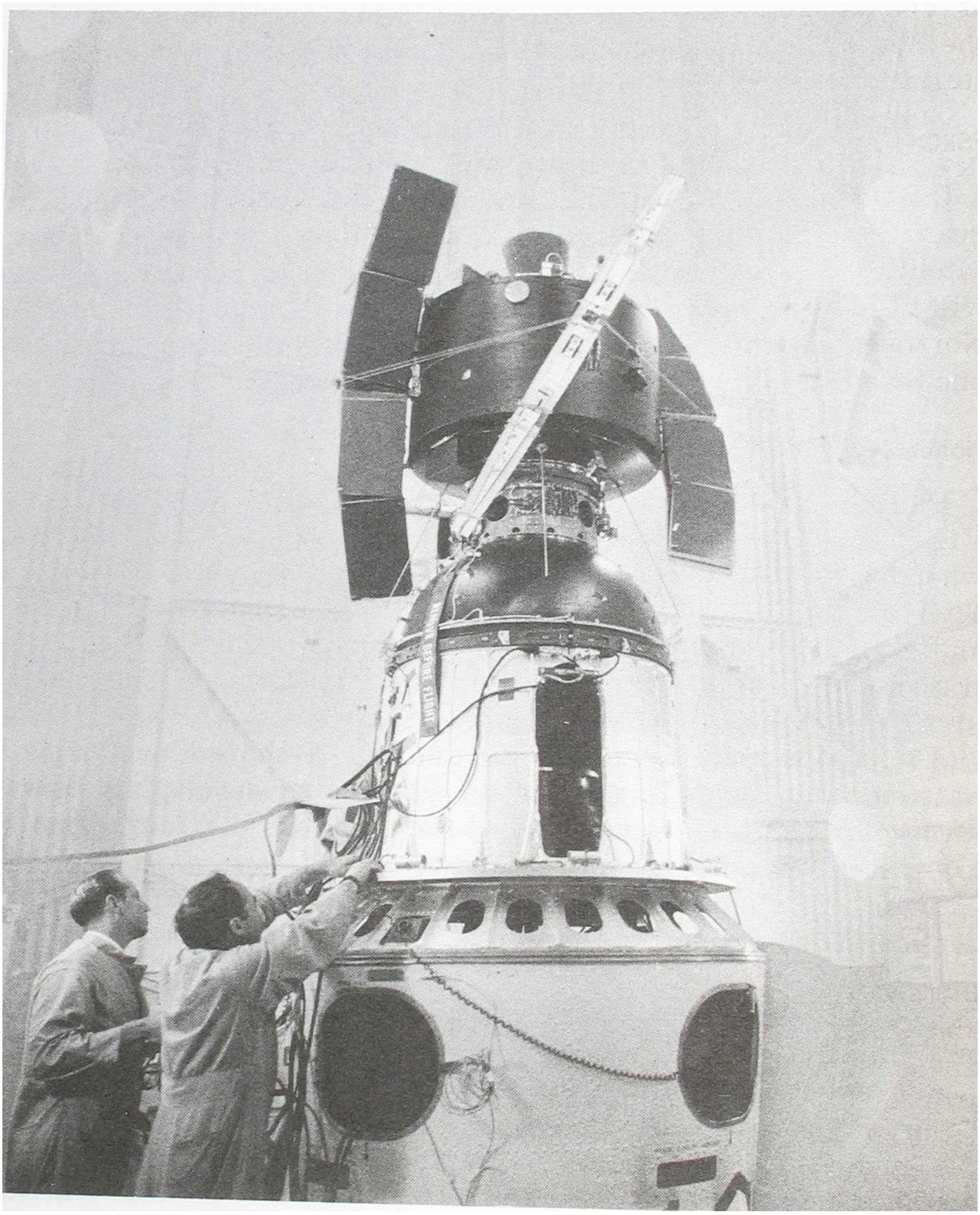


Figure 2–3. The Radio Astronomy Explorer (XXXVIII).

Iowa—is one of a number flown by the University. It measures particles in the geomagnetic field and related very low frequency electromagnetic phenomena. From initial observations by Injun V, scientists have established that the electrical current in the auroral zone is carried by electrons and protons with energies of from 5 to 20 electron-volts. The spacecraft also observed the effects of the large solar flare of October 21, noting that the fluxes of energetic protons and energetic alpha particles trapped in the Van Allen zone changed significantly during the magnetic storm following it.

ESRO–I

On October 3, NASA orbited Aurorae, ESRO–I, for the European Space Research Organization (ESRO). This 185 pound-satellite, designed and built by the international organization, will study the polar atmosphere and the Aurora Borealis (the Northern Lights). It carries four British, three Norwegian, and one Swedish experiment to make these studies (ch. 7).

Pioneer Spacecraft

Pioneer IX—launched on November 8—joined Pioneers VI, VII, and VIII in their widely separated orbits about the sun where they investigate the interplanetary medium and solar activity and their influence on earth's environment (Fig. 2–4 and 2–5). The four spacecraft were operating satisfactorily and transmitting useful data to scientists. (*19th Semiannual Report*, p. 39.) Pioneer VI was orbited in 1965, Pioneer VII in 1966, and Pioneer VIII in 1967.

Sounding Rockets and Balloons

Fifty-five sounding rockets were launched to carry out space research and to test instruments which will be flown aboard satellites. Their astronomical observations—ranging from X- to infrared rays—complement the findings of Explorer XXXVIII and OAO–II. Also, 37 balloons carried experiments in astronomy above much of the mass of the earth's atmosphere.

LUNAR PROGRAMS

Apollo Surface Experiments Program

Astronauts set up and tested flight units of the Apollo Lunar Surface Experiments Package (ALSEP) while simulating a lunar mission. They will place this geophysical station on the moon to transmit data to earth for at least a year (ch. 1, p. 33).

PLANETARY PROGRAMS

Mariner Spacecraft

As part of its Mariner Mars '69 Program, NASA plans to launch

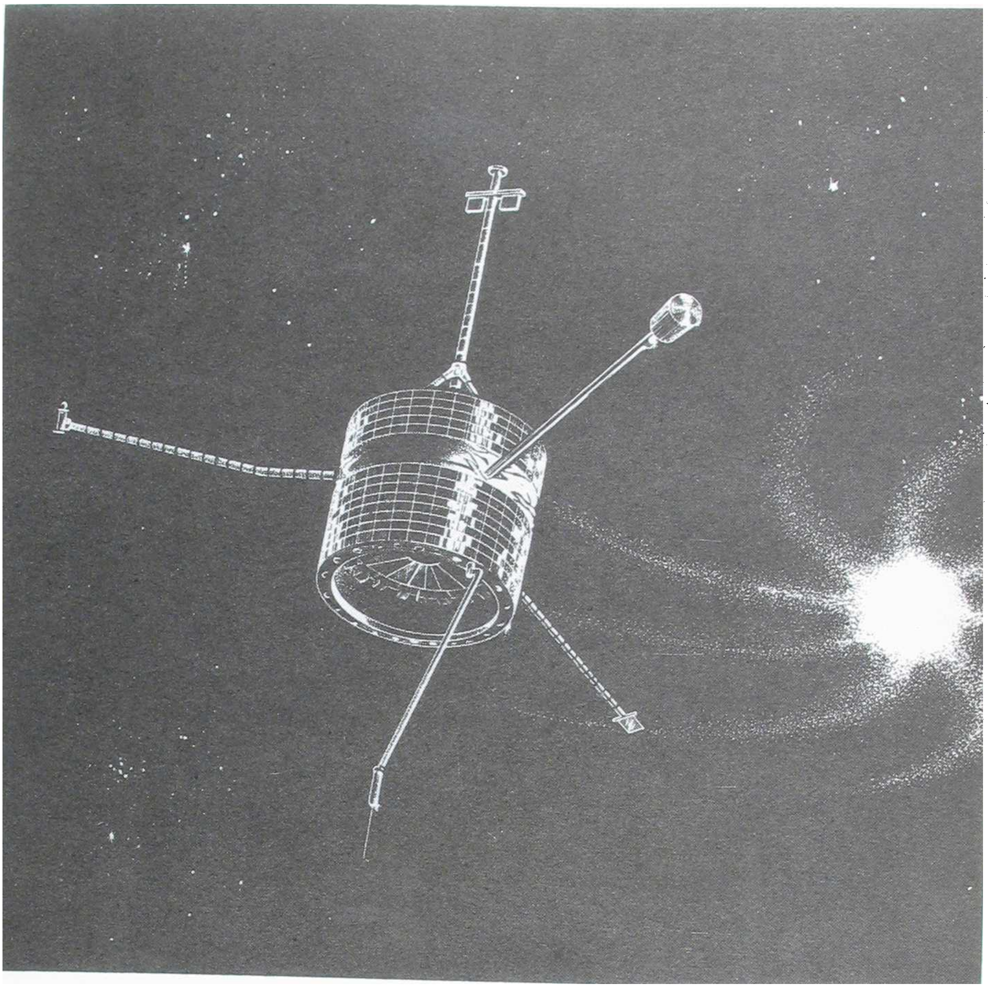


Figure 2-4. Sketch shows Pioneer IX orbiting the sun.

two spacecraft on flyby trajectories of the planet during February and March of 1969. They will carry identical scientific instruments to within about 2,000 miles of the Martian surface for measurements in the infrared, ultraviolet, and visual ranges. The first spacecraft would encounter Mars on July 31 and the second on August 5. After the encounters, both would orbit the sun. (*19th Semiannual Report*, p. 46.)

The spacecraft hardware subsystems underwent acceptance testing, the subsystems were assembled into a complete spacecraft, and checkout and flight qualification tests were completed for the two flight spacecraft and their backup spacecraft. Following the assembly and initial subsystem tests, each spacecraft underwent such tests as vibration, calibration of instruments, and runs in the thermal vacuum space simulator for a minimum

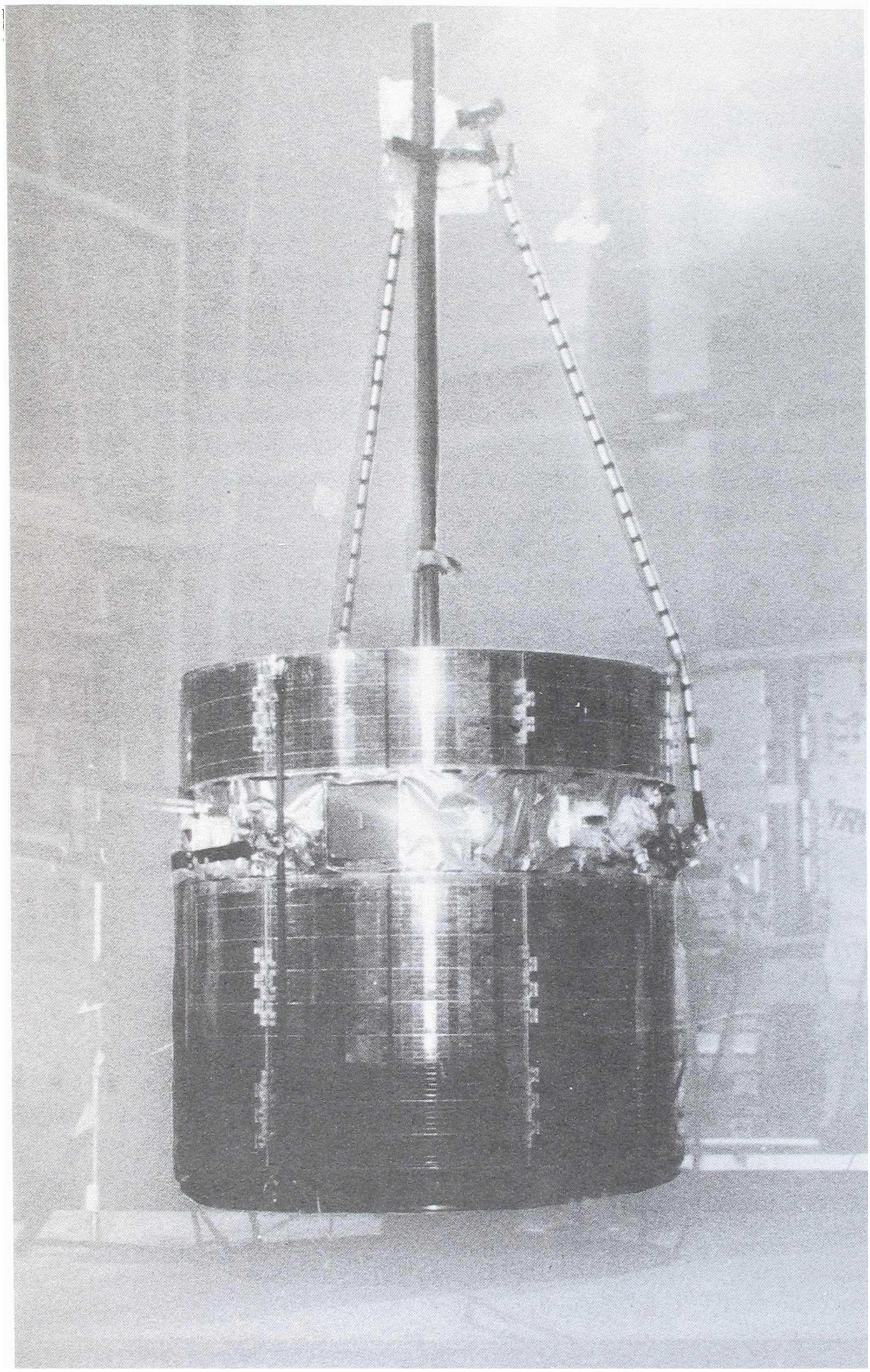


Figure 2–5. Pioneer IX being checked out at Cape Kennedy.

of 500 hours. After between 800 and 900 hours of testing each was qualified for flight. Following further tests and pre-shipment reviews at the Jet Propulsion Laboratory, the spacecraft and their operational support equipment were transferred to the launch site at Cape Kennedy.

Mariner Mars '71.—Initiated in August, the Mariner Mars '71 Program will be managed by the Jet Propulsion Laboratory, which will also manage the spacecraft, tracking and data, and mission operations systems. Lewis Research Center will manage the launch vehicle system.

Preliminary design of the spacecraft was begun, and the Mariner Mars '69 spacecraft design was selected as the basic configuration. A larger propulsion subsystem will be added to insert the spacecraft into orbit about Mars. Twelve requests for proposals to participate in the Mariner Mars '71 Program were sent to potential subcontractors.

Instruments to be flown by the spacecraft (launched by an Atlas-Centaur) include TV cameras, an infrared radiometer, an infrared interferometer spectrometer, an ultraviolet spectrometer, a multiple-frequency radio receiver, and particle detectors. An S-band radio frequency occultation experiment and a celestial mechanics experiment will also be carried out.

ADVANCED TECHNICAL DEVELOPMENT PROGRAM

To prepare for outer planet missions—such as the "Grand Tour" of successive flybys of Jupiter, Saturn, Uranus, and Neptune—an advanced technical development program was begun.

A low-drift, gas bearing gyro was developed for such missions, which require a long-life precision inertial sensor; a mathematical model for the magnetic tape record-reproduce process was also prepared to assist in developing better techniques for data storage aboard planetary spacecraft. Also, a complete relay link telecommunications subsystem (including all equipment to be carried on a planetary lander and associated orbiter or flyby spacecraft) was successfully demonstrated. The subsystems will be used to investigate further possible operational problems of a typical capsule-spacecraft relay link subsystem.

ADVANCED STUDIES

A study was completed of this multiple outer planet-mission which would be carried out during the late 1970s to take advantage of an opportunity that will not occur again for about

180 years. The flight times to Neptune would vary between 8½ and 12 years, depending on whether the spacecraft flew inside or outside the rings of Saturn. The study envisaged a spacecraft weighing up to 1500 pounds, powered by a radioisotope thermoelectric generator, and launched by a Titan-Centaur-Burner II vehicle.

BIOSCIENCE PROGRAMS

Biosatellites

Scientists, after completing analyses of the results of the biological experiments from the two-day flight of Biosatellite II in September 1967 (figs. 2–6 and 2–7), verified the data in ground tests of experiments identical to those aboard the satellite. The ground tests simulated the in-flight environment (except weightlessness), and data from this research assured experimenters that the effects on the organisms flown in the Biosatellite were

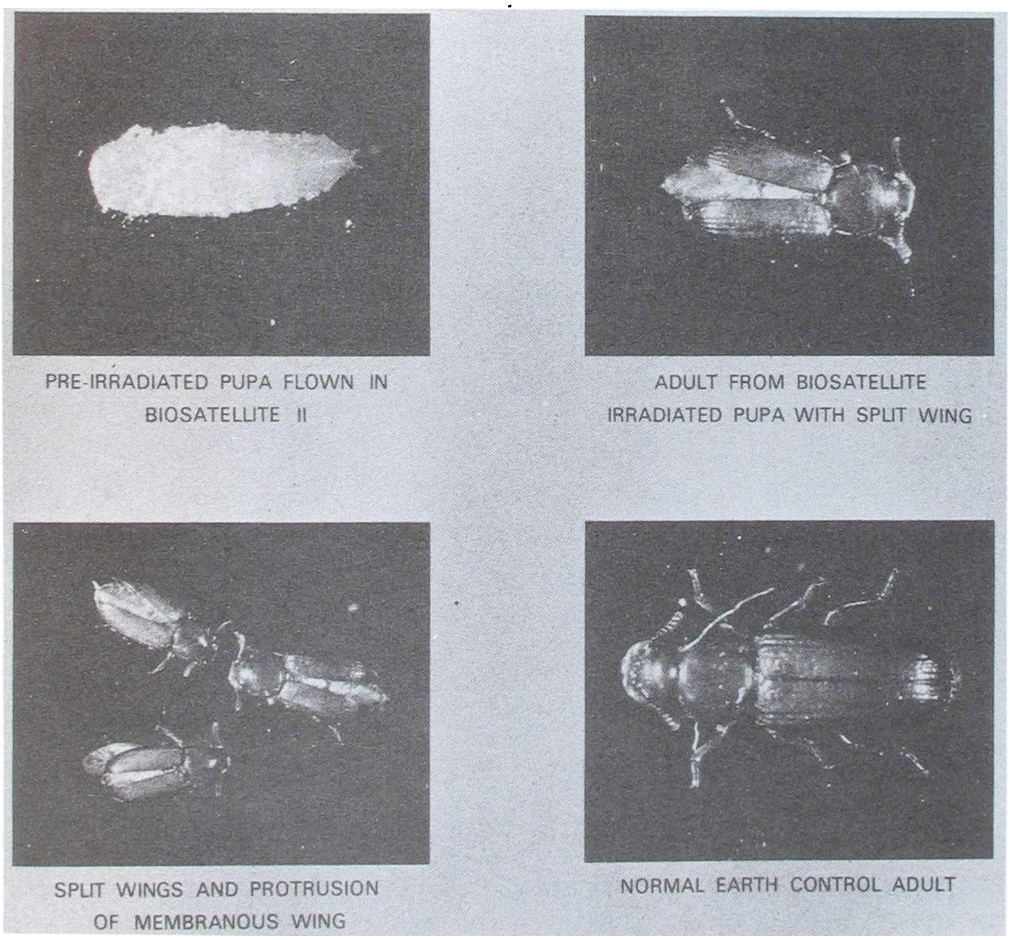


Figure 2–6. Effects of weightlessness and radiation on *(Tribolium)* flour beetle.

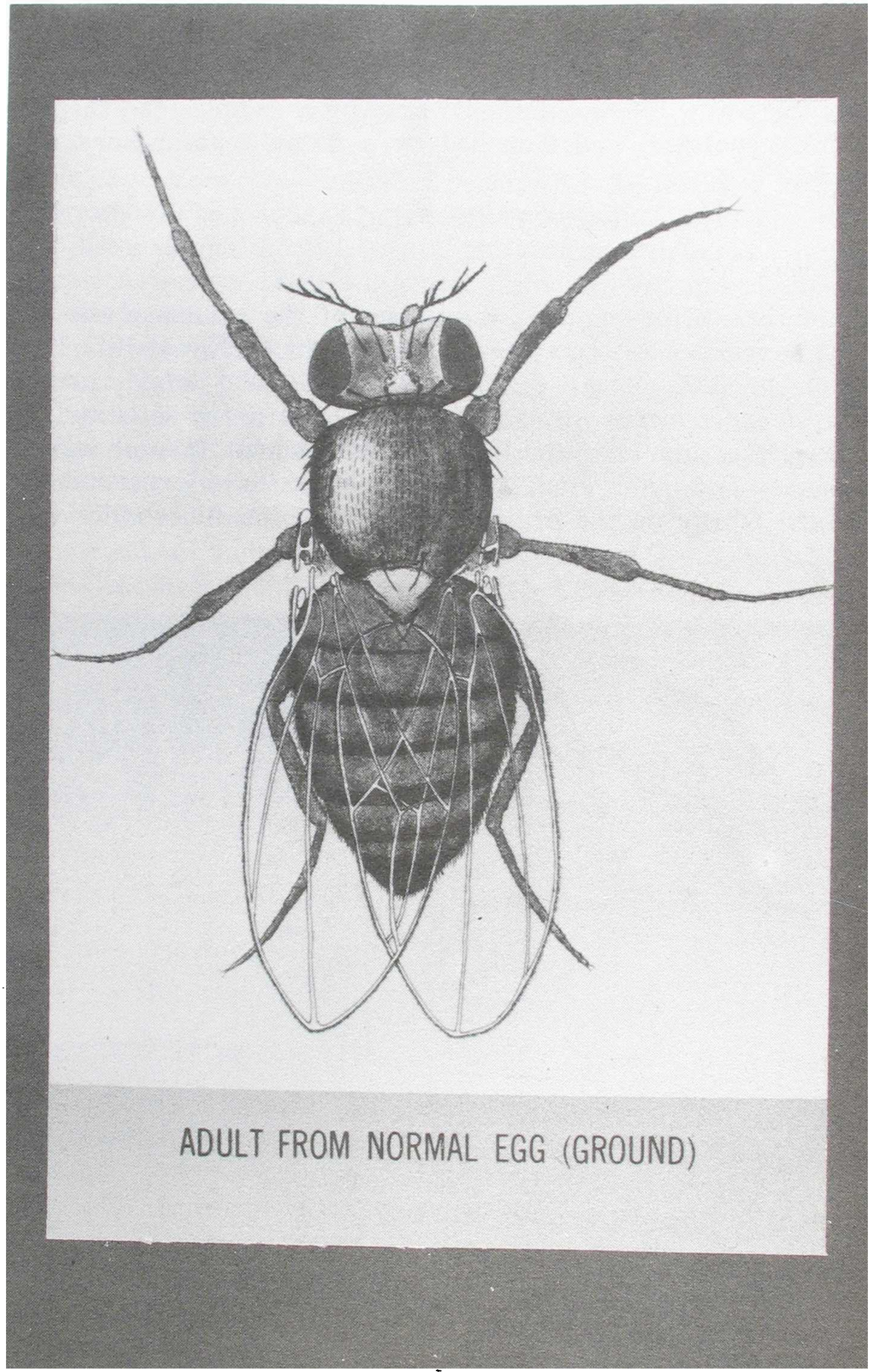


Figure 2–7(a). Vinegar gnat *(Drosophila)* affected by radiation and weightlessness.

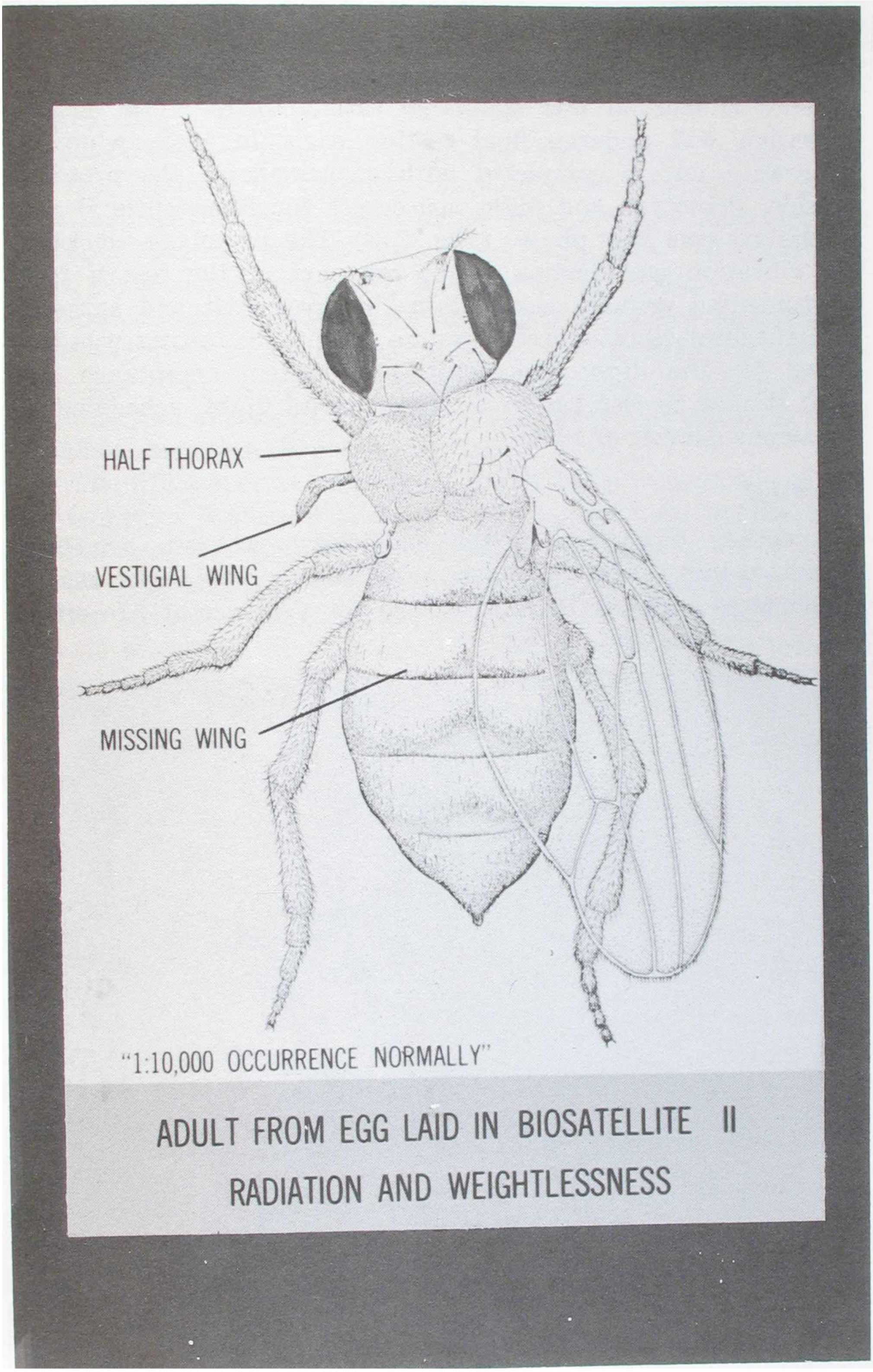


Figure 2–7(b). Vinegar gnat *(Drosophila)* affected by radiation and weightlessness.

due to weightlessness or to an onboard radiation source and not to the acceleration or vibration of the launch.

At the University of California (Los Angeles) the 30-day Biosatellite D mission was simulated satisfactorily. Total systems operation will undergo final testing early in 1969, when the endurance test is completed with a primate in the prototype capsule. Prototype and flight spacecraft for Biosatellite D were in the systems test phase. (Fig. 2–8) The prototype completed the vibration qualification tests; for part of the test a fully-instrumented primate was put in the spacecraft and subjected to flight-level vibrations. Subsystem acceptance testing was completed for the flight spacecraft, and system acceptance tests were started in October to prepare for its flight, scheduled for the second quarter of 1969.

Exobiology

Scientists interested in the exobiology program are being organized into teams to support a Martian Lander which may be launched as early as 1973, to search for evidence of life on the

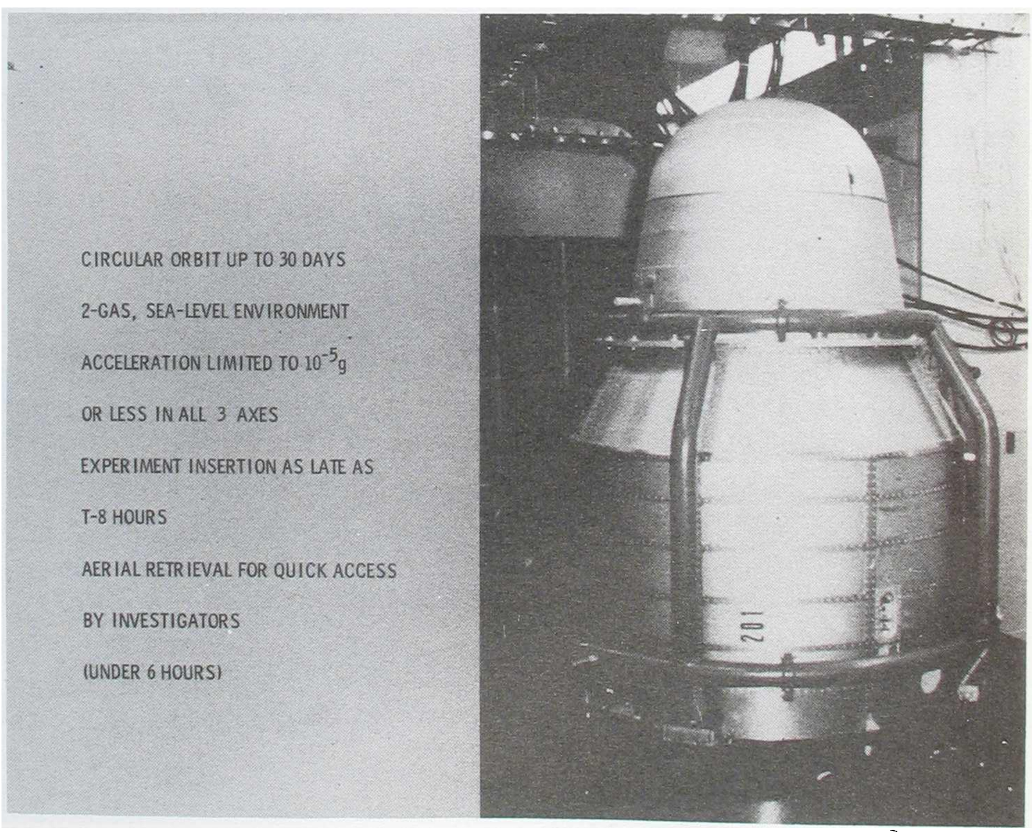


Figure 2–8. Characteristics of Biosatellite D.

planet. The science teams will design experiments (and later instruments) for life detection, organic analytical chemistry, water detection, atmospheric analyses and for supplying meteorological data.

The exobiology program sponsored two special symposia in October attended by chemists, biologists, microbiologists, geologists, and astronomers whose major interest is in detecting and studying extraterrestrial life. In general, their proposals for flight experiments for an early Mars lander were that—

- Life detection and organic analytical chemistry experiments should be integrated to provide data on extraterrestrial life from the same sample for both experiments. In addition, the life detection experiment should be able to determine more than one characteristic of biological activity.
- The life detection experiment should be as simple as possible to assure its success, and be carried out so that the planetary environment would be changed as little as possible.
- The organic analysis should be a survey experiment determining the presence, relative amounts, and nature of families of organic molecules. If possible, wet chemistry should be included in this analysis to permit much more specific identification of these molecules.
- Detecting the presence and distribution of water, as a key experiment, should be a primary objective of fly-bys and orbital flights preceding the lander.

Planetary Quarantine

NASA continued to investigate various methods of sterilizing planetary spacecraft to prevent the transfer of earth microorganisms to the moon and the planets. The sterilization techniques were being developed for minimum interference with spacecraft performance and maximum economy. Minimum time-temperature sterilization requirements (D-values) were established through studies determining the heat resistance of microorganisms in spacecraft hardware, and the probability of their release on impact with planetary bodies was under study.

To minimize the probability of an accidental impact on the planet, a trajectory analysis of the Mariner Mars '69 mission was prepared and approved as meeting planetary quarantine requirements. Also, planetary requirements and procedures to guide NASA centers and potential contractors in planning and designing the '73 Viking Mars landing mission were prepared for issuance early in 1969.

The Public Health Service stepped up its sampling and laboratory assay work at Cape Kennedy to determine the biological contamination in Apollo lunar spacecraft. The increased pace will also meet the need for more qualitative information on identifying microorganisms for use in the Back Contamination Quarantine program at the Manned Spacecraft Center's Lunar Receiving Laboratory. (Fig. 2–9)

Behavioral Biology

As part of an extensive program to assess the general problem of visual-motor coordination as it may be affected by alterations in gravity and the resulting changes in feedback from the muscles, bioscientists were investigating the origins of sensorimotor coordination in animals and in man. Especially noteworthy were

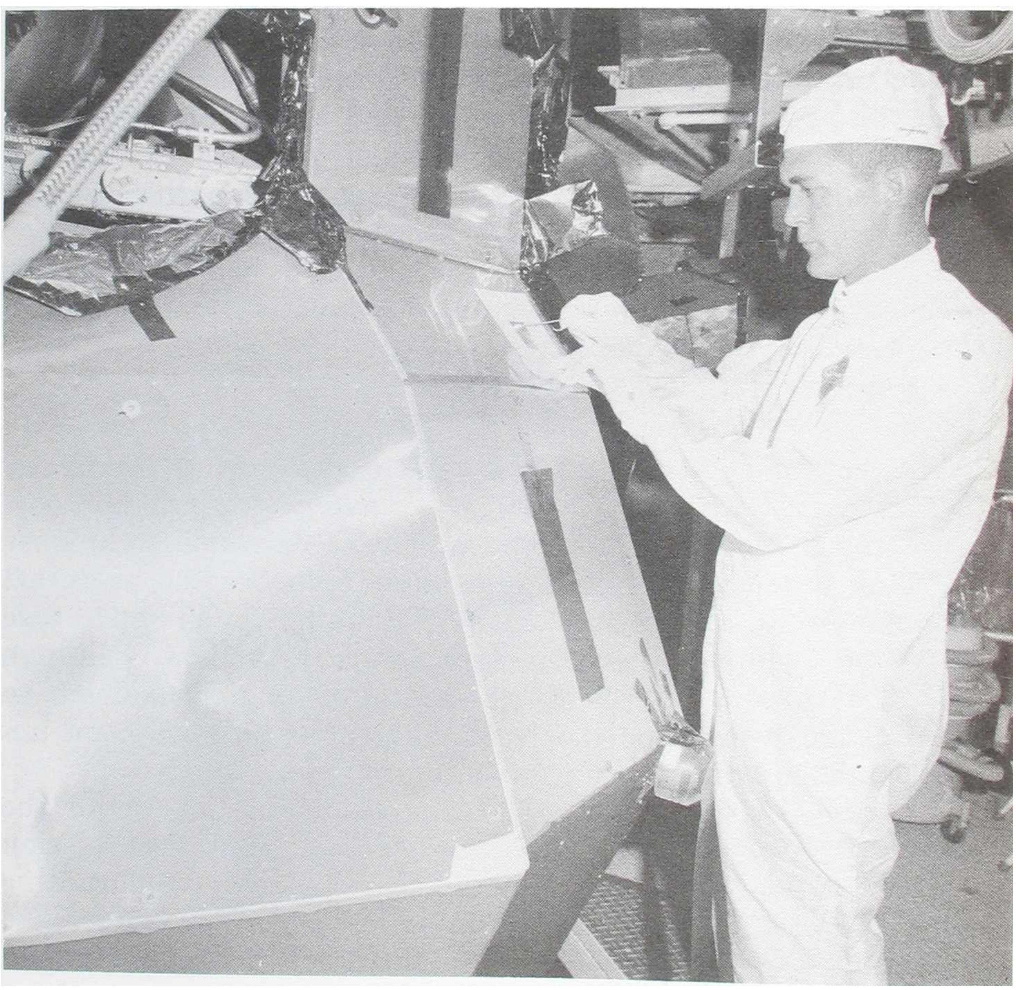


Figure 2–9. Microbiological sampling on Apollo spacecraft at Kennedy Space Center.

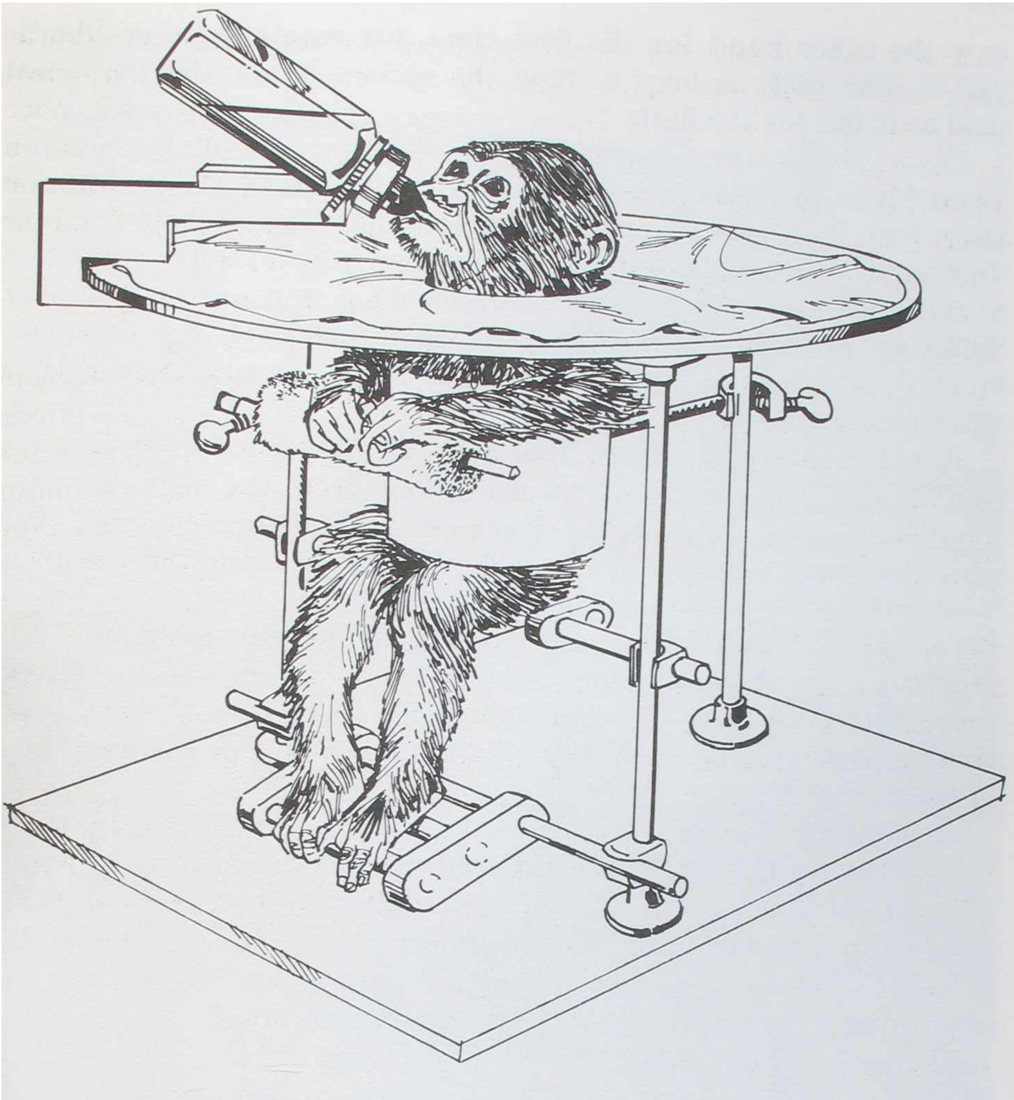


Figure 2–10. Visual-motor coordination studies of a baby monkey.

the experiments in visual-motor coordination with baby stump-tail macaque monkeys deprived of seeing their own limbs. (Fig. 2–10)

In these experiments, the monkeys were raised from birth in padded chairs with an opaque shelf surrounding the upper part of their bodies to keep them from seeing their own limbs. After eight weeks in this apparatus, the animal was permitted to see one of its hands for the first time. The monkey was extremely curious, looking at the hand as if it were not his. The hand was totally uncoordinated, but when he was unable to see it again he used the hand normally. (The monkey took from two to three days to "map" the hand into its visual system.) When he saw the other hand for the first time, his reactions were identical. It also took as long to map the second hand into its visual field as it did for the first.

Three Dimensional-Mapping of the Brain.—Animals, ranging from birds to man, may be able to function effectively because they live in a stable visual environment. Visual cues tend to dominate their other sources of sensory information. But when visual cues are reduced—for example when the animal is under water or in flight—it must depend on information from its vestibular system and neural feedback from its gravity-sensitive internal organisms.

Experimenters at Ames Research Center were studying the ability of the pigeon to detect deviations from the vertical without visual cues. (Fig. 2–11) Enclosed in a tilting chamber, the pigeon earned food by pecking a small disc when the chamber was tilted to a certain position—in any other position its pecking was ineffective. The experiments define the ability of the pigeon to discriminate using its vestibular system and its muscle sense inputs. Future experiments using pigeons with their vestibular systems removed will distinguish between the reactions of the two systems.

A complete *Stereotaxic Atlas of the Brain of a Pigeon* was published. Before this three dimensional-map of the brain was available, operations on the pigeon's vestibular system were difficult and often unsuccessful. The pigeon was selected for the atlas since it was used widely in earlier anatomical studies of the avian nervous system and was also the subject of extensive behavioral investigations.

Stereotaxic methods provide one of the most important techniques for investigating the structure and function of specific regions of the brain. They make possible accurate placement of experimental lesions, electrical and chemical stimulation of the brain, and electrical and thermal recording studies. Anatomists, physiologists, biochemists, psychologists, and ethologists use the techniques in the laboratory, and they are applied in human clinical procedures.

Studies of EEG Data.—At the MIT Research Laboratory of Eltronics, studies were being made of electroencephalographic (EEG) data using signals recorded from the intact human scalp in various stages of alertness. Several methods for summarizing and displaying large amounts of EEG data in three dimensional-perspective were developed by investigators. The three dimen-

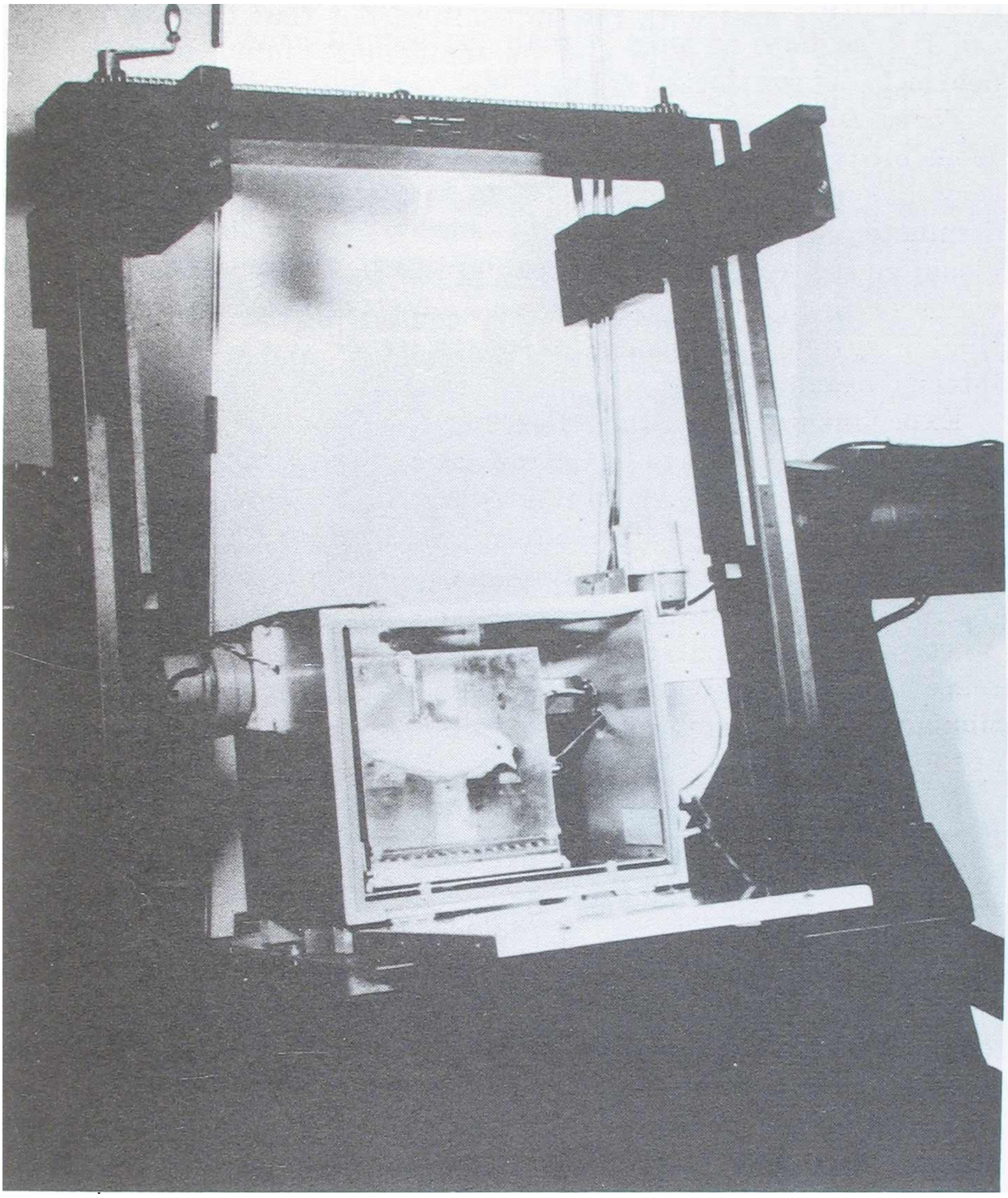


Figure 2–11. Pigeon detects gravity changes without visual cues.

sional-displays of electrophysiological activity will be an effective way for continuous monitoring of the alertness of pilots and astronauts.

Physical Biology

Nutrition and Prolonged Space Flight.—Bioscientists studying the nutritional problems of long term space flight found that the calories in carbohydrate and fat in the human diet can be varied a great deal with few difficulties, but that the nutritional requirements for protein and its component amino acids cannot vary. The investigators defined for the first time man's exact protein nutritional requirements and formulated equations for predicting them. In addition, they discovered that the needs may be met at lower protein levels than was suspected, if the protein is of high biological value.

Human Temperature Control.—Scientists also spelled out the the roles of two thermo-regulatory centers in the brain stem—a "temperature eye" or "human thermostat" and a temperature-blind relay station. Their work on temperature control revealed that the spontaneous rhythmic fluctuations of average skin temperature in 10- to 15-minute cycles resulted from a spontaneous rhythmic fluctuation of the rate of sweating and subsequent evaporative cooling of the skin. Similar cycles of skin temperature and sweating were produced artificially by repeated ingestion of ice and by increasing the temperature of the blood supply to the brain.

Environmental Biology

Depressed Metabolism.—Experimenters at the University of Missouri found that hibernation and hypothermia may afford some protection for animals against gamma radiation. (Hypothermia results in subnormal temperature in warm-blooded animals; hibernation in a considerable decrease of metabolic processes in their body tissues.) Hypothermic hamsters exposed to 800 to 1,000 roentgens of gamma radiation survived 90 days or longer, but non-hypothermic irradiated animals died within 15 to 30 days. (*17th Semiannual Report*, p. 52.)

Also, clinical studies in the irradiation of cancer patients indicated that decreasing the oxygen requirements by lowering the body temperature reduces cellular metabolism, decreasing tissue sensitivity to gamma radiation.

In depressed metabolism—even in hypothermia—it is helpful to keep one part of the body warm. At Emory University, Atlanta, Ga., tumors in mice were kept warm while the rest of their bodies was cooled. Investigators discovered that the warm tumor collected most of the anticancer drug administered, since the depressed cells were less active metabolically. After two hours of this type of treatment the animals were rewarmed and 40 days later the tumor disappeared entirely. But when the same quantity of the drug was injected into an uncooled animal, its tumor was unaffected, and the animal died in a few weeks.

Prolonged hypothermia, the application of the principles of hibernation, drugs, and electronarcosis seem to promise a reduction of the daily metabolic requirements of mammals. If one or more of these methods should prove to be practical, human needs for food and oxygen could be drastically reduced, as could the production and elimination of waste. Any of these methods might offer protection to astronauts exposed to gamma and cosmic radiation, and enable them to tolerate the forces of increased acceleration. (Fig. 2–12)

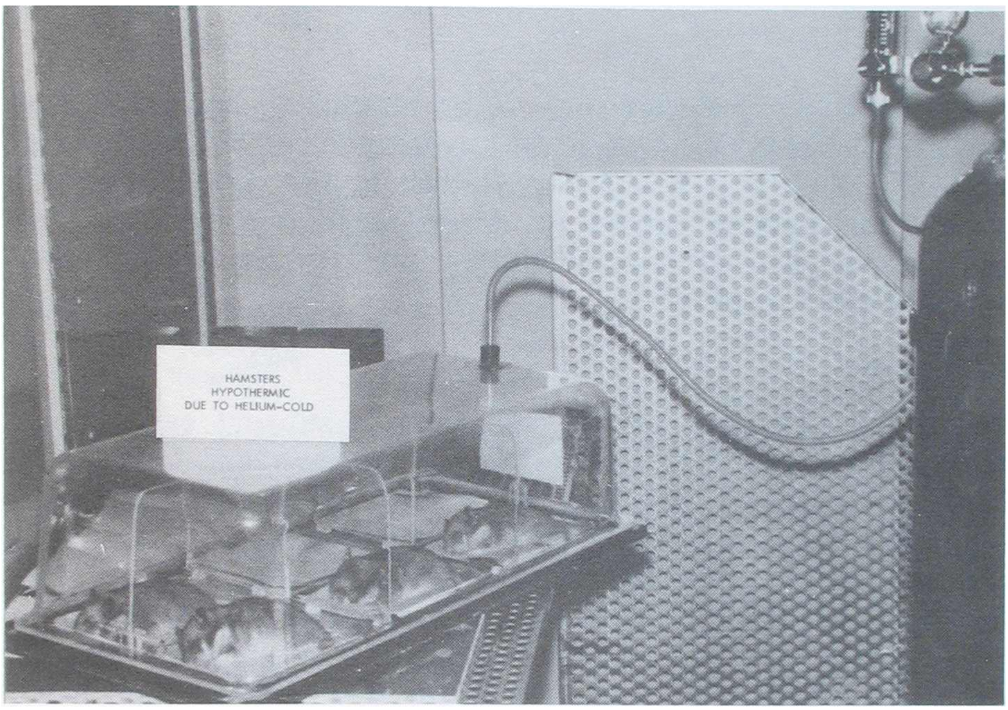


Figure 2–12. Experiments with hypothermic hamsters.

LIGHT and MEDIUM LAUNCH VEHICLES

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

Scout

Scout vehicles successfully carried out four missions—launched the Air Density Explorer XXXIX and the Injun Explorer XL on August 8, the RAM C–II radio attenuation experiment, August 22, and the ESRO I international cooperative satellite, October 3.

Delta

In July, a Delta orbited the Radio Astronomy Explorer satellite (Explorer XXXVIII) using a Surveyor retromotor as its third stage. The launching of ESSA VII in August marked two firsts for the Delta vehicle—the first long-tank Thor booster used with Delta and the first two-burn mission for the vehicle's second stage. In September, a malfunction occurred in the control system of the Intelsat III–A Thor booster, and the vehicle was destroyed about 110 seconds after liftoff. However, Delta closed out the year with the successful launches of Pioneer IX in November, and HEOS I, ESSA VIII, and Intelsat III–B in December.

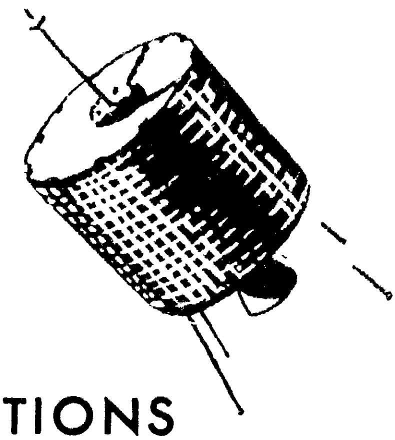
Agena

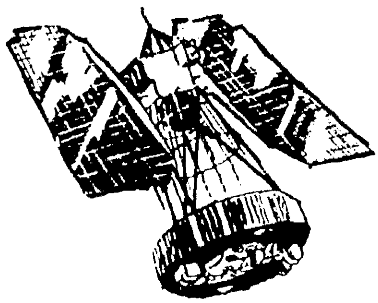
Thorad-Agena vehicles were being readied to launch Nimbus B–2 and Orbiting Geophysical Observatory-F during the first half of 1969. Nimbus B–2 replaces Nimbus B, lost as a result of a vehicle malfunction caused by misorientation of the yaw rate gyro in the Thorad booster flight control system. (*19th Semiannual Report*, p. 59.)

Atlas-Centaur

The Atlas-Centaur vehicle was used to support earth-orbital missions for the first time when it launched an Applications Technology Satellite (ATS–D) in August and an Orbiting Astronomical Observatory (OAO–II) in December. The ATS–D vehicle was unable to carry out its mission because the Centaur stage failed to reignite for a second burn following a successful insertion into a parking orbit. The OAO–II mission was successful. Atlas-Centaur will next support the two Mariner Mars planetary missions early in 1969.

3 SPACE APPLICATIONS





During the period of this report, NASA made preparations to orbit a second generation operational meteorological spacecraft for ESSA in 1969; cooperated with several other agencies in designing an earth resources technology satellite; continued to provide launch service for ComSat, scheduling the launch of three INTELSAT III communications satellites in 1969; and studied the feasibility of using satellites for navigation, air traffic control, and related telecommunications services. In addition, NASA Applications Technology Satellites photographed tornadoes and hurricanes, and other satellites supplied geodetic data.

METEROLOGICAL SATELLITES

ESSA and TIROS

The wheel-type TIROS spacecraft ESSA I and II—orbited in February 1966—inaugurated the operational weather satellite system. (*15th Semiannual Report*, p. 65.) In May of this year, the one-millionth cloud cover photograph from the combined TIROS and ESSA (TOS) satellites was received from ESSA VI. The total includes the pictures taken by the ten TIROS research and development satellites and the six ESSA satellites which NASA has turned over to the Environmental Science Services Administration, ESSA.

Two types of spacecraft of this wheel design are needed to provide meteorological satellite information. One of these uses an Automatic Picture Transmission system to supply direct local readout of daytime cloud cover data to over 400 small relatively inexpensive ground stations around the world; the other an Advanced Vidicon Camera System (AVCS) to provide global recorded daytime cloud cover data for ESSA's National Environmental Satellite Center.

Figure 3–1 is a mosaic of pictures received during one day from two ground stations served by the Automatic Picture Transmission system (APT)—one station at Goddard Space Flight Center and another an experimental mobile unit taken to Vienna, Austria for the United Nations Conference on the Peaceful Uses of Space. By using these ground stations only, contiguous coverage was provided from the far Western U.S. to the Ural Mountains of Eastern Europe, and from near the North Pole to within about 10° of the Equator. APT equipment used by the Mexican Government also proved its value (ch. 7, p. 157.)

An ESSA spacecraft (VII) carrying the Advanced Vidicon Camera System was launched by NASA for ESSA on August 16 and, an ESSA satellite (VIII) of the APT type was orbited on December 15. (Fig. 3–2)

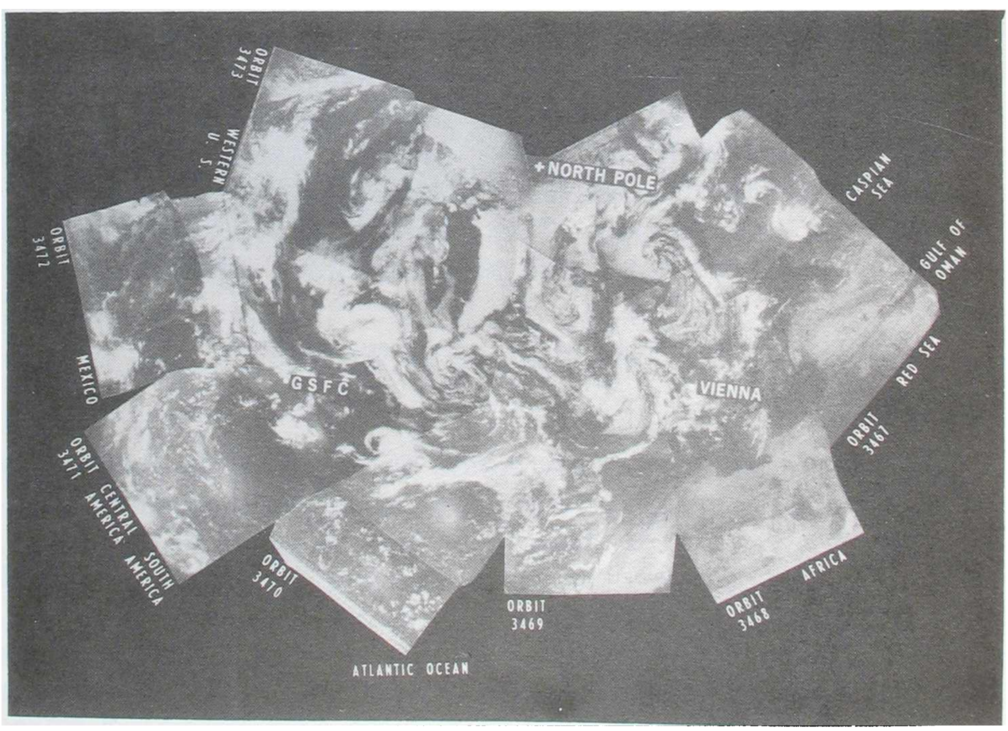


Figure 3–1. Cloud cover photograph transmitted by ESSA VI in August.

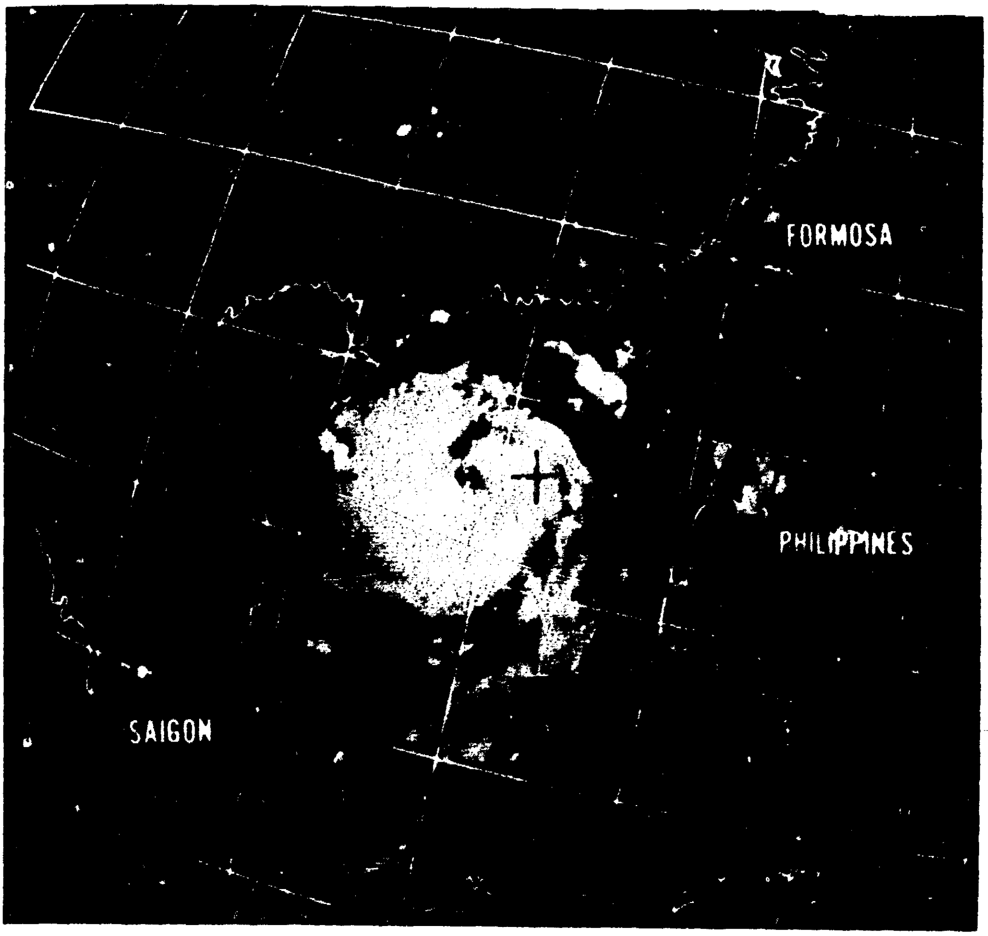


Figure 3–2. ESSA VII view of tropical storm Shirley.

TIROS–M—the prototype second-generation operational meteorological satellite—was being prepared for a 1969 launch. This satellite will carry AVCS and APT systems, a scanning radiometer to provide cloud cover data at night (direct locally and globally), and instruments to determine cloud-top height. TIROS–M will also be able to carry several other advanced sensors when they are ready for flight. (Fig 3–3)

Nimbus

The reliability of a three-axis stabilized meteorological satellite was demonstrated by Nimbus II which operated for over 31 months. Its useful life ended (on January 16, 1969) when the stabilization system failed.

The third Nimbus, B, was destroyed at launch on May 18 when the launch vehicle veered off course (*19th Semiannual Report,*

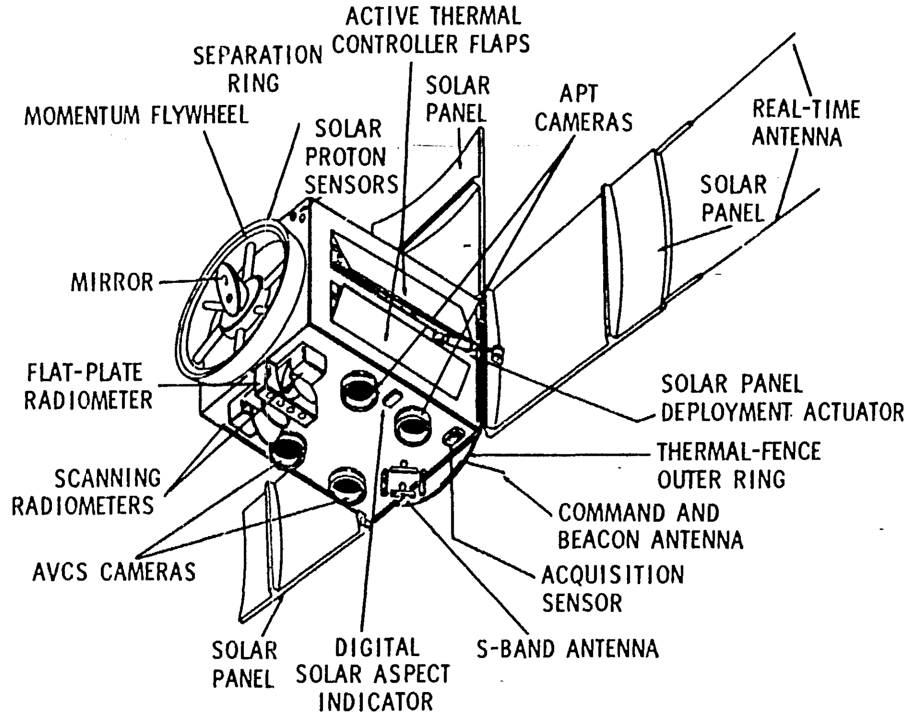


Figure 3–3. TIROS–M meteorological satellite.

p. 63). The SNAP–19 radioisotope thermoelectric generator, which fell into the ocean off the California coast, was recovered. The fuel container design proved its soundness, remaining intact and eliminating any chance that the isotope fuel might enter the water.

Preparations for a repeat mission (Nimbus B–2) in 1969 proceeded slightly ahead of the original schedule. Nimbus D, next in this series, continued on schedule for orbiting in 1970. Nimbus E and F will emphasize research into and the development of microwave and advanced infrared sounders to obtain global measurements of the structure of the earth's atmosphere. A payload for Nimbus E was selected tentatively, and the payload for Nimbus F was being chosen.

Meteorological Sounding Rockets

NASA used sounding rockets for meteorological measurements above altitudes reached by sounding balloons and below those of satellites. Acoustic grenades, pitot-static tubes, and light-reflecting or luminous-vapor experiments were employed.

The Agency developed a rocket chemiluminescent ozonesonde experiment using a 40 foot-parachute deployment system, which was launched at Wallops Island in September. An ozone profile was obtained from 12 to 44 miles. This experiment was carried out in conjunction with other rocket and balloon ozonesonde flights. The chemiluminescent ozonesonde can make soundings at night because it does not depend on ultraviolet energy from sunlight as do other ozonesondes.

Also, a break away tip pitot-static tube technique was successfully demonstrated on a Nike-Apache rocket in November. It keeps the pitot tube covered during the early part of the flight to prevent moisture or pollutants from the lower layers of the atmosphere from contaminating the pitot tube system.

Research Rocket Firings.—Twenty-six sounding rockets were flown in meteorological research. These firings included grenade experiments from Pt. Barrow, Alaska, Ft. Churchill, Canada, and Wallops Island, to study the onset of the wavelike structure observed in temperature profiles of the mesosphere in winter. Other grenade experiments will be conducted early in January from these rocket launching sites and from sites in Sweden to investigate the dynamics of the polar mesosphere and stratosphere and explore stratospheric warming phenomena (if they develop).

Operational Sounding Rocket System.—An inexpensive meteorological sounding rocket system affording reliable, routine launches up to 60 miles altitude for range support, research, and network operations continued under development.

An immediate goal—to develop an efficient, low-cost rocket motor for routine probings up to a height of 45 miles—is the object of a joint NASA-Army program. Most of the static test firings of this rocket motor were completed.

Field Experiment Support.—To assure that sounding rocket data are of maximum use for research or operations, launch sites must be related to one another, and launches coordinated. International cooperative programs are planned to establish self-sustaining coordinated meteorological sounding rocket launches from sites which will contribute valuable data. Several nations have taken part in this program (ch. 7).

COMMUNICATIONS SATELLITES

INTELSATSs

Early Bird or INTELSAT I was the first commercial communications satellite launched by NASA for ComSat on behalf of the 63 nations making up the International Telecommunications Satellite Consortium, INTELSAT. It was scheduled to be retired on January 19, 1969 after over four years of continuous operation. The three INTELSAT II satellites orbited by NASA for ComSat in 1967 continued to serve more than two-thirds of the world. (*19th Semiannual Report*, p. 65.)

NASA launched a second INTELSAT III on December 18. (The first in the INTELSAT III series was launched on September 18, but a launch vehicle failure kept it from achieving its planned orbit.) The 1,200 circuit, 640 pound-satellite, launched for ComSat on behalf of INTELSAT, was designed to operate for five years. INTELSAT II, with only 240 circuits, was designed for a three-year lifetime (Fig. 3–4).

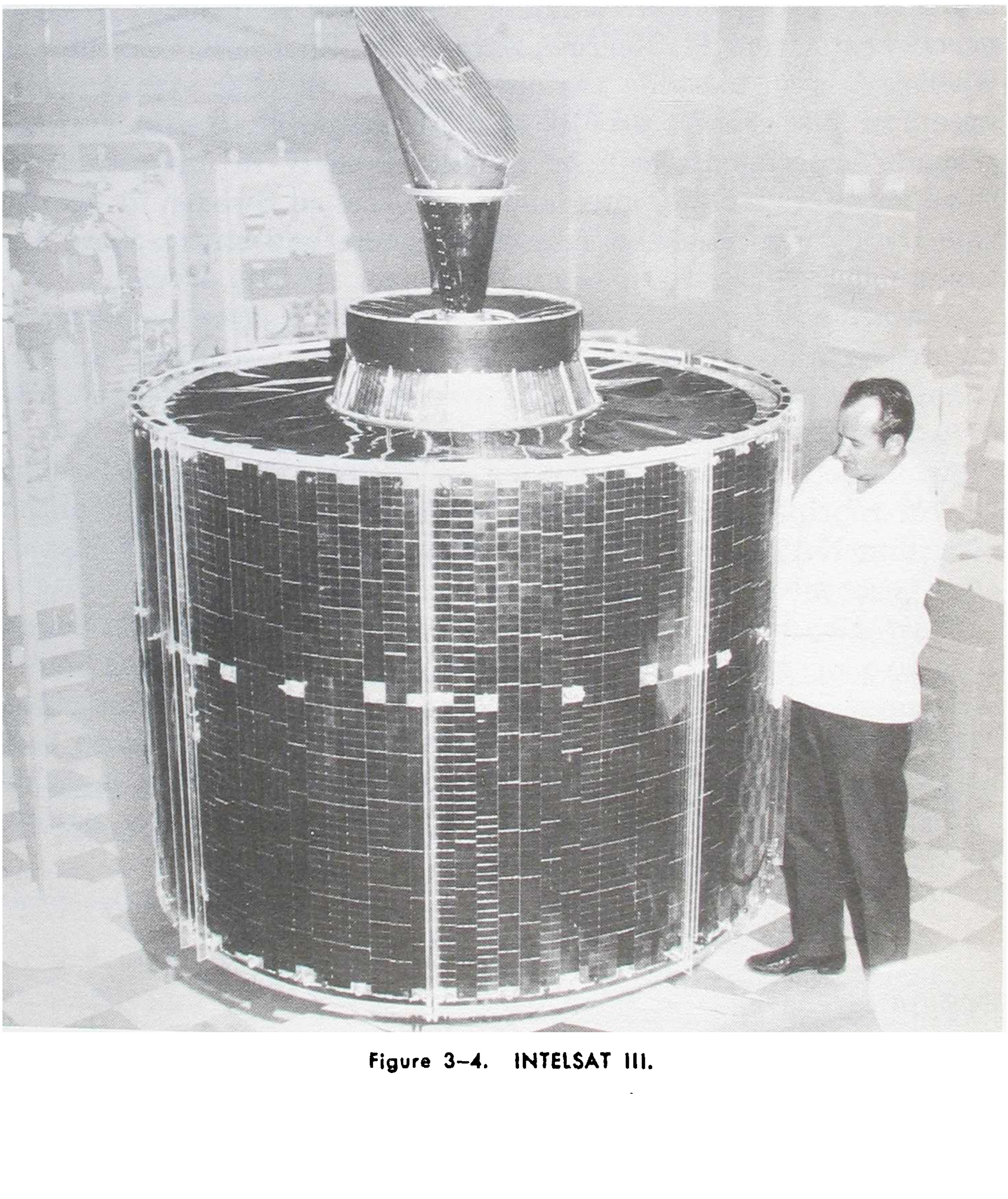


Figure 3–4. INTELSAT III.

Before it began regular commercial service—scheduled for January 2, 1969—INTELSAT III was used for a live telecast from Rome of Pope Paul's midnight mass on Christmas Eve, and on December 28 through New Year's provided an emergency link between the U.S. and Germany when cable service was interrupted.

INTELSAT III was placed in a synchronous equatorial orbit over the Atlantic Ocean; a second of this type was scheduled to be orbited over the Pacific on February 5, 1969; a third over the Atlantic in May 1969; and a fourth over the Indian Ocean later in 1969. With the launching of the spacecraft over the Indian Ocean, the communications satellite network will become worldwide.

In October ComSat contracted for an advanced spacecraft—INTELSAT IV—to be launched in 1971. (*19th Semiannual Report*, p. 65.) INTELSAT IV will provide between 5,000 and 6,000 two-way voice circuits and operate (for seven years) with greater flexibility and power than earlier INTELSATs. NASA will provide launch services, on a reimbursable basis, similar to those provided for the INTELSAT I, II, and III series. In addition, responding to requests from the Federal Communications Commission and ComSat, NASA provided technical advice on stabilization systems for INTELSAT IV, and reviewed and commented on specifications for this satellite.

NAVIGATION and TRAFFIC CONTROL SATELLITES

Position Location Experiment

In a test of the Omega Position Location Experiment (OPLE), carried by Applications Technology Satellite III 22,300 miles over the earth, an airplane was located within two miles, a ship and buoy within three miles, and a balloon within half a mile. An airplane of the Federal Aviation Administration was used in this experiment, as were a buoy and ship of the Environmental Science Services Administration, and a drifting balloon of the National Center for Atmospheric Research. Additional experiments with balloons will test OPLE's capacity for relaying data from meteorological sensors.

Satellite Studies

Based on the recommendations of the Joint Navigation Satellite Committee in 1966 (*15th Semiannual Report*, p. 74), two studies were completed of the technical feasibility of satellites to provide navigation, air traffic control, search and rescue, and related telecommunications services. The studies of two different satellite system configurations included cost estimates and schedules to bring the systems to research and development flight demonstration stages. NASA was analyzing the results of these studies to consider the possible development of navigation and air traffic control satellites.

APPLICATIONS TECHNOLOGY SATELLITES

A gravity gradient-stabilized spacecraft, Applications Technology Satellite IV (ATS–IV), failed to achieve its intended orbit after launch on August 10 and its experiments were unable to provide data. The satellite re-entered the earth's atmosphere on October 17. However, experiments continued with ATS–I and ATS–III (orbited in 1966 and 1967), including extensive observations of tornadoes and hurricanes.

Early this year ATS–III was moved from 47° to 90° W longitude for a cooperative experiment with the Environmental Science Services Administration (ESSA) during the 1968 season of maximum tornado activity. Also, from March 6 to May 18 the satellite carried out 22 "tornado watches." In this cooperative experiment, it took 870 pictures which were being analyzed by investigators from ESSA and other investigators.

When the tornado season was past its peak, ATS–III was moved eastward over the Atlantic for a joint "hurricane watch" experiment with ESSA. Although the 1968 hurricane season was notable for a lack of major storms, excellent photographs were taken of Hurricane Abby, which were also being analyzed by ESSA and other experimenters.

A mechanically despun ATS–III antenna operated satisfactorily in space for more than a year and performed better than the more complicated electronically despun antenna tested on ATS–I. The improved antenna was in communication with a 15-foot diameter antenna of a small mobile ground terminal in successful communications experiments. The ground terminal promises to be the forerunner of such small, inexpensive terminals for mobile communications. The 15-foot ground antenna can be furled, carried in a station wagon, moved to various locations, and set up for use under diverse conditions. (Ground stations for the ATS satellites can be simpler, because they do not need ground antenna tracking devices due to their geostationary orbit.)

The next Applications Technology Satellite (ATS–E) was scheduled for a 1969 launch.

GEODETIC SATELLITES

GEOS

The passive gravity gradient attitude stabilization system of GEOS–I continued to position the satellite so that ground stations could track it precisely through its 334 laser corner cube retroreflectors. (*19th Semiannual Report,* p. 67.) No other instruments aboard the spacecraft, launched in 1965, can be used.

GEOS–II, orbited January 11, was also operating successfully, although its power supply was reduced. The satellite was expected to support Air Force camera teams in their geodetic observations of South America; help calibrate a selected group of C-band radar systems and determine if useful geodetic data might be supplied; and aid in comparing and calibrating ground tracking equipment at NASA's Carnarvon, Australia, tracking site.

GEOS–C is planned for a 1970 launch. This satellite will carry a radar altimeter to measure mean sea level and the dynamic variations of the ocean's surface. In a low inclination orbit of about 20°, it will provide data vital to further describing the gravity field of the earth.

PAGEOS

Geodetic information was still being provided by the large passive balloon satellite, PAGEOS–I, which was launched in 1966.

EARTH RESOURCES SURVEY

Aircraft Program

NASA—cooperating with the Departments of Interior, Agriculture, Commerce, and Navy—continued to investigate possible uses of space-acquired data in surveying the world's natural resources. In support of these studies (detailed in the *19th Semiannual Report*), aircraft at low and intermediate altitudes were flying remote sensors over a network of ground test sites to provide scientists with earth resources information.

The low altitude flight missions (from 500 to 20,000 feet) and the intermediate altitude flight missions (20,000 to 40,000 feet) are two of the three major phases of the aircraft program. A third phase—flights above 40,000 feet—will be carried out beginning next summer through the use of a high altitude aircraft loaned to NASA by the Air Force's Air Weather Service. By flying remote sensors at altitudes above about 90 percent of the earth's atmosphere, the range of sensor performance is extended, and data handling and analysis techniques are verified. Space flight sensing can most nearly be simulated at such heights.

The ground test sites over which these missions are flown were developed by scientific investigators from the agencies and universities participating in this aircraft program, as well as by instrument teams. Sites were chosen to provide earth resources data on crops, forests, water, fisheries, and cities. These data were then compared with "ground truth" information collected by the investigating agencies and cooperating scientists to find out if the sensing methods were feasible. Nineteen flight missions were conducted over 75 test sites during 1968 (some repeated above several sites). The Manned Spacecraft Center publishes a monthly accession list of information gathered from these flights.

A data processing and distributing facility at the Center handles the data acquired by the sensors during each mission. This information is collected in the form of film, magnetic tapes, strip charts, and logs and processed quickly for the convenience of scientific investigators.

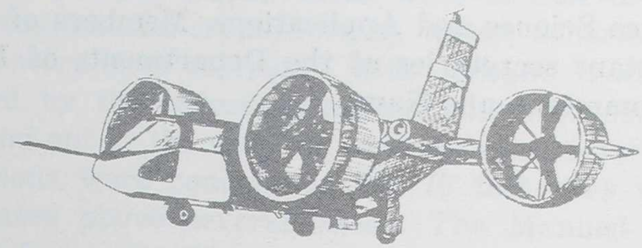
Spacecraft Studies

Substantial progress toward realizing the basic goals of the Earth Resources Survey Program through this airborne remote sensor testing has led to the beginning of the design of flight hardware for an Earth Resources Technology Satellite (ERTS). Involved are aircraft-based investigations, development of remote sensors, spacecraft data analyses, systems and benefits studies, spacecraft definition, and interagency coordination of ERTS requirements.

Remote sensor data from aircraft, infrared imagery from Nimbus II, and photography from Projects Gemini and Apollo when evaluated by investigators from many Government agencies have permitted users to refine further their various needs for satellite-based sensors. Nine systems and benefit studies by NASA, the Departments of Interior and Agriculture, and the National Council on Marine Resources and Engineering Development were made to estimate benefits and costs of operational space-assisted earth resources survey systems and assist in evaluating priorities for ERTS experiments. These studies have indicated that potential benefits may overshadow estimated system costs for geographic areas about as large as the United States or larger.

Plans were being completed to begin the final Earth Resources Technology Satellite definition/design study. Also, advanced sensor studies were started and were extensively reviewed with the user agencies. To ensure interagency coordination, an Earth Resources Survey Program Review Committee was established in July chaired by NASA's Associate Administrator for Space Science and Applications. Members of this committee are assistant secretaries of the Departments of Interior, Agriculture, Commerce, and Navy.

4 ADVANCED RESEARCH AND TECHNOLOGY



The Office of Advanced Research and Technology continued to carry out the many and various programs which support current activities and anticipate future requirements in aeronautics and space. This was a particularly fruitful period as indicated by the multitude of accomplishments reported in the following pages.

SPACE POWER TECHNOLOGY

Solar and Chemical Power

Commercial and normal space-type batteries, which may be used in spacecraft intended to land on planets, do not have the ability to withstand sterilization or the hard impacts of planetary landings. To adapt such batteries to this type of use, it was necessary to develop new separator and case materials that could withstand the temperatures and pressures of sterilization without chemical attack and physical weakening. Structural changes made to convert the parts of a normal cell to those of an impact resistant cell are shown in Fig. 4–1. The improvements include a more elaborate lid and special insert to hold the plates in place, substantial tabs and reinforcement of the plates themselves, and a larger and heavier case.

Batteries composed of 12 of the new cells were built into a prototype Mars lander package and dropped twice from a height of 250 feet. The second time, the package landed on asphalt and was subjected to a shock 2,500 times the force of normal grav-

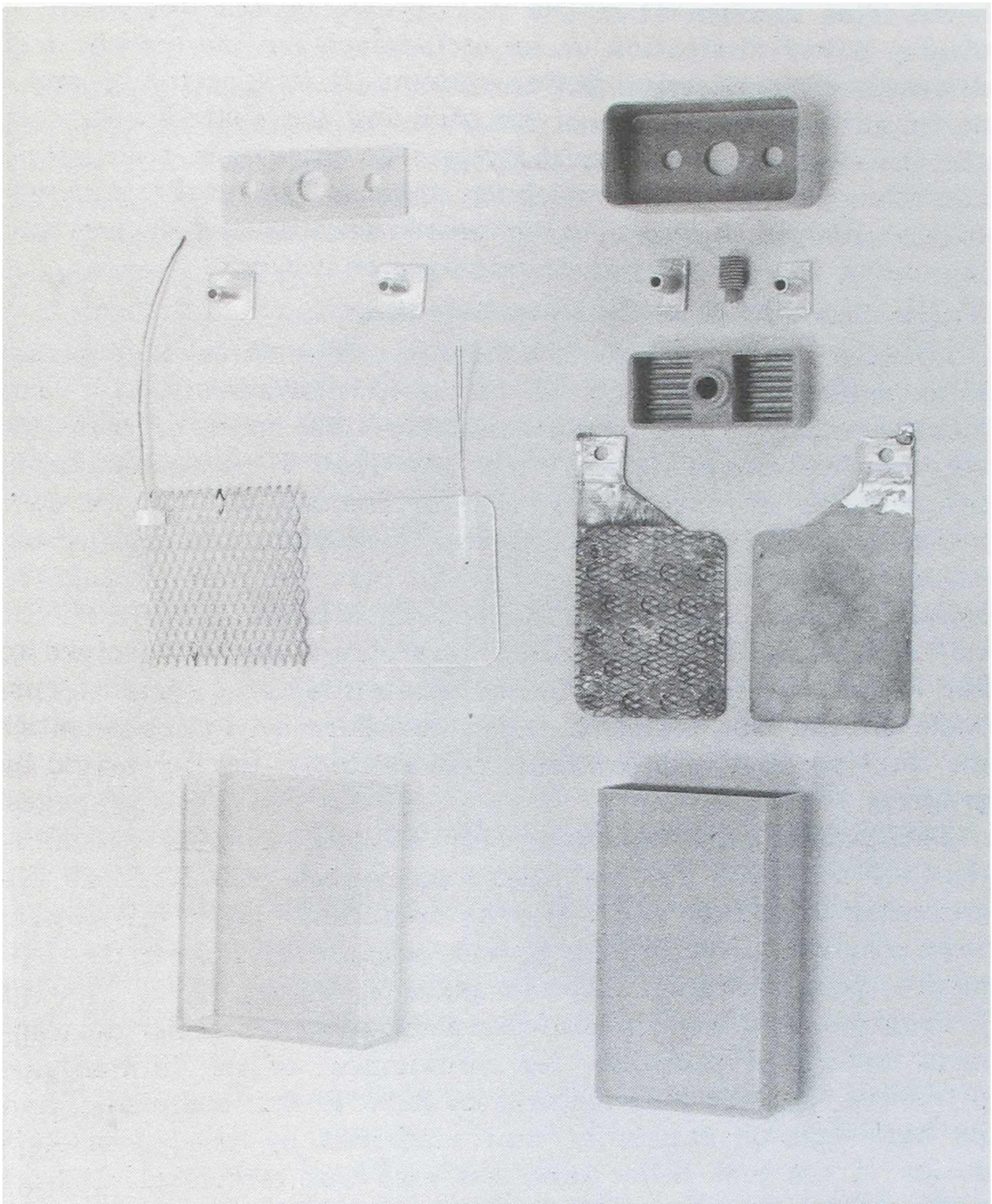


Figure 4–1. Normal cell parts (left); impact-resistant cell parts (right).

ity. The sterilized batteries operated as required both times. Preliminary results from another test program indicated that conventional cells and batteries can also be improved by the application of these tough new plastics.

The Power Systems Laboratory at the NASA Electronics Research Center demonstrated an operating laboratory model of a watt meter with a near linear response from DC to 1 megahertz. This instrument makes it possible for the first time to display power dissipation on an oscilloscope for the circuits and devices used in electrical power systems. It is expected to prove an important diagnostic tool for studying the characteristics of and the electrical and thermal stresses on capacitors, transistors, and other devices in DC switching circuits. The resulting knowledge should aid in developing improved circuits and devices and increasing the reliability of electrical power systems.

Nuclear Electric Power Research and Technology

Rankine Turbogenerator Technology.—The three-stage potassium vapor turbine built of advanced molybdenum-base and nickel-base alloys logged approximately 1350 hours of performance and endurance testing with 1500–1550°F potassium vapor temperatures at entrance to the turbine and 10–13 per cent potassium moisture content in the third-stage wheel. Turbine efficiencies, which ranged from 73–78 per cent over a range of operating pressures, were in good agreement with predicted values. The turbine and facility were shut down for inspection and repairs on August 22; inconclusive evidence of some turbine blade erosion was found. Detailed metallurgical examination of the turbine and preparations for resumed testing were in progress.

Two preliminary turbogenerator designs, meeting specifications of a 2100°F turbine inlet temperature, 450 KWe at the generator terminals, and 3–5 year operating life at full power, were completed. The designs provide a basis for further development of potassium Rankine power plant technology.

Progress continued in fabricating the advanced boiler development test rig. The facility for containment of the lithium and potassium loops at temperatures to 2200°F was completed, and its high vacuum capability was confirmed by test. Geometric design of the first boiler tube test unit was completed, and an experimental program to investigate stability effects in multitube condensers was initiated.

Accomplishments in the development and testing of advanced materials included initiation of a long-term corrosion test of tantalum-base T-111 alloy at temperatures up to 2150°F; completion of a 12,000 hour creep test of tantalum-base ASTAR 811–C at 2600°F, and an 8000 hour creep test of molybdenum-base alloy TZM–1175 at 2000°F; completion of a 10,000 hour test of T–111 welds; and progress in developing a high-temperature braze for the electromagnetic potassium boiler feed pump. A 10,000 hour test at 1300°F was completed on an alternator statorette and a potassium-filled bore seal without degradation of materials or electrical performance.

Tests on a small-scale, two-loop lithium-to-potassium Rankine cycle system coupled to a reactor simulator showed excellent system stability under abrupt changes in operating conditions and during 100 hours of hands-off operation.

Thermionic Conversion Technology.—In-pile capsules for high-temperature testing of fuel emitter specimens were developed, and irradiation programs were started at the NASA Plum Brook Reactor. The capsules incorporate high-temperature (1500–1700°C) thermocouples for measuring temperatures during the irradiation tests; the thermocouples operated successfully for 2,000 hours and are still working. Uranium dioxide, porous uranium zirconium carbide, and uranium dioxide cermet fuels are being irradiated over a wide range of test conditions in these programs.

Performance mapping was completed on two cylindrical converters employing tungsten emitters with oriented surface crystals. The two converters differed from each other only in the crystallographic structures of the emitters. The performance maps included data for interelectrode spacings of .002 to .020 inch, emitter temperatures of 1400 to 1800°C, and collector temperatures of 700 to 1000°C. An electrically heated cylindrical converter employing a double tungsten layer emitter has operated for over 16,000 hours at a 1700°C emitter temperature, and a similar converter was run for 5000 hours at 1700°C and was then performance mapped. The output of the latter device was 10 watts/cm^2 of emitter area after 5000 hours; there was no output power degradation for either of these converters.

An electrically heated externally fueled thermionic converter 8 inches in length, operated for 500 hours in a life test which began on December 1, and is continuing.

In studies of fission gas venting with uranium dioxide fuel, investigators built a uranium dioxide, tungsten-clad specimen that can be heated along its center line and that allows periodic injection of inert gas to simulate fission-produced gases. The unit makes it possible to conduct out-of-pile testing to determine uranium oxide vapor redistribution rates and gas diffusion through uranium oxide at thermionic temperatures; testing with the device was in progress.

Brayton Cycle Equipment.—The performance of individual components was verified: compressor, turbine, and alternator efficiencies measured at 82 per cent, 91 per cent, and approximately 91 per cent, respectively, exceeded the predicted values. Off-design tests of the individual components were also completed. The program entered the subsystem test phase with contractual and in-house testing about to start on key subsystems, and most of the components for a combined system test delivered. (Fig. 4–2)

In other work, a turboalternator unit mounted on gas bearings logged about 1160 hours of successful testing under multi-

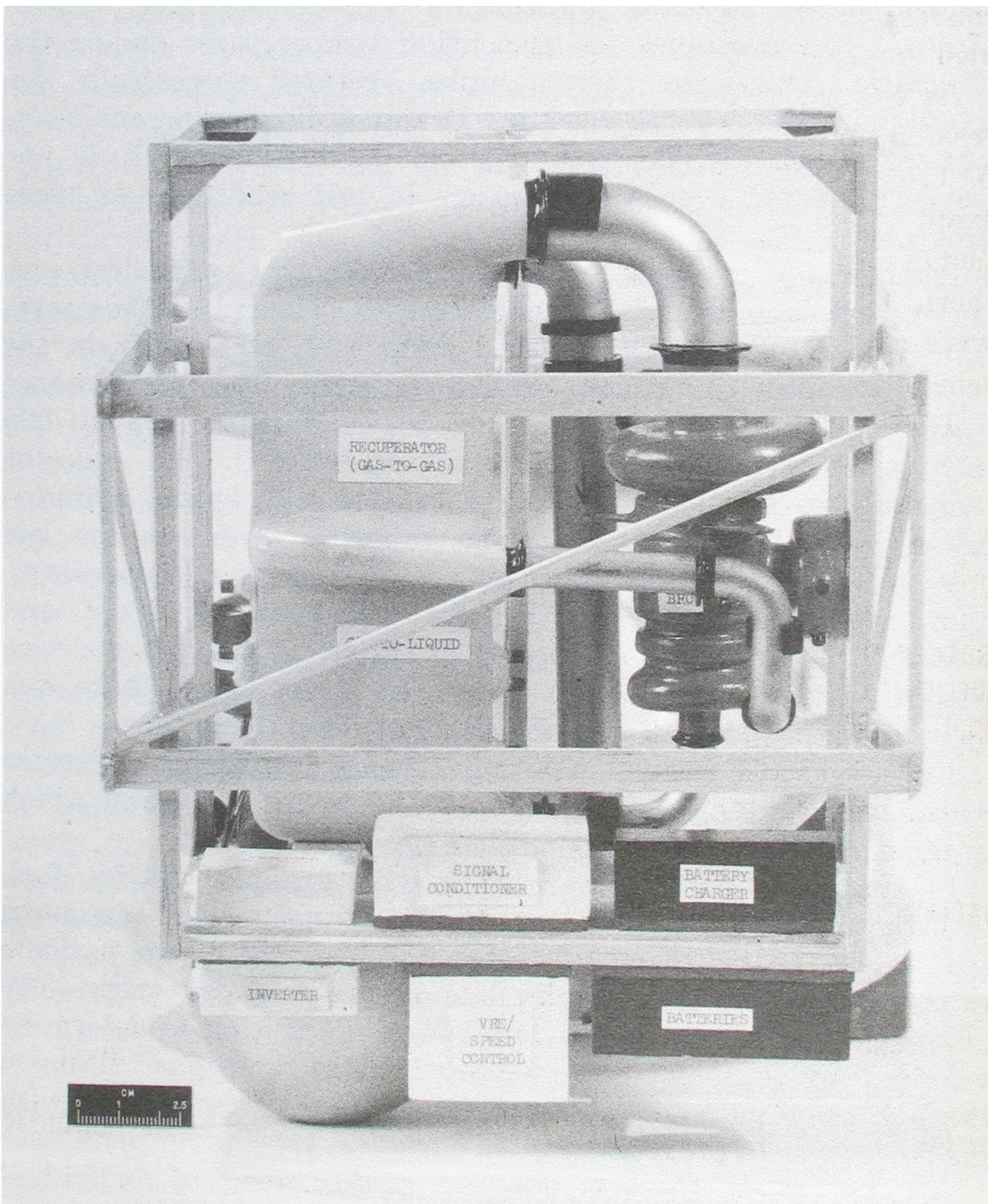


Figure 4–2. Brayton Power Generation System Mock-up.

ple start-stop and magnetic unbalance conditions; it was also operated successfully for several hours at more than 200 per cent of design power.

Two prototype single-shaft turbine-alternator-compressor units mounted on gas bearings were delivered to the Lewis Research Center, where one was being readied for hot performance tests with a prototype recuperator. The second unit was being assembled with other components into a test engine for delivery to the Plum Brook Station, where the first test of a complete power conversion system employing an electrical heat source is scheduled to start during 1969.

Isotope Power.—The SNAP–19 fuel capsules of the unsuccessful Nimbus B mission of May 1968, (*19th Semiannual Report*, p. 110) recovered from the ocean near San Miguel Island and examined at the AEC Mound Laboratories, were found to be intact. (Fig. 4–3) Two additional SNAP–19 units with improved thermoelectric materials in the thermopile were completed. They were delivered in December and will be used on the Nimbus B–2, scheduled for launch in 1969.

The SNAP–27 unit for the Apollo ALSEP was completed, a

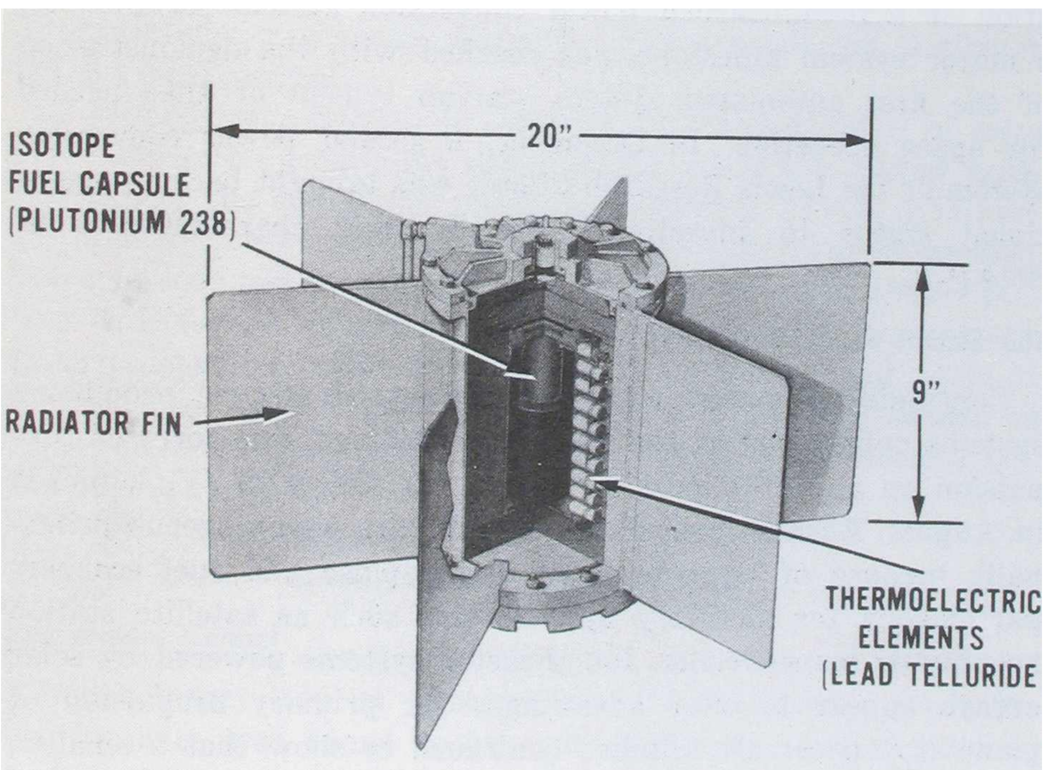


Figure 4–3. SNAP–19 Radioisotope electric generator.

safety analysis conducted, and a Safety Evaluation Report was being prepared.

Several thermoelectric materials and systems that may substantially improve conversion efficiency were being evaluated, and studies were initiated of the suitability of radioisotope thermoelectric generators (RTG) as prime supplies for lunar and Mars landers and planetary missions.

SNAP–8 Development Project

Major accomplishments in the endurance development of the major components of the 35–50 KWe SNAP–8 power conversion system were the completion of a 12,000-hour test of the mercury pump and operation of the first tantalum boiler for 2500 continuous service hours without failure or repair. Testing experience indicated the need for structural improvement in the boiler to achieve 10,000-hour life. The turbine exceeded 4500 hours of operation without sign of difficulty, and endurance testing of the other major components was also continued.

In other work, the AEC began testing of the second SNAP–8 reactor to demonstrate its performance and 10,000-hour design life.

The accumulation of basic system data continued through operation of a breadboarded power conversion system. In October, a major system milestone was reached with the demonstration of the first automated system startup typical of that needed for space operation. In December, a second power conversion system at the Lewis Research Center was brought back to operational status to investigate the dynamic characteristics of SNAP–8.

The Electric Propulsion Program

Continuing advances in the technology of electric propulsion systems culminated in the first application of this form of propulsion on a NASA mission spacecraft, the ATS IV, launched in August. Electric propulsion systems are advantageous principally because of their high specific impulse and fuel economy particularly for auxiliary applications, such as satellite station keeping or maneuvering. Ion thruster systems powered by solar arrays appear to offer advantages for primary propulsion of planetary spacecraft. Studies continued to show that a smaller, less costly launch vehicle can be used with a solar-electric spacecraft than with equivalent all-chemical propulsion.

Auxiliary Propulsion.—The ATS IV low thrust level resistojet system for spacecraft station keeping was designed so as not to disturb the sensitive passive attitude control system during station keeping. Although the spacecraft failed to achieve its design orbit, the 50-micropound-thrust ammonia resistojet system operated successfully for over 800 hours.

The ATS IV also carried a cesium ion engine experiment which functioned as intended. The system was capable of varying thrust level from 5 to 20 micropounds and of steering the thrust electrically. The steering capability eliminates unwanted torques by having the thrust vector pass through the spacecraft center of mass. Both the resistojet and ion engine systems will be flown on the ATS E.

Resistojets capable of operating in the 3600–4000°F range may also find application in position control of manned space stations. The 10 millipound units (*19th Semiannual Report*, p. 111) undergoing life tests have now accumulated about 5,000 hours on ammonia and 3,500 hours on hydrogen. In addition, research was started on such units capable of using life support waste products as propellants.

Prime Propulsion.—The SERT II project progressed as assembly of the flight spacecraft was completed. Planned for launch in 1969, SERT II is intended to demonstrate six month performance of a 1 kilowatt mercury bombardment ion engine in the space environment.

A ground test program to demonstrate the feasibility of solar powered electric propulsion systems also made substantial progress. All of the equipment (thrusters, gimbals, power conditioners, and switches) required was on hand and being assembled. The open-loop test program, set to commence in 1969, should provide data for an advanced closed-loop test involving automatic failure detection, switching, power distribution, and attitude control. The closed-loop program, scheduled for 1970, should in turn isolate and resolve the operational problems of such a system during a mission.

SPACE VEHICLES PROGRAM

Temperature Control

In laboratory tests of pigments for thermal control coatings, zinc titanate was found to be very stable in simulated space environment, but grinding the pigment damaged its structure and reduced its stability. To meet the need for powdered zinc titanate suitable for use as a pigment, a method was developed for direct precipitation of the chemical from a gaseous mixture of zinc vapor and other chemical compounds in vapor form.

Thermal/Vacuum Test Technology

In research on methods of testing very large spacecraft in available thermal/vacuum test facilities, studies were being conducted to develop valid scale model test techniques. Procedures devised in testing a 1/6-scale model of a proposed space telescope under transient thermal conditions appeared to give more detailed and valid results than those achieved by analytical prediction techniques.

Lifting-Body Flight Program

The HL–10, which has now been flown 14 times by three pilots, used the XLR–11 rocket engine on the last three flights to boost the speed to approximately Mach 0.84. Vehicle performance has been good, and flight testing through the transonic speed range will continue.

The X–24A was undergoing ground checkouts in preparation for its first flight in 1969.

Advanced Guiding Parachutes

Nine flights of a 4,000-square-foot parawing were completed in the second flight test phase of the parawing technology program. The test flights, with payloads ranging from 2,900 pounds to 5,000 pounds, evaluated deployment characteristics under conditions simulating the deployment of large scale parawings with 15,000-pound payloads. The test flights are scheduled to continue, culminating in the testing of 10,000-square-foot wings and payloads up to 15,000 pounds.

Advanced Decelerator Concepts

A 40-foot-diameter supersonic parachute was successfully flight tested by the Langley Research Center at Mach 3.5 and an altitude of 33 miles. The objective of the test, in which the test vehicle and parachute were lofted to altitude by a three-stage rocket vehicle, was to measure drag and stability of the parachute under atmospheric density conditions simulating those believed to exist near the surface of Mars.

Apollo 6 Flight Anomaly

The Langley Research Center directly supported the Manned

Spacecraft Center investigation of the Apollo 6 (April 4, 1968) flight anomaly—a noncatastrophic structural failure on the adapter section containing the Lunar Module (*19th Semiannual Report*, p. 18). The Langley investigation included static and dynamic analyses and model tests of the adapter section and its neighboring components as well as model structural tests of the complete vehicle. The Langley work, which provided a base from which MSC could plan and devise similar tests on the full-scale hardware for the most critical conditions, was particularly valuable in determining the appropriate location of instrumentation for full-scale tests.

Apollo Pressure Vessel Problems

During proof tests, a few of the many pressure vessels in the Apollo system developed deficiencies resulting in leaks and structural failures, which in flight could be catastrophic. Lewis Research Center research on these pressure vessel problems produced significant data on fracture behavior of pressure vessels and on methods of resolving the problems expeditiously.

SPACECRAFT ELECTRONICS and CONTROL

Communications and Tracking

The RAM C–II vehicle, designed and developed by the Langley Research Center, successfully measured the free electron and ion concentrations in the plasma surrounding a spacecraft during atmospheric reentry at a speed of approximately 25,000 feet per second. (Fig. 4–4) The results, which indicated that the theory was ineffective in predicting the distance from the spacecraft of the maximum ion concentration, will be used to refine the theory and establish a sound basis for predicting communication blackout in both manned earth reentry and entry into planetary atmospheres. The test was conducted at Wallops Island on August 22, using a Scout booster. (Fig. 4–5)

The extensive optical communication research and development program was granted space on the ATS–F spacecraft for a ground to spacecraft and return communication system experiment. The system to be developed by Goddard Space Flight Center will use carbon dioxide lasers and five inch antennas. ATS–G is expected to carry a similar system in that spacecraft so that tests can be conducted from satellite to satellite with ATS–F and thus prove out some of the concepts proposed for

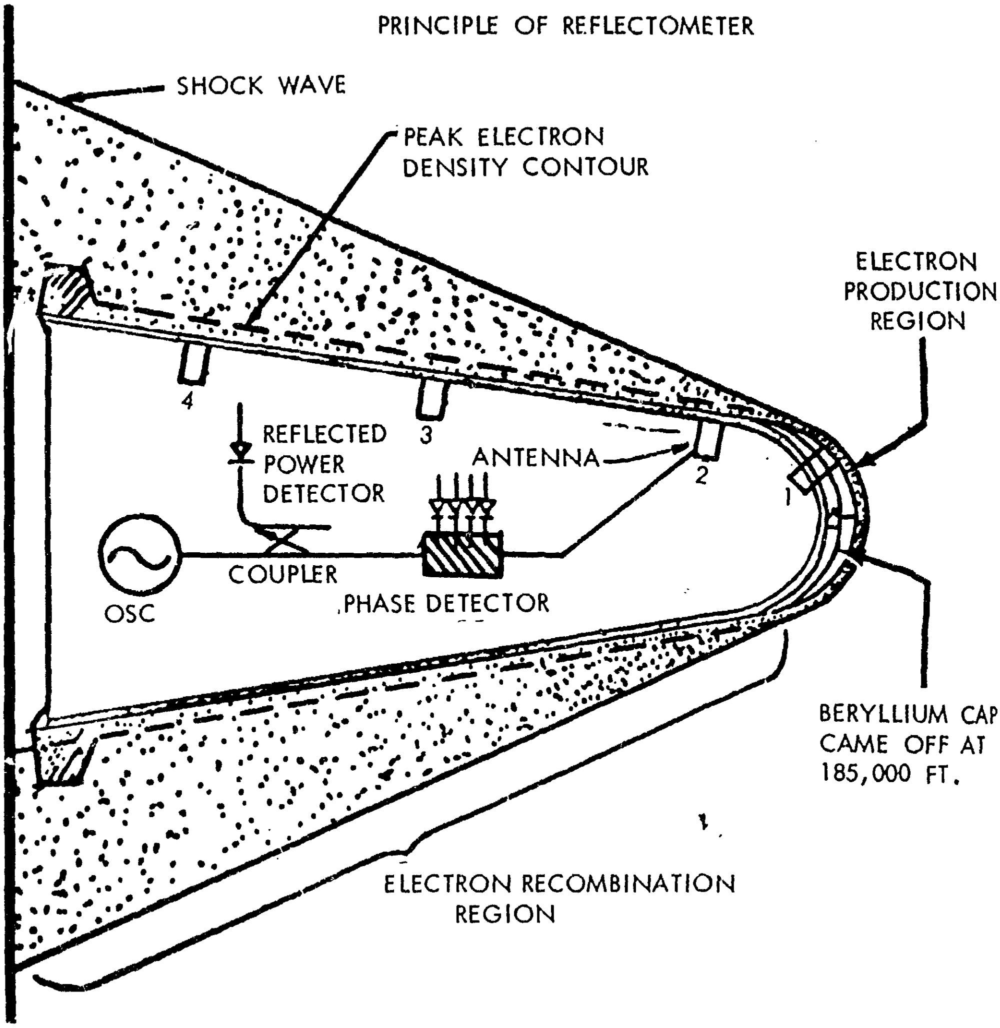


Figure 4–4. Construction of RAM C–II payload.

the data relay satellite system. Laser communication offers two significant advantages: a high data rate and narrow beams that can be developed with very small antennas. On ATS–F, for example, the beam of the laser system using a 5-inch dish will be narrower and have a much higher gain than the S-band system using a 30-foot dish.

In telescope technology research, a 30-inch thin mirror was constructed and figured to test the concept of using thin deformable mirrors for large diffraction-limited space telescopes. This concept was developed in the search for a substitute for the thick mirrors with "waffle" reinforcing on the back used in earth-based telescopes which are too heavy to be launched. By

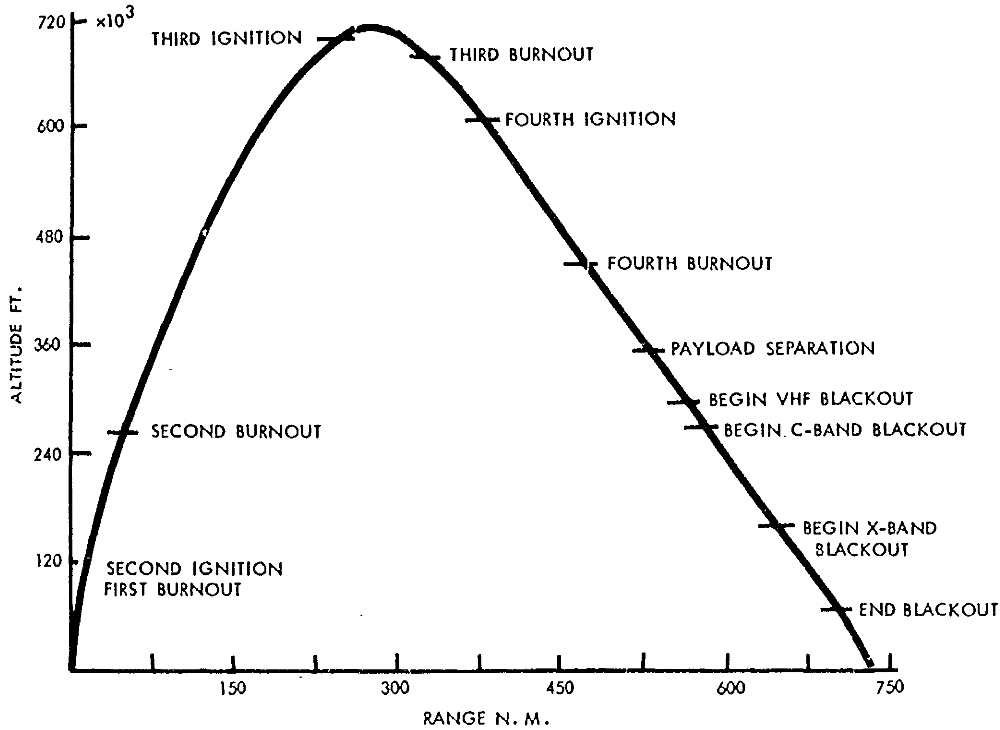


Figure 4–5. Flight profile of RAM C–II.

pushing and pulling the thin mirror, it can be made to retain the proper shape. Many small force elements attached to the back of the mirror do the pushing and pulling. They are connected to a laser measuring device in front of the mirror which continually senses its inaccuracies and causes the force elements to apply the proper force in the proper place to correct the observed errors. Such a large space telescope would be able to see much deeper into space than existing ground-based telescopes and might even be able to see the edge of the universe and thus add to knowledge of the forming of the cosmos. (Fig. 4–6)

The first space test of convolutional encoding and sequential decoding went into operation on the Pioneer IX spacecraft which was launched in November. The new deep space coding technique makes it possible to receive telemetering signals from a spacecraft at about a 40 per cent increase in range over uncoded systems or to send twice the amount of data in a given time at the same range. The system requires very little additional equipment on the spacecraft and uses existing computers on the ground to decode the messages and thus separate them from the high ambient noise. (Fig. 4–7)

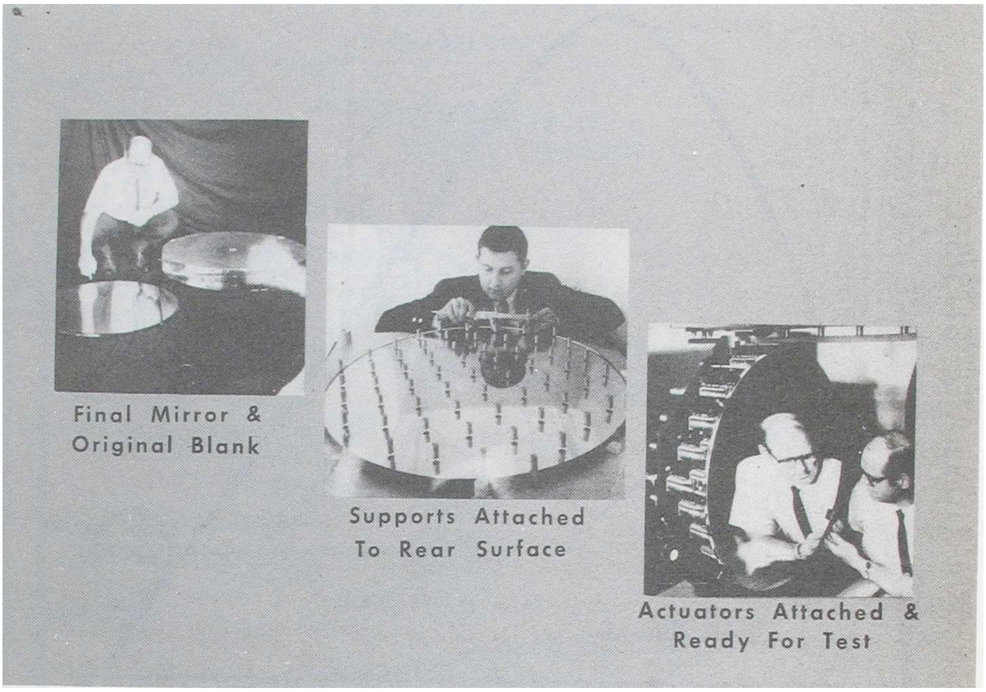


Figure 4–6. A thin deformable mirror.

The technique, first conceived under a NASA grant and mechanized by Ames Research Center for incorporation into Pioneer, uses error correcting codes which are related to one another in a time sequence. If an erroneous message is received, the computer can then proceed back down the chain of previous messages and determine where the sequence was most likely broken. By continuously weighing the overall message statistically most likely to be correct, the computer or decoder can assure that messages will be free of errors. The only limitation on achieving a completely error-free condition is the amount of ground computer time that can be devoted to that goal. The system improvement achieved by this inexpensive coding scheme is roughly equivalent to the benefits derived from adding a second 210-foot dish antenna (costing $15 million) at each deep space tracking site.

The Smithsonian Astrophysical Observatory (SAO), under a NASA grant, completed development of a laser system for measuring the range of near-earth satellites. The device, consisting of a ruby laser, a telescope, and a receiver, is relatively simple to operate and easy to maintain. SAO operates the NASA Baker-Nunn camera sites which provide excellent angular tracking

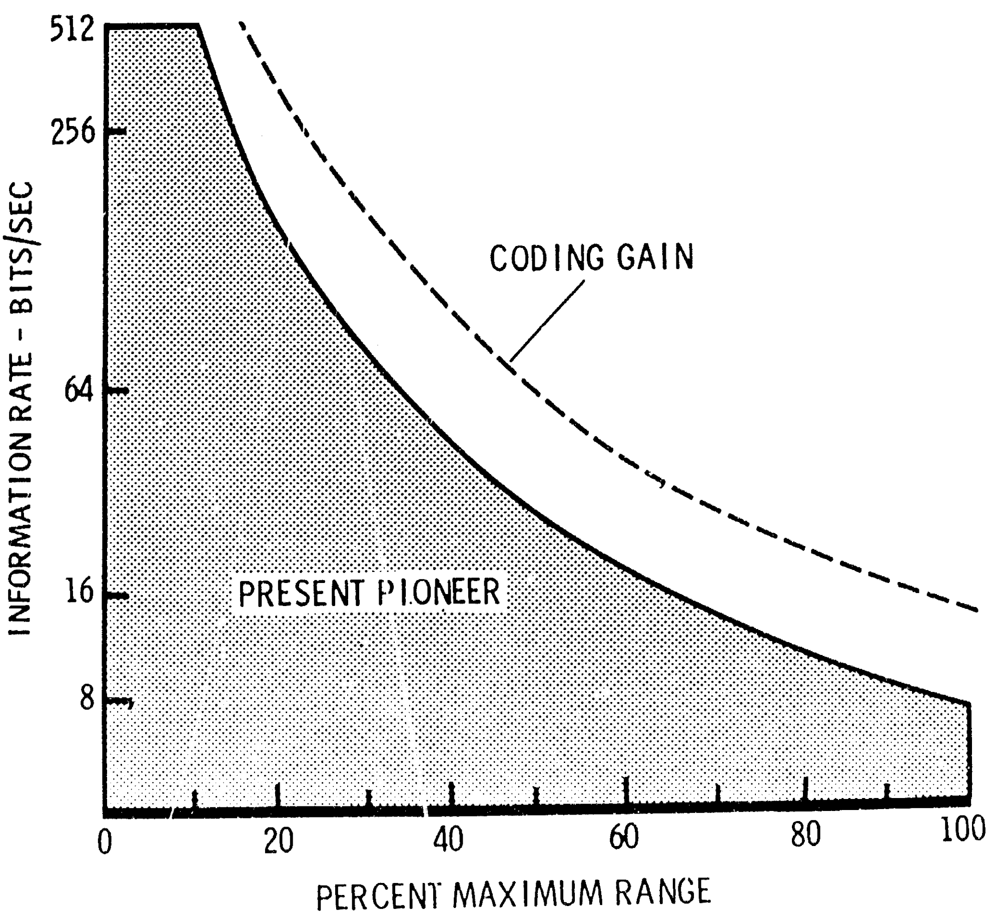


Figure 4–7. Benefits from deep space coding.

data but no range information. With the addition of a laser range measuring system, these stations will have a three-dimensional tracking capability at little increase in cost.

Attitude Control

Marshall Space Flight Center designed and developed a thrust vectoring control system, insensitive to nominal changes in engine and vehicle characteristics which effects changes in the flight trajectory of launch vehicles. The Marshall design reduces the cost and number of parts for thrust vectoring control systems and eliminates control system redesign which otherwise would result from nominal but significant changes in engine parameters. The system was incorporated in the design of Saturn V vehicles.

As part of the Langley Research Center's program on fluidic flight control systems, an advanced fluidic rate gyro was developed under a research contract. This gyro can meet aeronautical flight control requirements and may achieve inertial quality characteristics. On the basis of this work, it should now be possible to make progress in developing long life, fluidic control systems for aerospace missions.

Guidance and Navigation

The Massachusetts Institute of Technology under contract to the Electronics Research Center developed a solid state ultraviolet (UV) detector with characteristics that surpass those of detectors in use. The new detector has a high quantum efficiency and a flat (even) response which makes it most desirable for use in absolute spectral measurement in the ultraviolet region. The detector was also applied in a simple, small, reliable UV horizon sensor without moving parts which could, according to theoretical predictions, provide a low orbit navigational reference over the sunlit portion of the earth with an accuracy of about .01°.

V/STOL Avionics Program

The objective of this NASA program is to develop the technologies required to give V/STOL aircraft an all-weather operational capability in a civil air traffic environment. The program is based on the expectation that V/STOL aircraft will begin to play an important part in air transportation by about 1975. Such aircraft will follow flight paths and traffic patterns quite different from those of today's conventional air transports—paths will be steeper, closer in, and selected to reduce fuel consumption—and they will require an all-weather operational capability.

The first phase of the program—over 50 flight tests—was completed in October in a joint effort of the Electronics Research Center and the Langley Research Center. The avionics system tested included a Gemini inertial measurement unit, computer, command and communications link, and flight control unit installed in a helicopter. (Fig. 4–8) Purpose was to flight test a system using inertial velocity and position information coupled with ground based landing aid systems in a simulated air traffic environment. Although the Gemini system is too heavy and too expensive for practical application, it served as a means of obtaining information on the radar updating technique and the operational problems of inertial systems. The data was being analyzed, and the results will form a data base for the next phase in which the Gemini system will be replaced by strap-down inertial units being evaluated in the laboratory.

Thus far, inertial units were able to operate satisfactorily in a helicopter environment, data reduction and computer software requirements were established, inertial guidance platform alignment techniques were developed, and digital control equations were formulated and sized. Future ERC research will seek to develop technologies and conceptual designs for economical automatic flight systems and associated electronic equipment and to demonstrate such a system operating in a realistic environment. Langley Research Center will utilize the inertial measurement system to investigate variable stability helicopter and V/STOL characteristics.

Instrumentation

A flow visualization technique which uses an electron beam for studying flow fields around models in hypersonic test facilities was developed at the Langley Research Center. The new method, which uses an electron beam to excite the low density air and produce visible gas fluorescence, proved to be superior to the normal schlieren method in tests performed in the Langley helium

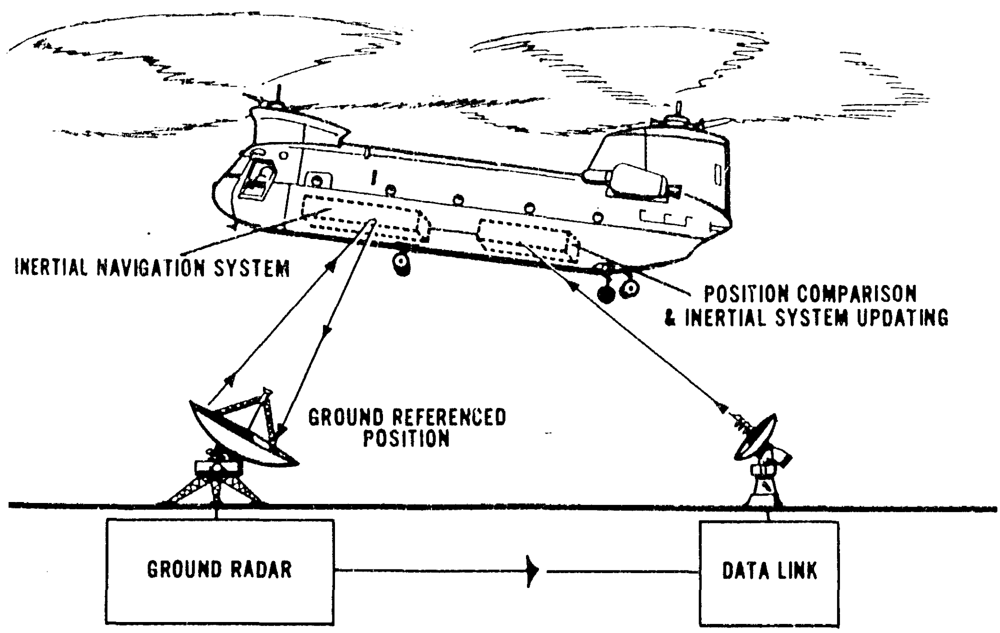


Figure 4–8. V/STOL Approach Navigation System.

tunnel. Wave patterns in the wake shock and wake core regions of a model at Mach 18 were clearly visible with the electron beam, but the pattern was not identifiable with schlieren techniques. The electron beam technique not only is more effective than schlieren techniques in revealing density gradients, but also makes it possible to visualize the entire flow field of two and three dimensional configurations.

A respiration monitor for biomedical applications was developed by the Ames Research Center. (Fig. 4–9) Based on miniature sensor telemetry systems used in aerodynamic testing, the device consists of a temperature transmitter with a small thermistor bead as sensor. It detects respiratory changes in patients with breathing difficulties by sensing temperature differences between inhaled and exhaled air in the trachea and uses the differential to modulate a radio signal. The signal activates an alarm whenever the difference falls below a certain value, indicating respiratory failure. Because the monitor summons help automatically only when needed, it eliminates the need for continuous observation of the patient by a nurse.

Data Processing

Research at GSFC indicated that laser/holographic techniques

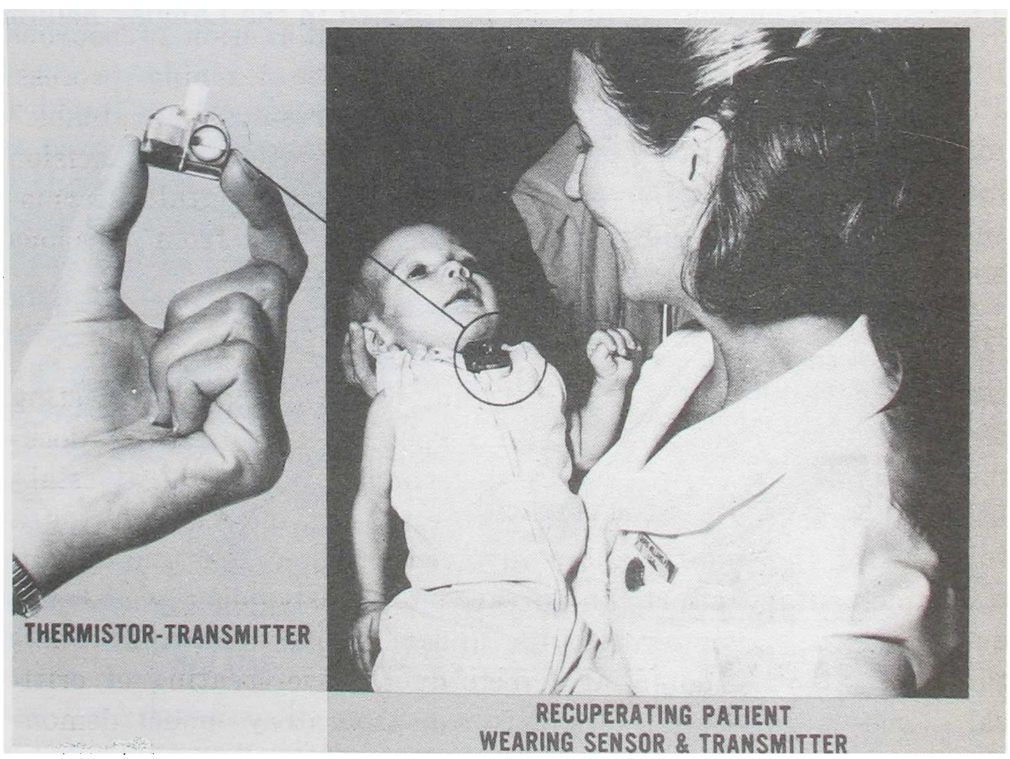


Figure 4–9. Respiration monitor.

could be used to transform image data aboard a spacecraft. This method would increase the amount of information which can be transmitted over limited communications channels and reduce the ground processing burden. The technique uses a laser beam to convert an image to a mathematically equivalent form known as the Fourier transform. In laboratory application of the technique to TIROS cloud pictures, it was found that satisfactory information on extent of cloud cover, cloud types, and cloud structure which now requires transmission of the entire image, can be derived from a limited amount of data describing only the general shape and orientation of the image fourier transform.

Research sponsored by the ERC indicated that it may be possible to construct electrical networks analogous to those of the human brain. Such a development may be considered a preliminary step toward designing "intelligent" machines which may reduce the human intellectual burden of complex space missions. In the research, an electrochemical process under control of an electric field was used to induce solutions of iron and gold to selectively penetrate the pores of a sintered, crushed glass block and form tree-like networks of conducting pathways within the glass. The branches and twigs resemble the highly involved branching of neurons in the human brain. Manipulating the controlling electric field may induce the network tree to grow appropriate branches thus simulating the interaction of neurons presumed to occur in the brain during the learning process. Further development of this process may result in "trainable" machines able to perform monitoring, recognition, and decision making functions in space, or to extract meaningful information automatically from large volumes of data from missions such as earth resources surveys.

Electronics Reliability

In a continuing research program on standards and testing techniques for microcircuits, an inspection and training document was developed for use by government inspectors. It establishes criteria for acceptance or rejection of microcircuits as a function of the workmanship involved in their construction. In a complementary effort, an infrared test instrument was being developed to test microcircuits under actual operating conditions and identify potential defects due to over-heating of critical elements in the circuits. After a laboratory model demonstrated its feasibility in experimental tests, the device was subjected to testing in a production facility to determine its on-line capability.

AERONAUTICAL RESEARCH

Aircraft Aerodynamics

Theoretical predictions of the aerodynamic performance of slender sharp-edge delta wings must take into consideration the effects of leading-edge spiral vortices because of their large effects on performance. Up to now, the theory, based on mathematical models of the spiral vortices, has not been sufficiently accurate because of the difficulty in calculating the size, shape, position, and strength of the primary and secondary spiral vortices and their feeding sheets. To get around these problems, a new approach was developed which formulates an analogy between the potential-flow leading-edge suction and the additional normal force induced by the vortex flow. In earlier studies, lift calculated according to this theory was in excellent agreement with experimental results.

Further studies, which compared the theory with experimental results over a range of aspect ratios from 0.25 to 2.0, indicated that the drag due to lift can also be predicted accurately by the zero-leading-edge-suction assumption, provided the vortex lift is accounted for by the new leading-edge-suction-analogy method. It was also found that because of the vortex lift, the drag due to lift for wings of extremely low aspect ratio can be less than that for optimum potential flow.

The vortex-lift concept based on leading-edge suction analogy was also used in developing a method of predicting the lift and drag of slender planar sharp-edge delta wings in ground proximity. The method employs a vortex-lattice computer program incorporating an image technique to compute the potential-flow, normal-force, and axial-force characteristics of delta wings in ground proximity. The results of the potential-flow theory were combined with the vortex-lift concept for making the prediction. A comparison of the theoretical and experimental lift and drag data for delta wings indicated that this method provides a reasonably good prediction of the lift and drag in ground proximity for aspect ratios less than 2.0 in the angle-of-attack range from 5° to 16°.

In a series of studies of favorable lift interference in supersonic flow, various configurations were examined including the half-ring-wing-body, the complete-ring-wing-body, and a flat wing strut mounted above a body. Theoretical calculations based on a flat-wing configuration indicated that further improvements in lift-drag ratios may be obtained from a model with a more conventional body shape than the broad flat body previously employed. The increased performance would result from lower skin-friction drag, improved area distribution, and increased favorable lift interference for a model with a body having circular cross sections. Accordingly, an investigation was conducted in the Langley Unitary Plan wind tunnel at Mach numbers from 3.00 to 4.63 to determine the longitudinal aerodynamic characteristics of a parasol-wing-body model. The model had a swept wing with a curved leading edge, a body with circular cross sections, and a Von Karman forebody shape. Variations in wing position and forebody shape were also studied.

The investigation showed that large favorable lift interferences were obtained at zero angle of attack for all configurations; the largest interference values were measured at Mach numbers from 4.00 to 4.63 in tests of the low, single strut configuration. Variation in wing vertical placement from a high to a low position improved the interference lift increments at the higher Mach numbers with a corresponding increase in the maximum values of the lift-drag ratio. Variations in forebody shape from the basic body resulted in only small changes in the maximum values of the lift-drag ratio. Finally, theoretical calculations of the lift-drag curve for the basic configuration at Mach 3.00 were in good agreement with the experimental data.

Aircraft Structures

Several topics were under study in this research area. One was a structural concept calling for the use of high strength, high modulus filamentary materials, such as boron, bonded to conventional metals, such as aluminum alloys. In a preliminary investigation, compression tests on metal tubes reinforced with filaments bonded to the outer surface confirmed the weight savings and high efficiency of this concept. Another subject was the rates of fatigue-crack propagation in 7075–T6 aluminum-alloy sheet specimens containing symmetric or non-symmetric cracks. Specimens were subjected to various combinations of end loads and concentrated loads simulating rivet forces, and a method of calculating rates of crack propagation was developed which furnishes satisfactory predictions for such structures subjected to cyclic loads.

Finally, an ultrasonic device was developed and used to observe the formation and growth of fatigue cracks in notched cylindrical specimens subjected to reversed axial fatigue loading. Fatigue curves showing cycles to initially detectable cracks as well as cycles to fracture were obtained for an aluminum-, a titanium-, and a cobalt-base alloy and for a maraging steel. Depth of initially detectable cracks ranged between approximately 0.0005 and 0.004 in. Curves relating ultrasonic system output voltage to crack depths up to 0.030 in. for three materials were also obtained and used to demonstrate the capability of the device for monitoring crack growth.

Air Breathing Propulsion

Lewis Research Center carried on a flight research program to determine aircraft installation effects (fuselage-nozzle interference) on the operation and performance of advanced complex exhaust nozzle designs.

The location of an exhaust nozzle with respect to the wing of a supersonic aircraft can produce undesirable effects, such as excessive nozzle thrust losses, which could prerent the aircraft from achieving supersonic flight.

Twenty-seven flights of an F-106 aircraft (Fig. 4-10) were required to check out the aircraft modifications and instrumentation and to clear the aircraft for operation in the rigorous environment (Mach 0.8 to 1.5) required for the research program. Research flights with the first series of advanced nozzle concepts began in October; data from the 12 flights completed since then showed important fuselage-nacelle interaction effects which could not be studied with sufficient accuracy in ground test facilities. (Fig. 4-11)

Operating Environment

Research on a practical method of modifying warm fog (above 32°F.) to improve visibility moved ahead into the field test stage. (Fig. 4-12) Theoretical studies and laboratory tests showed that seeding warm fogs with salt crystals of very small and carefully controlled size could improve visibility; relatively small amounts of seeding material were used. In field tests at an airport in upper New York state, a very dense fog was seeded with salt by an agricultural spray airplane flying just above the fog. Swaths over 200 yards wide were cleared in the 350-foot-deep fog within a few minutes after seeding and persisted for up to 20 minutes. (Fig. 4-13) The results were encouraging since the objective of this research is to develop a practical method of dissipating warm fog—a frequent cause of delayed

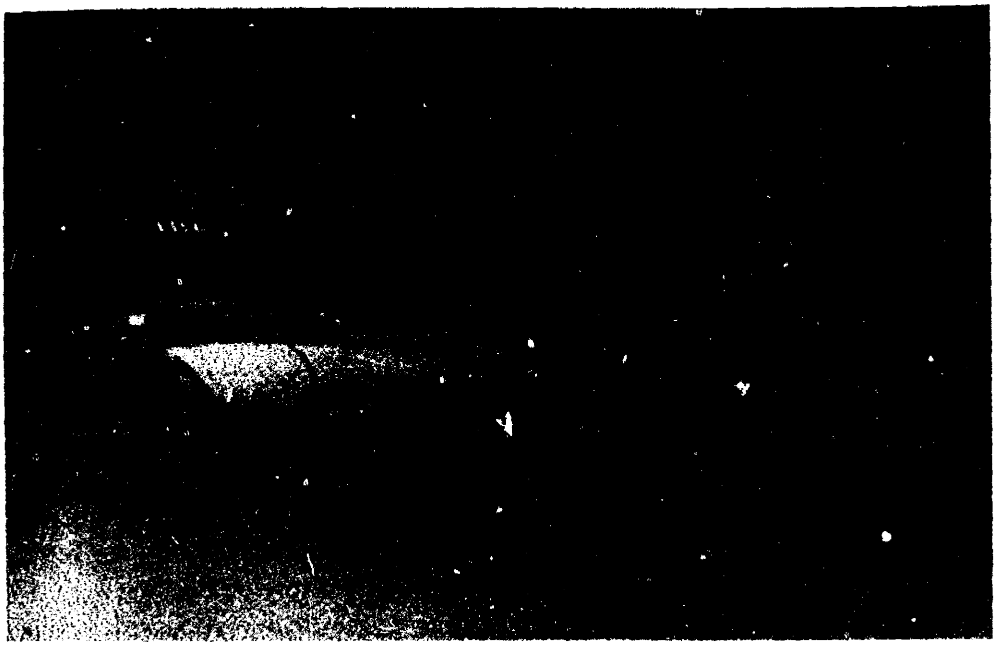


Figure 4–10. F–106 used in nozzle research program.

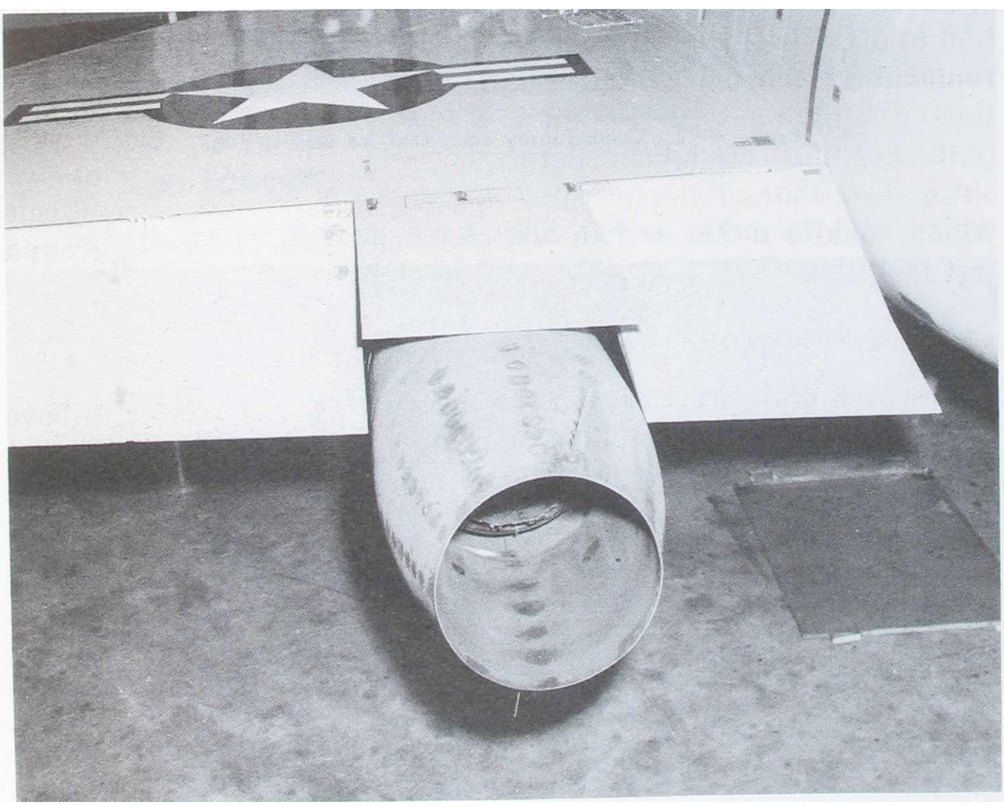


Figure 4–11. Nacelle under F–106 wing.

and cancelled flights. (Cold fog—below 32°F.—accounts for only about 5 percent of the fog occurrences in the U.S. and can be modified to improve visibility.)

Runway traction research discussed in the *19th Semiannual Report*, p. 82, was the subject of a NASA conference held at

Figure 4–12. Ground-spray equipment for seeding fog.

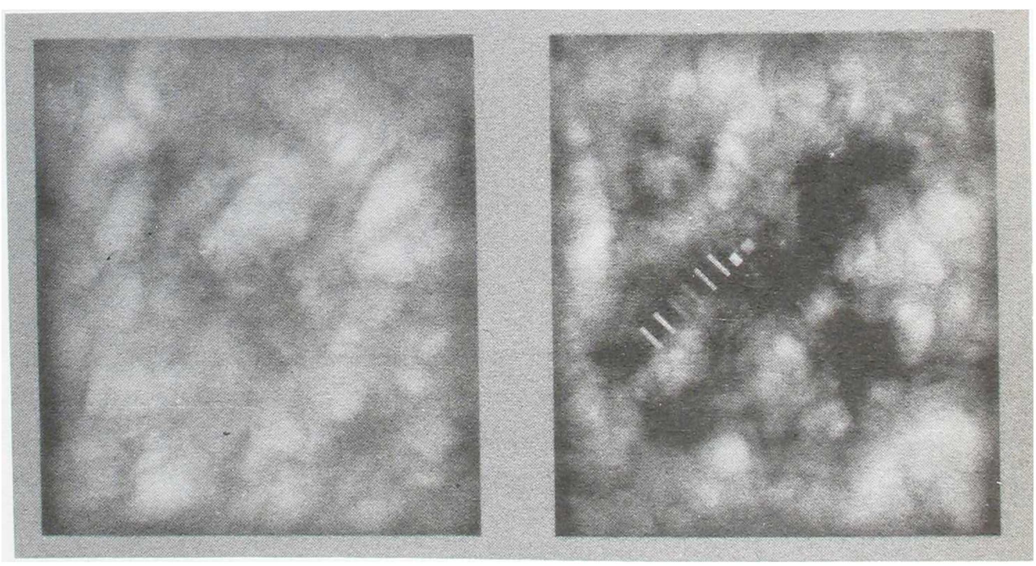


Figure 4–13. Results of aerial seeding.

the Langley Research Center in November. Proceedings are reported in NASA SP 5073, *Pavement Grooving and Traction Studies*.

Aircraft Noise

Results of studies of aircraft noise and full-scale engine-nacelle ground tests (*19th Semiannual Report*, p. 82) were presented at another Langley Research Center conference in October. Proceedings are reported in NASA SP–189, *Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft*. The ground tests indicated that it is technically feasible to reduce the noise near the approach path of 4-engine commercial jet transport aircraft, where compressor whine is particularly bothersome, by using acoustically treated material in the engine inlets and elongated fan exhaust ducts. Modified nacelles were being fabricated by the contractors for installation on two large commercial jet aircraft for flight test verification of the ground tests. In ground tests of the choked inlet concept, propagated noise generated by the fan was markedly reduced. The choked inlet uses a variable intake area to establish near-sonic flow of the air to the engine, and the high velocity air prevents transmission of sound forward of the engine intake. The choked inlet thus may be another way of reducing noise under the approach paths of large jet aircraft.

Aircraft Flight Dynamics

Flight tests by NASA, FAA, and airline pilots of a specially-equipped variable stability jet transport aircraft showed that two-segment steep landing approaches for noise-abatement could be flown with the same precision as a conventional straight-in approach without a significant increase in pilot workload. The research indicated that a two-segment profile guidance system, a modified flight director, and an auto-throttle were primary requirements for the noise abatement approaches. Secondary requirements, which might be needed for some current jet transports with less desirable characteristics than those of the test aircraft, included a rate command control system, advanced cockpit displays, and direct lift control.

General Aviation Aircraft

A simple yaw damper installed in a typical twin engine light airplane improved Dutch roll damping thereby reducing pilot workload and bettering ride qualities in turbulent air. The yaw damper also provided a stabilizing effect on airplane motions encountered during stall or engine malfunctions, giving the pilot more time to effect corrective control action.

Research literature applicable to small airplane design produced since 1940 by NACA/NASA was reviewed and collated; summaries of the more significant areas are being prepared.

V/STOL Aircraft

An investigation in the 17-foot test section of the Langley 7- by 10-foot tunnel extended previous work on how inlet mass flow and the jet-induced effects of the exiting jets affect the longitudinal aerodynamic characteristics of one type of jet VTOL fighter airplane. Tests were also made to determine the jet interference effects on the lateral-directional aerodynamic characteristics. The test model represented a configuration with three lift engines in the forward fuselage and two deflected lift-cruise engines in the aft fuselage. It was tested with three wing configurations and up to three horizontal tail heights.

The jet-induced interference test showed that the expected increase in lift loss and nose-up pitching moment with increasing speed was rather small because of the counteracting effects of the front and rear jets. Increasing the angle of attack had very little effect on interference lift and drag, but significant increases in interference pitching moment can occur if the horizontal tail is on or below the wing-chord plane. Further investigation of tail height showed that the jet-induced downwash was highest for the low tail position but that the jet-induced longitudinal instability was mild for the three tail positions used in the tests. The effects of ground proximity were found to be relatively small for the configuration studied.

Other research focused on a potentially serious problem associated with jet VTOL aircraft—ingestion into the engine inlet of hot exhaust gases or air heated by the hot exhaust. Hot-gas ingestion is a problem because a thrust loss occurs as a result of the elevated temperature of the engine inlet air or an uneven inlet temperature distribution across the engine face. To obtain generalized information on this problem at relatively large scale, the Langley Research Center began an investigation using jet VTOL fighter-type configurations with in-line, rectangular, and single engine arrangements. Tests were conducted in the Langley full-scale tunnel and outdoors for purposes of comparison; test variables were model height above the ground, wing height, engine-inlet position, and wind speed and direction. The exhaust-gas source was a turbojet engine operating at a nozzle pressure ratio of about 1.8 and a nozzle temperature of 1200°F.

The ingestion of hot-engine exhaust gases into the inlets was found to be closely related to the aircraft configuration and the wind speed. An in-line arrangement of engine exhaust nozzles resulted in virtually no hot-gas ingestion, whereas a rectangular arrangement of nozzles resulted in an inlet air temperature rise of 100°F to 200°F for many test conditions. The ingestion of hot exhaust gases was greatest at wind speeds from zero to 20 knots, with virtually no hot-gas ingestion at wind speeds greater than about 30 knots. Top inlets were, in general, less subject to hot-gas ingestion than the side inlets, and lower inlet air temperatures were found in the low-wing configuration than in the high-wing configuration. Deflecting the jet exhaust 25° rearward with the vectoring nozzles generally eliminated the ingestion of hot exhaust gases.

Another subject studied was the jet flap, which has been considered in several forms for integration into the lift propulsion systems of STOL turbojet or turbofan aircraft. However, integrating the jet flap into aircraft designs creates two difficulties: the problem of delivering sufficient gas flow to the wing trailing edge to achieve the needed jet thrust, and the large nose-down pitching moments which result when the jet is expelled near the wing trailing edge. One proposed solution to the difficulties is the augmented jet flap or augmentor wing. In this concept, the thrust of the primary jet is augmented by an ejector system combined with the trailing-edge flap, resulting in higher jet thrusts and less negative pitching moments.

To determine the aerodynamic characteristics of the augmented jet flap at high Reynolds number, a large-scale model was built and tested in the Ames 40- by 80-foot wind tunnel. The wing of the model was unswept, and the augmentor wing section extended 60 percent of the span. Static tests and wind-tunnel tests out of ground effect were made for flap angles from 30° to 100°; at augmentor flap angles of 60° and 100°, the model was tested with a high-positioned horizontal tail. The effects of sideslip and differential airleron deflection were also studied. With the horizontal tail installed, the variation of pitching moment with angle of attack was stable up to and including wing stall. Comparisons with jet flap tests results on the basis of the same static thrust output of the systems indicated that the present augmented-jet flap configuration produced slightly higher lift increments and had more forward center-of-pressure locations. For the same isotropic primary thrust, the augmented jet flap produced 50 percent more jet force and 22 percent more lift than the jet flap.

Wind-tunnel investigations of powered models of twin-propeller deflected-slipstream STOL configurations were carried out to obtain stability and control information. One, conducted in the 17-foot test section of the Langley 7- by 10-foot tunnel, concentrated on two items:

- the effectiveness of an inverted V-tail with boundary-layer control on the elevator to improve longitudinal stability and control;
- the effectiveness of the inverted V-tail with boundary-layer control for yaw control, especially with an engine failure.

The results indicated that with further development, an inverted V-tail with boundary-layer control can be designed to produce the longitudinal and directional trim required for an engine-out situation with no control input by the pilot. The data also showed that the lateral control required for an engine-out situation can be obtained from a spoiler with the attendant lift loss.

At the Ames Research Center, a study was made of helicopter rotor performance characteristics at high forward speeds to obtain data on the magnitudes of rotor forces and moments and the character of rotor operation, for example, flapping stability at advance ratios as high as 1.0. Five full-scale rotors were tested at various advance ratios and advancing tip Mach numbers in the Ames 40- by 80-foot wind tunnel. The primary differences between rotors were twist, articulation, and tip airfoil section. Force, moment, power, and control-setting data were obtained for a wide range of lift and propulsive forces and should be applicable to helicopter design and serve as a basis of comparison for rotor performance prediction techniques and advanced rotor systems.

In research tests on flexible lifting rotors, which are of interest because of their lightness, stowability, and capability for in-flight deployment, the hovering characteristics of a 30-foot-diameter flexible-rotor configuration were compared with those of a conventional rotor. The flexible rotor exhibited much lower hovering efficiency while attaining higher mean lift coefficients than the conventional rotor. Also, fabric instability, commonly called "luffing," severely limited the envelope of tip speeds and blade pitch settings within which the flexible rotor could be operated.

Research at the Langley helicopter test tower showed that the rotor attained very high mean lift coefficients because of the large amount of aerodynamically induced camber. The investigation also revealed how luffing restricted the envelope of tip speed and collective pitch angles within which the rotor could be operated. In the rotor's operating range, variations in tip speed altered the blade camber and resulted in substantial tip speed variations in hovering performance, particularly at the higher thrust conditions. The results suggest that there may be optimum combinations of tip body mass, tip center of gravit and tip stabilizer incidence for each value of tip speed since these variables determine the amount and distribution of blade camber and twist.

Another type of research was concerned with instrument display requirements for VTOL aircraft, which may be more severe than those for STOL and CTOL (conventional takeoff and landing) aircraft because of differences in speed control and guidance in the final phase of the approach. In VTOL landings, the pilot must vary the speed precisely to bring the aircraft to a stop over a prescribed location on the ground; he must then execute a descent to touchdown at essentially zero speed. The instrument display, therefore, must present the ground speed and guidance information with sufficient accuracy and in such a form that the pilot will be able to maneuver with great precision. In addition, since the attitude and position of the aircraft can change rapidly and continuously during the final phase of the approach, guidance information must be presented so as to facilitate rapid assimilation by the pilot.

Attempts to reduce the difficulty of information assimilation have been made from two viewpoints:

• combining individual items of information in a computer and presenting the combined signal as a single indication; this method reduces the number of indications and also makes it possible for the indications to take the form of simple control commands;

• combining the items of information in the presentation itself in a realistic or pictorial form that permits rapid interpretation in terms of the pilot's real-world experience.

Eight instrument displays based on these two methods of combining information were assembled as representative examples, classified in terms of basic display concepts, and compared on the basis of a common set of instrument display requirements. In tests of displays in simulators or in flight, the only display with which VTOL landings were achieved in flight (under simulated zero-zero conditions) was the "real-world" display of a closed-circuit television system. These results suggest that a televised display of a simulated real-world landing site may be the form for achieving VTOL landings under zero-zero conditions.

Supersonic Transport

At the request of the FAA, NASA assigned approximately twenty technical experts to assist in the technical validation of the proposed SST design. NASA personnel also participated in the FAA sponsored Government-industry review of tentative airworthiness standards for the SST held in October.

Tests were made in the 40- by 80-foot wind tunnel of a 1/5 scale

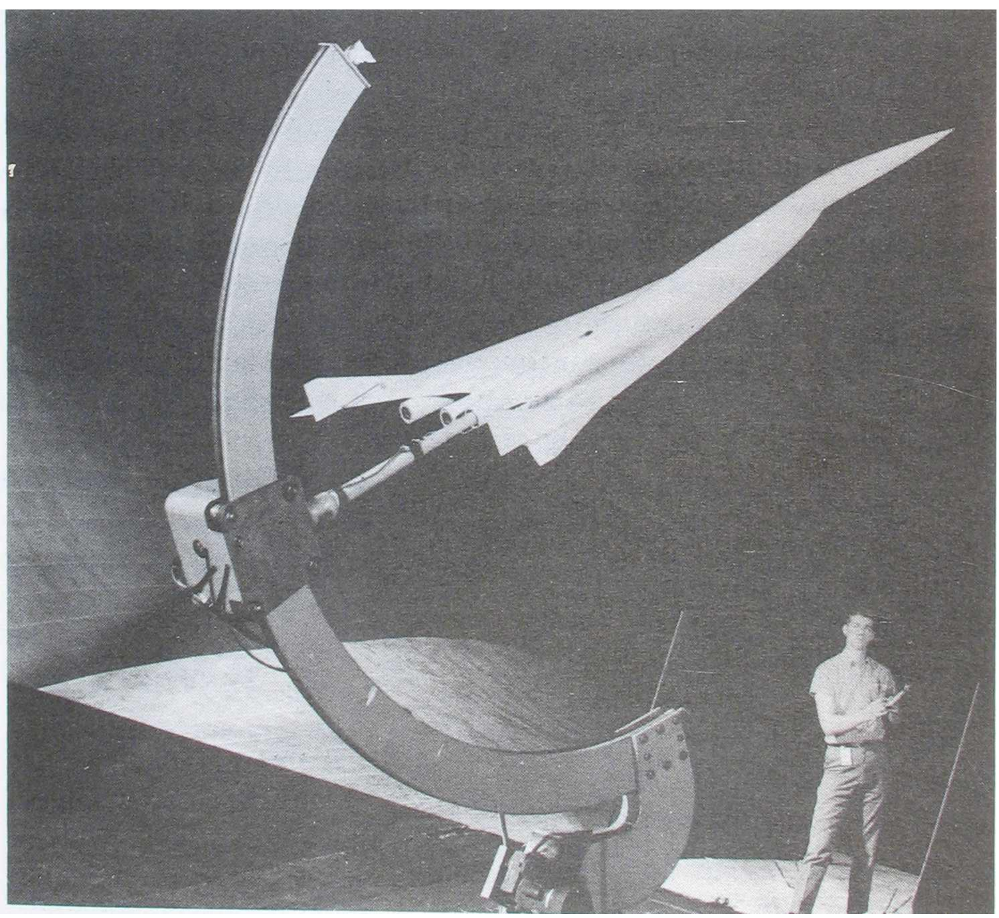


Figure 4—14. Scale model of the SCAT—15F concept.

model of an SST design based on SCAT–15F (Fig. 4–14). Initial results indicated signficiantly better low speed lift/drag values than had been predicted.

XB-70 Flight Research Program

The XB–70 Number 1 made seven flights during this period, to acquire data related to the design and operation of large supersonic aircraft. (Fig. 4–15) These flights, together with the six flights made during the first half of 1968, brought the total number of XB–70 flights to 128. Thirty three of these flights (all flights after November 3, 1966) were in direct support of the national supersonic transport program.

The 7 most recent flights were made to obtain data on the structural dynamics of the airplane and the effects of atmospheric turbulence; stability, control and handling qualities; overall airplane performance; engine inlet air duct performance; boundary-layer noise and skin-friction; and take-off and landing noise.

The structural dynamics tests used the recently-installed modal control (elastic mode control) system, which is designed to reduce the structural dynamic response of the airplane to atmospheric gusts. The preliminary tests indicated that the system should be

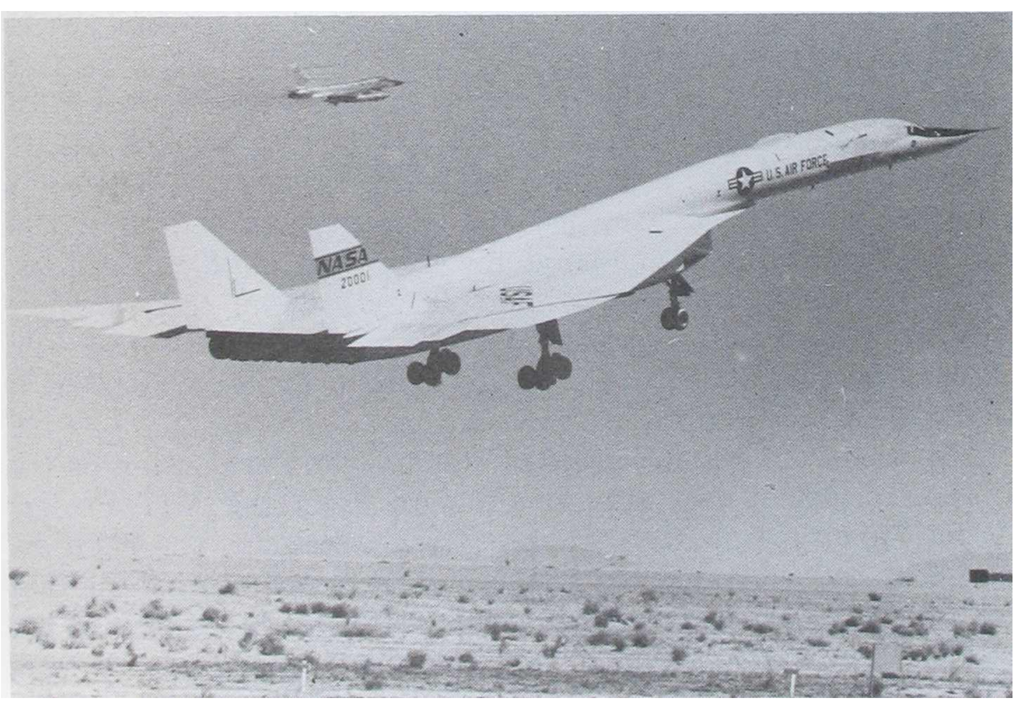


Figure 4–15. The XB–70 taking-off.

effective in reducing the structural response to turbulence. When fully developed, the system should improve the "ride" characteristics of large flexible airplanes in rough air, thereby extending the fatigue life of the aircraft. Data obtained from these flights were being reduced and analyzed at the end of 1968.

In December NASA and the Air Force decided to terminate the XB–70 flight program on or before January 31, 1969; one flight may be made in January. Upon termination, the XB–70 aircraft and all available equipment, material, and facilities loaned to NASA and the contractors will revert to the Air Force.

Military Aircraft

At the request of the Department of Defense, NASA conducted a fighter aircraft study to provide idealized fighter aircraft concepts embodying the upper level of current technology in external and internal aerodynamics, engine/airframe integration, and airplane stability and maneuverability throughout the speed range. Also, in response to an Air Force request to participate in the F–X source selection, NASA technical specialists were assigned to Air Force technical committees evaluating proposals submitted by prospective contractors.

X-15 Research Aircraft Program

The X–15–1 made four flights—on July 16, August 21, September 13, and October 24—to obtain data for several high-priority Air Force experiments.

The objectives of the July 16 flight were to evaluate the USAF Western Test Range (WTR) launch monitor experiment and to obtain data from the Air Force high-altitude sky-brightness experiment. A malfunctioning pressure trandsucer caused an erroneous indication of hydraulic pump failure during the flight, and the pilot elected to reduce maximum altitude as a precautionary measure. As a result, the WTR equipment was not activated and no data were obtained, but satisfactory data were obtained from the high-altitude sky-brightness experiment.

The August 21 flight continued checkout and evaluation of the WTR experiment and also sought data from the MIT/Project Apollo Simultaneous Photographic Horizon Scanner. The WTR experiment was activated but it again experienced component failures. Satisfactory data were obtained from all data channels of the Horizon Scanner experiment except the star magnitude channel. The edgetracker portion of the experiment functioned normally and data were obtained.

The September 13 flight was made to continue the development of the WTR experiment hardware and to maintain pilot proficiency for the scheduled high-altitude flights.

The flight on October 24 was made to obtain data for the WTR and the sky-brightness experiments, but equipment problems were encountered with both experiments. Data were obtained, however, from the fixed-sphere flow direction sensor and the fluidic temperature measurement equipment.

Following a joint USAF/NASA review of the current status of the X–15 flight program, it was decided to terminate the X–15 program no later than December 31, 1968.

The three X–15 aircraft (Fig. 4–16) made a total of 199 flights, from the first flight on June 8, 1959, to the last on October 24, 1968. Of these, 154 exceeded Mach 4, 109 exceeded Mach 5, and four exceeded Mach 6. The maximum speed and altitude attained during the program were 4,520 miles per hour (6,630 feet per second; Mach 6.70) and 354,200 feet, respectively. Thirteen flights, by eight different pilots, exceeded an

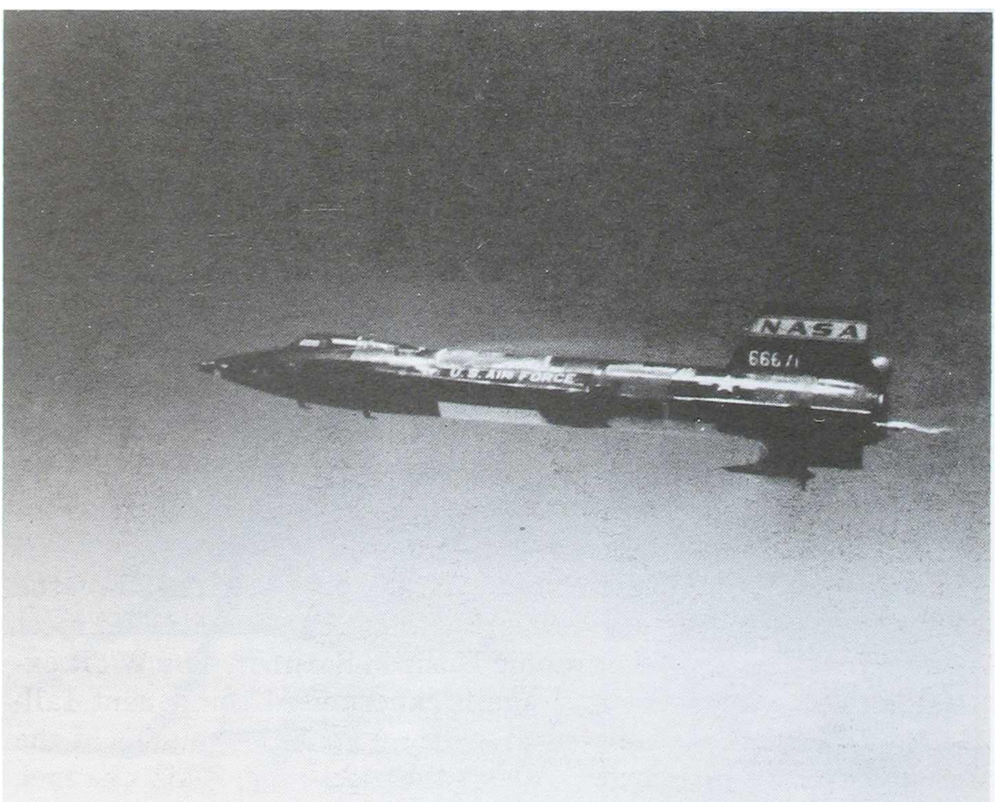


Figure 4–16. The X–15 in flight.

altitude of 50 miles. Twelve pilots (5 Air Force, 5 NASA, one Navy, and one contractor pilot) flew the X–15 aircraft during the more than nine-year flight program. (Fig. 4–17)

A total of 200 NASA technical reports and papers presenting information obtained during the flight program were published before the end of 1968, and four NASA-Industry technical conferences were held during the course of the program to present results to the technical community.

BIOTECHNOLOGY AND HUMAN RESEARCH

Human Research

Ames Research Center directed studies of ways to apply the fluorescent antibody technique for detecting microbial infections to the preclinical diagnosis of viral infections. The work underway will extend the technique to provide almost instantaneous detection of viral agents and rapid diagnosis of a variety of viral infections. It will be valuable in preflight examinations of astronauts preparing for space flights since it will enable doctors to detect

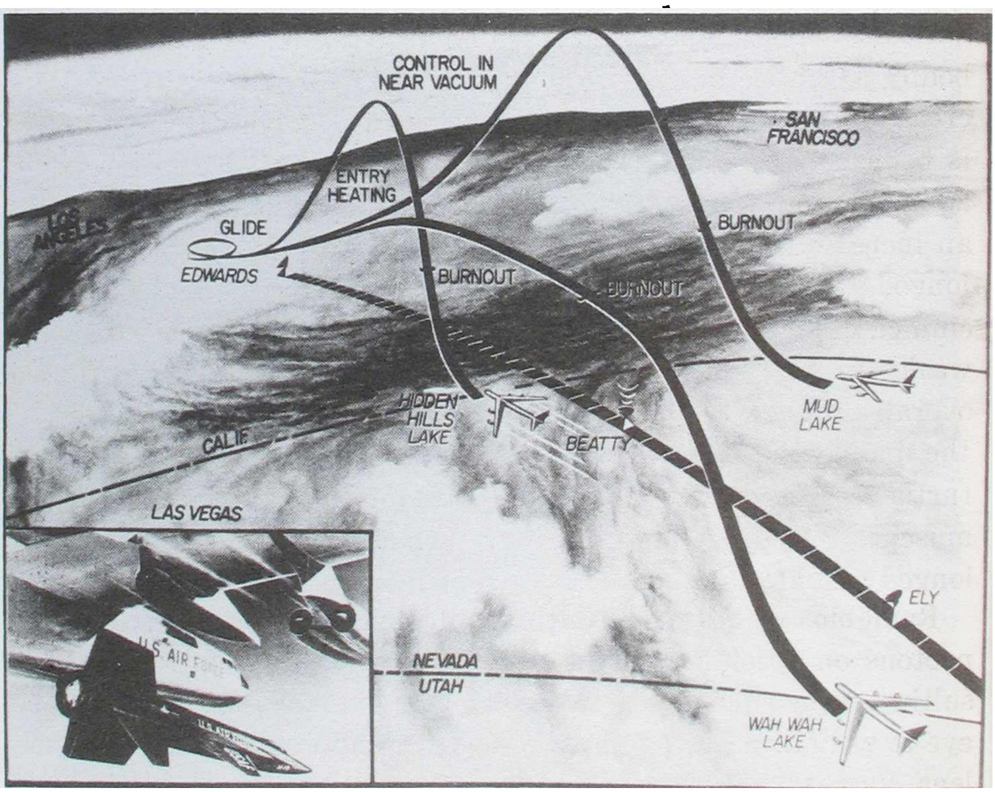


Figure 4–17. Typical X–15 research flight paths.

disease in the preclinical stage, minimizing the chance that the astronauts will suffer clinical illness in flight, as happened during the Apollo 7 flight and perhaps also during Apollo 8.

Ames was also developing toxicity criteria for gas environments in closed ecological systems. Studies indicated that prolonged breathing of pure oxygen causes a decrease in the circulatory red blood cell mass, even at the pressures now used in spacecraft, the collapse of alveolar air spaces (atelectasis), resulting in inadequate ventilation, and damage to the alveolar capillaries. Research was continuing to increase knowledge of the mechanism of oxygen toxicity.

The physiological and biochemical effects of candidate diluent gases for extended manned space flights were also being investigated. In long term exposure of rats and mice to helium-oxygen and nitrogen-oxygen mixtures, the only difference found was that in the helium-oxygen environment more food, water, and oxygen were consumed with no attendant increase in growth rate. The disparity is believed to be due to the differing thermal properties of nitrogen and helium.

The threat of incapacitating postural hypotension following prolonged weightlessness continued to cause concern. From studies of human volunteers subjected to two weeks of absolute bed rest (to simulate weightlessness), it was concluded that bed rest reduces bodily tolerance to standing erect, probably resulting from a decrease in plasma volume caused by extravascular dehydration. It is believed that some protection could be afforded astronauts by administering a drug (9-alphafluorohydrocortisone) which causes an increase in plasma volume, during the last 48 hours of a prolonged flight. A 30-week bed-rest study confirmed loss of body calcium and phosphorous; other findings included profound muscular weakness, pain in the feet on resumption of walking, decreased overall endurance, and psychological depression. On the basis of the findings in the shorter bed-rest study, it was determined that further work must be done on the possibility that decreased heart muscle strength and kidney stone formation can result from prolonged weightlessness.

Radiobiology research continued to concentrate on the effects of protons on specific parts of the body and on systemic effects resulting from whole body exposure. For example, exposure of the eye to radiation can result in opacity or cataract formation in the lens. Recent studies conducted for NASA at the Medical College of Virginia, examined the effects of fractionated proton irradiation

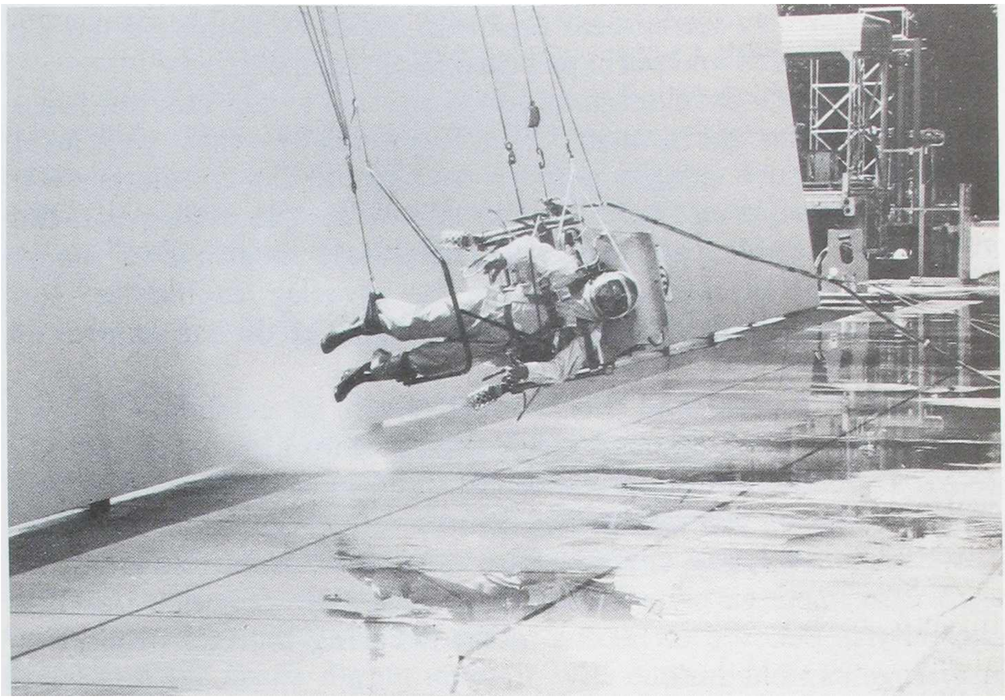


Figure 4–18. ICARUS in flight training.

on the lens of rabbit eyes. At the doses where definite blood changes start to appear, between 25 and 50 rads, in both the acute and fractionate exposures, some lens damage was found but no loss of visual acuity.

Man-Systems Integration

Design, construction, and man rating were completed of ICARUS, a flying vehicle developed to evalaute the handling characteristics of a backpack flying device in lunar gravity. It is controlled by hand and arm manipulations which vary the magnitude and direction of thrust of two independent rocket motor assemblies pivoted to rotate in the fore-aft plane. Flight training was started, using an inclined plane lunar gravity simulation technique. (Fig. 4–18) ICARUS will be used to determine the effects on handling of various control systems and pressurized space suits; the use of the pilot's feet as landing gear with a burden of approximately 300 earth pounds (50 lunar pounds) will also be tested.

Life Support and Protective Systems

Techniques used to supply oxygen to spacecraft crews were under study for application to tactical military aircraft as a means of eliminating the need for liquid oxygen systems. An electrochemical technique which uses a water electrolysis module and a carbon dioxide concentrator to produce oxygen was being developed. (Fig. 4–19) The system package, which will operate on a small amount of aircraft power, will include a rebreather to conserve the oxygen normally discarded in open-loop breathing and provision for a pressure breathing mode in a depressurized cabin. Design goals call for the system to generate oxygen at a rate equal to approximately 1.5 times the 0.10 pounds/hour metabolically consumed by the crew, to have an operating time of 10 hours (plus a 25 percent reserve) and a 5-minute turn-around time (water refill), to weigh less than 50 pounds and have a volume of less than one cubic foot, and to require less than 700 watts of power. Tests of an engineering prototype indicated that the system will meet or exceed the requirements.

A matrix-type water vapor electrolysis cell capable of operating directly from humid cabin air was designed, and a unit producing about 1/4 a man's daily requirement was being evaluated. (Fig. 4–20) The device has several advantages: it can produce more than enough oxygen to fulfill a man's requirement (about 2 pounds

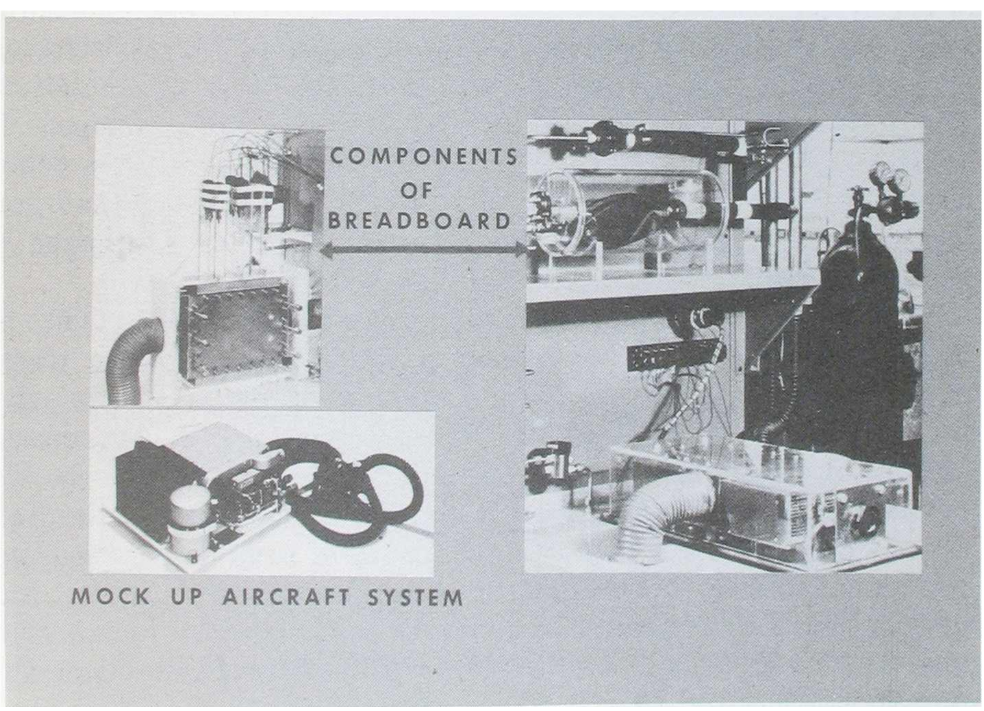


Figure 4–19. Components of oxygen supply system.

per day) and at the same time control humidity, the by-product hydrogen can be used for reducing carbon dioxide to generate additional water, and it is independent of gravity, eliminating the gas-liquid separation problem. Multi-man units were in the design stage.

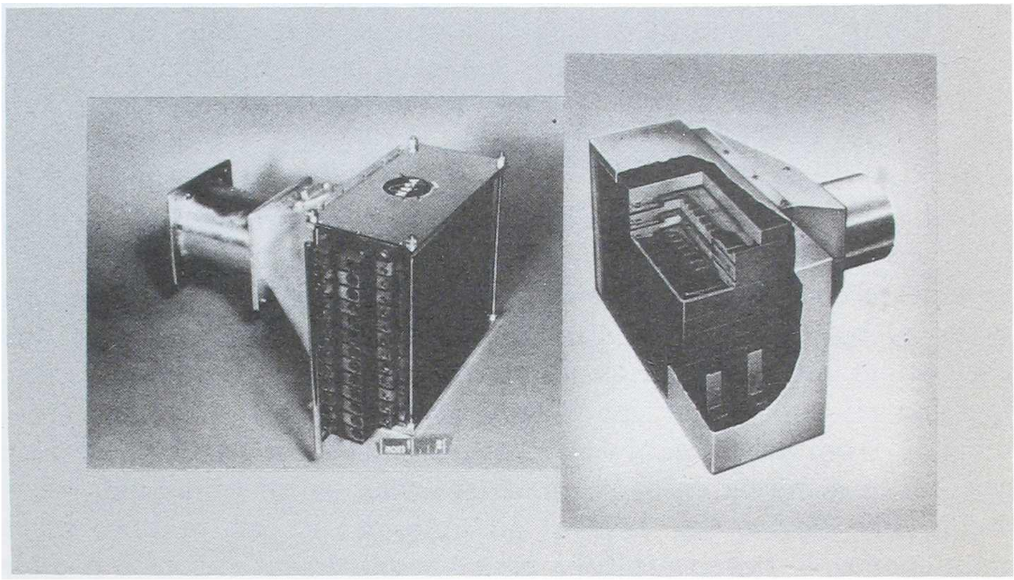
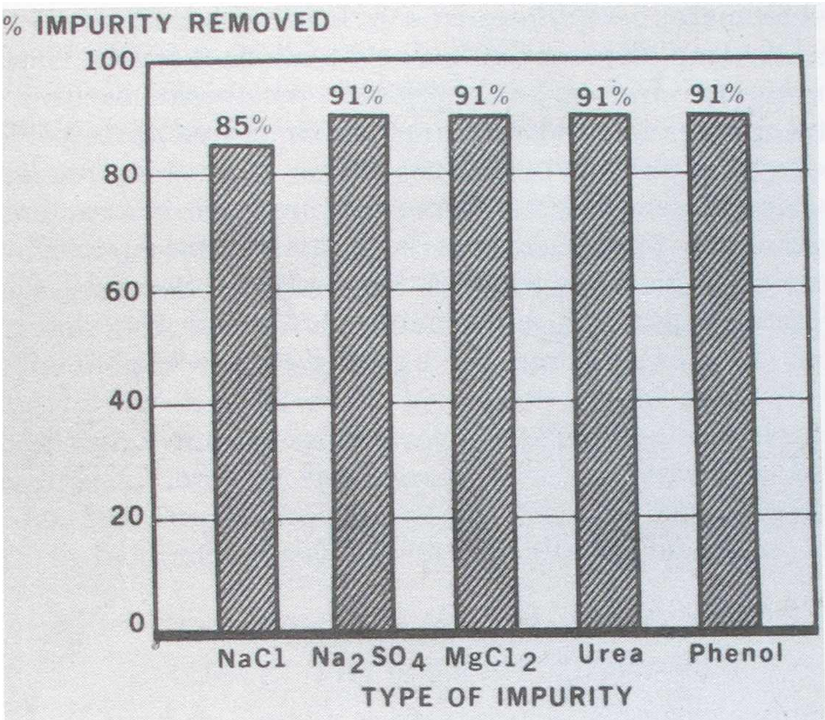


Figure 4–20. Water vapor electrolysis modules.

The NASA *Eighteenth Semiannual Report* (p. 90) reported a joint NASA/Federal Water Pollution Control Administration project on removal of organic wastes from water by oxidation. The special catalyst required for the process was developed. It oxidizes the organics in the gas phase at temperatures below 200°F and one atmosphere of pressure, but it appears that pre-treatment of the liquid effluent with the catalyst will make it possible to reduce the power and pressure requirements.

In another cooperative effort, this time with the federal Office of Saline Water, NASA investigated a technique for waste water purification which has space applications and may also help solve the problem of river pollution. In this technique, called reverse osmosis, water is forced through a membrane which removes impurities. The membrane must not rupture under the osmotic pressure of urine with its high concentrations of organic constituents. Such a membrane, consisting of porous glass hollow filaments, was developed and incorporated in a reverse osmosis water reclamation unit which will be evaluated in 1969 with both brackish water and human waste water. (Fig. 4–21)

Langley Research Center combined gas chromatograph and



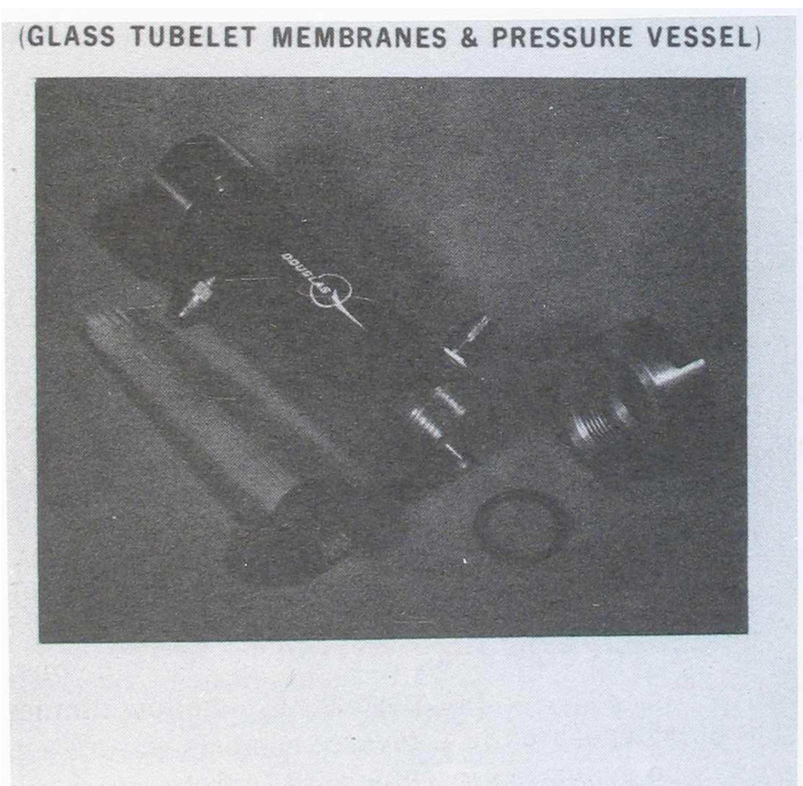


Figure 4—21. Water recovery test cell and performance.

mass spectrometer techniques in a hybrid sensor to provide accurate data on complex gas mixtures, even at trace levels. Gases such as sulfur dioxide and carbon monoxide which can occur in space cabin atmospheres in concentration as low as five parts per million can be detected by the hybrid sensor. Two laboratory models were evaluated and development efforts continued. An instrument based on this principle is expected to be provided for use by the air pollution control group of the U.S. Public Heath Service.

An intravehicular spacesuit being developed for the Manned Spacecraft Center features a lightweight (12 pounds design weight) low-bulk fabric. It provides the fit and comfort of shirt sleeves during unpressurized operations, can be quickly donned and doffed, and can be stored in minimal volume. The pressurization principle used is based on the expansion of trapped gas to provide a circumferential construction for mechanical pressurization.

ADVANCED PROPULSION SYSTEMS

The chemical propulsion program continued to have three broad objectives: to attain the best possible performance for advanced rocket engines; to advance economical concepts of developing and fabricating rocket propulsion equipment; and to improve the reliability of engine components.

Solid Propellant Systems

The NASA high energy restartable motor program moved ahead with the selection of a contractor to design and build a high performance 3,000 pound solid rocket motor with a quenching system, which can stop burning at any time, and an extra igniter to subsequently restart it. Studies showed that a motor of this type could add to the payload capability of present launch vehicles such as Atlas-Centaur and Delta.

Final negotiations were in progress for the initiation of a hybrid motor demonstration program. The motor, which will burn solid propellant fuel with a powerful liquid oxidizer, will weigh about 3,000 pounds and will be capable of thrust variation over a wide range and any number of stops and restarts. The specific impulse of the system will be 30 percent greater than that of a high energy all-solid motor, but the motor will have somewhat lower structural efficiency because of the requirement to carry tanks and valves. The first phase of the program calls for a firing of the basic configuration under simulated altitude conditions, although not in final lightweight hardware.

Advances in the technology of very large solid motors continued. Under a contract to develop low-cost welding procedures for HY 150 steel, test vessels were fabricated and burst to prove that flaws several inches long and 80 percent of the way through the wall thickness had only a minor effect on theoretical burst strength. Lack of sensitivity to large flaws means that reliability is higher, inspection procedures can be minimized, and that fewer repairs are necessary. The 50 percent lower initial cost of the steel and the reduced cost of inspection and repair may make large motor case costs 20–50 percent lower than those of the maraging steels now in use.

A contract was let to determine why unburned propellant was ejected from the last 260″ solid motor firing (June 1967, *17th Semiannual Report,* p. 99). (Fig 4–22) Flow characteristics of

Figure 4–22(a). Propellant chunks ejected in 260″ motor test.

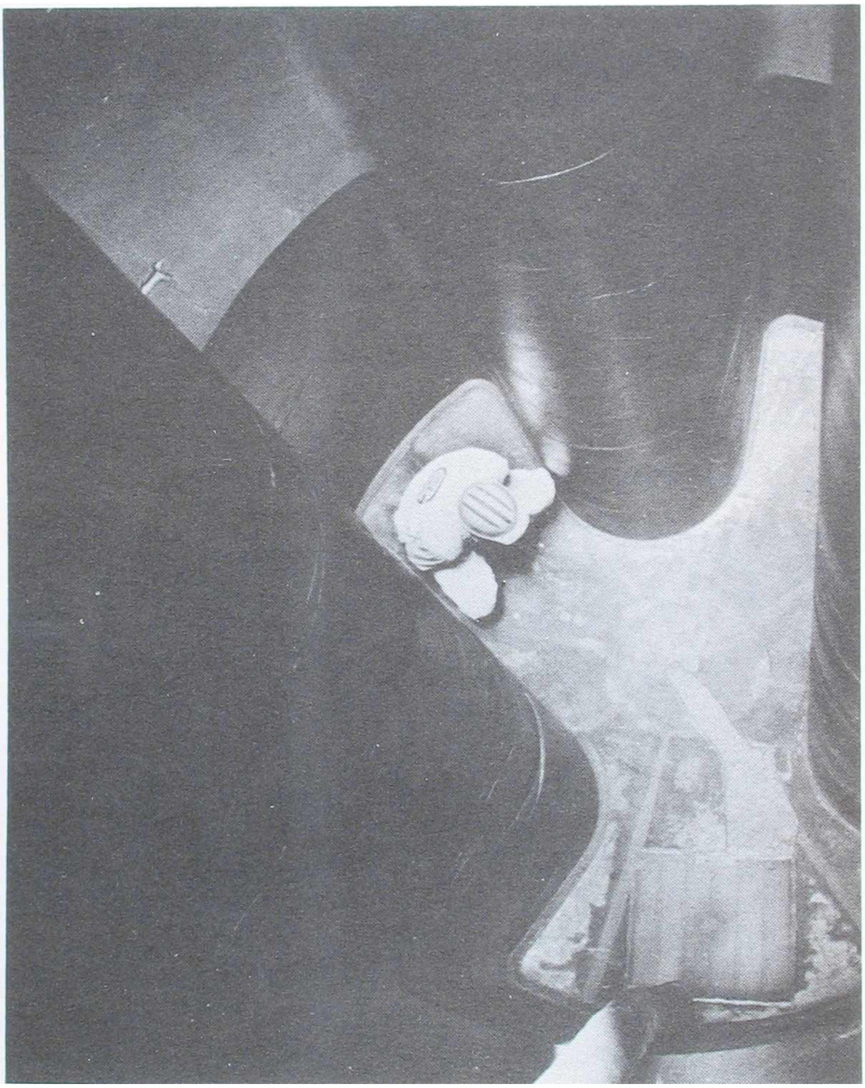


Figure 4–22(b). Bonding imperfections show-up at core surface as striations.

the highly viscous propellant as poured in the large motor were found to be considerably different from those theorized, and these peculiar flow patterns could have caused the displacement of 'old' propellant to the motor walls resulting in a poor bond. Weakly bonded propellant would have been ejected near the end of burning, as it was in the 1967, 260" motor test.

Tests of lower cost nozzle ablative materials proceeded successfully. Three tests of 8-inch-diameter nozzles indicated that price reductions of about 20 percent could be made almost immediately by selecting different materials. A compression molded material which could reduce cost by as much as 80 percent showed some promise in early tests.

For unmanned planetary missions, hardware must be subjected to sterilization procedures involving the application of 250°F heat in six 53-hour cycles. Such heat can adversely affect propellants that are to be heat sterilized, as was evidenced in early tests with conventional propellant formulations, which swelled during sterilization.

Considerable research has been carried on during the last several years to develop new liquid prepolymers with backbone of saturated hydrocarbon chains to replace conventional prepolymers such as polybutadenes and polyethers, which have molecular structures too easily attacked. The outgrowth of this work is a number of new materials with more stable characteristics.

Jet Propulsion Laboratory investigators developed and tested a comprehensive theory which can relate the properties of the vast number of possible synthetic rubbers to the different chemical structures. The ability to predict the physical qualities of various compounds is important to NASA's chemical propulsion work—both for solid propellant binders and for liquid propulsion bladders. In addition, such theory has direct implications for predicting long term behavior of rubbery materials in such problem areas as tires, sealants for high speed aircraft fuel tanks, and rubber components in general, such as shock mounts.

Liquid Propellant Systems

A 250,000-pound-thrust plug nozzle thrust chamber, called an "aerospike" because it employs an aerodynamically-formed plug for expansion of the rocket exhaust gases, was tested at altitude conditions simulating the flight regime of a launch vehicle. (Fig. 4–23) The aerospike engine design gives better overall performance through the wide environmental range encountered by the booster stage of a vehicle, than a nozzle of conventional design. In addition, this type engine is short and may prove advantageous for boost and entry vehicles that do not have circular aft-end cross sections. The tests conducted during this period are the latest step in an investigation of unconventional nozzle designs begun in 1961.

Research on space storable propellants included verification of their theoretical performance by testing oxygen difluoride or

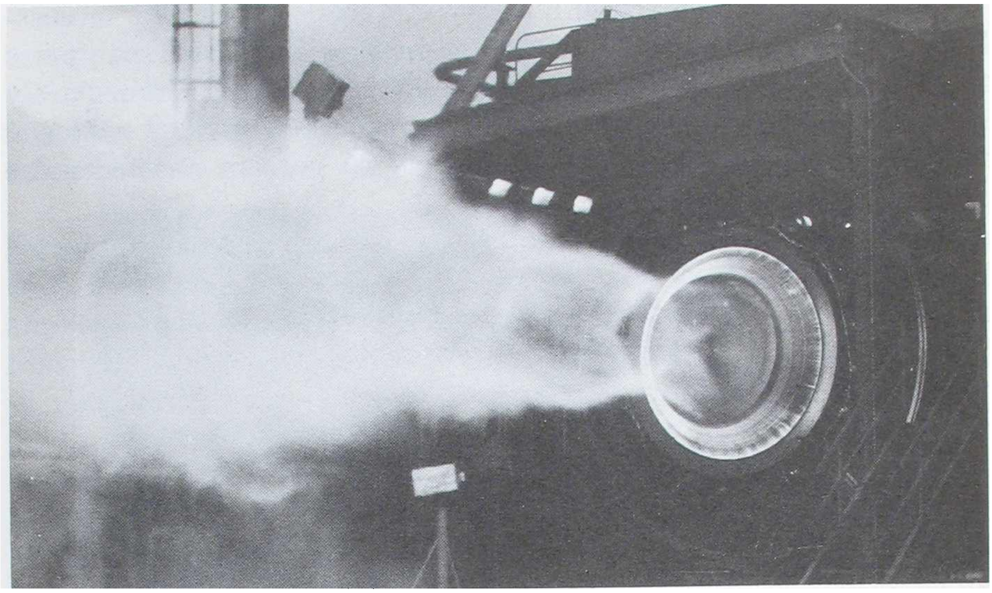


Figure 4–23. Aerospike engine test.

oxygen-fluorine oxidizer mixtures with methane and diborane fuels. The accurate assessment of performance derived from the tests makes it possible to compare the new class of propellants with older combinations and to begin preliminary design of new spacecraft configurations using these propellants. The space storable class has an approximately thirty percent specific impulse advantage over the storable propellants in use on Apollo and other current spacecraft and is much easier to store for long periods of time than the high performance hydrogen-fueled combinations. Thermal design studies were conducted for hypothetical planetary missions, and preliminary engine designs were prepared. The space storable technology will be a significant addition to NASA's overall capability in spacecraft propulsion, and efforts will be increased to ready it for development as part of the new planetary programs proposed for the 1970's.

Research on minimizing the inert weight and size of the very high performance *tripropellant* engine system developed the idea of introducing the fluorine, hydrogen, and lithium in a close-coupled combustor rather than in a three-stage device. Preliminary design layouts of possible engine concepts were made and weights estimated to provide a basis for evaluating the performance obtainable from various versions of tripropellant engines in future space vehicles.

A project was started to investigate the possibility of achieving very long propulsion system life in space (or orbit) by repairing or refurbishing the system in place. To develop such techniques it will be necessary to investigate methods of avoiding or contending with leakage while refueling, minimizing extra-vehicular activity to replace components, and modifying component design to facilitate replacement. The development of such technology would lead to improved space orbiting workshops and other nearly permanent space installations.

Research on the problems associated with handling slush hydrogen on the ground indicated that equipment modifications will be necessary. Slush hydrogen can absorb substantially more heat without vaporizing than can liquid hydrogen. This characteristic permits it to be stored longer on space vehicles, or the weight of the insulation to be reduced. However, it is this heat absorption capability that causes problems in standard ground handling equipment,—for instance by chilling vacuum jacket "O" rings until they no longer seal.

Small auxiliary propulsion systems with very low thrust levels to provide spacecraft position and attitude control for precise experiments and communications were tested. A system using liquid hydrazine as a propellant was tested and showed considerable advantage over existing gas systems in weight and efficiency. The single liquid propellant is converted to a gaseous state through catalytic action, eliminating the need for heat or power addition, and is stored in light weight, low pressure tankage. Another project developed very accurate miniature valves to meter the gaseous propellants to small thrust nozzles for vehicle control, which in some cases requires thrust measured in thousandths of pounds.

BASIC RESEARCH

Fluid Physics

In research on gas dynamic techniques, theoretical predictions indicated that continuous power levels a thousandfold greater than those available from conventional lasers may be attainable at efficiencies a hundredfold better. An experimental program was established to validate the various gas dynamic laser concepts—gas expansion, plasma expansion, chemical excitation mixing lasers, and magnetoplasmadynamic (MPD) arc configurations. During this period, lasing action was achieved experimentally in both the gas expansion and MPD concepts. In the former, an existing shock tube was modified by the addition of an expansion nozzle on the end wall. Various mixtures of gases were tried in the facility and lasing action was attained. A program was instituted to investigate the gas dynamic details, chemical kinetics, and lasing mechanisms.

NASA is already using such a laser as a materials test facility to simulate radiant heating rates associated with high speed entry. Future possible laser applications include space communications, space power generation and transmission, and fog removal at airports. The new laser concepts are also expected to have a major impact on industrial technology—in such applications as the chemical processing and ore reduction industries.

Applied Mathematics

At Langley Research Center and the Jet Propulsion Laboratory, mathematicians developed mathematical techniques which, when applied to a very precise analysis of lunar orbiter motions, proved the existence of large concentrations of mass 50 to 100 miles below the surface of the moon. The correlation between the location of the mascons and several circular lunar seas indicated that the masses are probably metallic concentrations involved in the formation of these seas, i.e., either impacting nickel-iron asteroids or upwelled denser lunar core material. Their influence on the motion of a close lunar orbiting spacecraft can be significant, and consequently this discovery has immediate application to Apollo operations as well as to space science research.

Materials

Lubrication.—High vacuum techniques and new scientific instruments for examining metal surfaces on an atomic scale gave increased understanding of the basic nature of lubrication. In one study, perfectly clean metal surfaces were rubbed across one another in controlled crystallographic directions, then various gases were introduced in amounts corresponding to a layer less than 1-atom thick. The results indicated that the presence of any such absorbed layer will reduce adhesion and friction. When the adsorbed gases were hydrocarbons, the results were especially significant since commercial lubricants are mixtures of hydrocarbons. Hydrocarbons with long chain lengths were found to be more effective in decreasing friction than those with short chains, and hydrocarbons containing unsaturated bonds, such as acetylene, were more effective than those, such as ethane, without these bonds. The results give an insight into the effect of these foreign materials upon the bonds between metal atoms, although they must be applied with caution to everyday lubrication situations where the lubricant is many atom layers thick. They are more directly applicable to the "boundary lubrication" situation where the lubricant layer is very thin and direct metal-to-metal contact is approached. Such a situation is likely to occur in space, where lubricant supplies cannot easily be replenished.

Diffusion in Materials.—Many of the mechanical and physical changes in materials which occur at elevated temperatures are caused by the migration of atoms within the materials,—a process called diffusion. Diffusion is responsible for such varieties of behavior as the hardening of steel, oxidation of metal surfaces, mechanical creep, and the introduction of charge carriers in electronic devices such as transistors. Studies at the Lewis Research Center produced new, more advanced theoretical calculations of atomic motion (diffusion) in metals, yielding significantly greater ability to calculate the energy required for atomic migration and the rates of diffusion. Research is continuing to further refine and extend this method of predicting diffusion rates from theory. Expanded knowledge of diffusion reactions in solids may lead to the ability to control such reactions, thus increasing the likelihood that materials will perform more satisfactorily on missions.

High Temperature Polymers.—Pyrrones, a new class of heat resistant plastics discovered by Langley investigators (*13th Semiannual Report,* p. 116), were being developed for potential aerospace and aeronautical applications as films, foams, composite resins, and moldings. One result of the work was a modified process for making Pyrrone molding powders which gives moldings greatly improved thermal resistance. Preliminary tests showed the improved moldings to be at least twice as strong and rigid as commercially available polyimide moldings at temperatures up to 900°F. (Polyimides serve as a bench-mark for comparsion since present plans call for their use in SST applications.) The improved ability of these modified Pyrrones to retain strength over relatively long periods at elevated temperatures suggests that the new processing technique refined the chemical structure of the polymers with the resultant improvement in strength properties. Research will be continued to establish their long-time service-life for advanced aircraft and spacecraft applications.

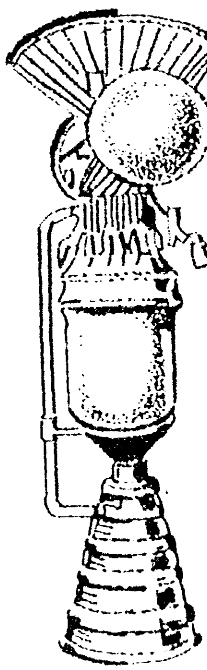
Electrophysics

Ammonia molecules were recently detected for the first time outside the solar system by an investigator (Nobel Prize winner Charles H. Townes) working under a NASA grant at the University of California, Berkeley. Using a new ultrasensitive 20-foot radio telescope and scanning the region of Sagittarius near the center of the Milky Way galaxy, a region about 8.5 minutes of arc in diameter was found in which characteristic ammonia (NH_3) radiation at a wavelength of about 1.25 cm was present. In addition to this main spectral line of ammonia, a second line corresponding to a different transition in the ammonia molecule was found, adding to the certainty of the identification.

The significance of this finding is that to date only a simple molecule like hydroxyl (OH) has been found in the far reaches of our galaxy, and it was supposed that more complex molecules could not be formed in interstellar space. The fact that the ammonia density and temperature can now be measured at a distance of many light years makes possible its use as a probe for determining some of the conditions at the center of the galaxy. This can be done, for example, by noting the behavior of NH_3 as it interacts with its surroundings. Since ammonia is of special significance as a possible stepping stone in the formation of primitive living organisms, this finding provides a strong basis for the possibility of life forms beyond our solar system.

Research was initiated on an electron beam oscillator which uses a spiral electron beam instead of a beam which follows the usual linear path. The advantage of the spiral beam is that it can be made to interact with millimeter or submillimeter modes of a resonant cavity having sufficiently large dimensions for practical use. To produce the spiraling beam, magnetic fields are employed, and varying the intensity of the magnetic field changes the diameter of the beam spiral and so makes possible tuning of the output frequency. In preliminary tests, a 20 milliampere beam spiraling in a 3.5 kilogauss magnetic field produced a 3 watt continuous output at a wavelength of about 3 cm. Work continued with the objective of increasing the magnetic field so as to obtain first an output at 3 millimeters, and then at even shorter submillimeter wavelengths.

In studies to improve the efficiency of space propulsion, attention was centered on systems utilizing plasmas at very high power density. Such energetic plasmas were created in a rapid plasmadynamic process in which large amounts of stored electrical energy were suddenly discharged to accelerate the plasma and subsequently to randomize that energy in a collapse called "plasma focus." The energy content of such plasmas is equivalent to that of matter in the interior of stars. When deuterium was used, nuclear fusion occurred, as was shown by the detection of neutron bursts emitted from the plasma. Research in this period was directed toward making an accurate spectral analysis of this neutron emission to determine the degree of randomization of the kinetic energy and the temperatures of the electrons and ions in the plasma.



5 THE NUCLEAR ROCKET PROGRAM

The objective of the joint NASA/AEC nuclear rocket program is to provide a significant increase in propulsion capability for future space activities. To achieve this objective a number of key goals must be attained: providing the basic technology for nuclear propulsion systems; developing a NERVA engine of approximately 75,000 pounds thrust for flight applications; extending the technology of graphite reactors and engine system components, thus establishing the basis for improving nuclear rocket performance; furnishing the technology for a nuclear flight stage; and investigating advanced concepts.

During the second half of 1968, NASA and AEC made further progress toward the identified technology goals, Highlights included completion of tests on the high-power Phoebus–2A reactor and the Pewee–1 reactor, and the initiation of tests on the ground-experimental engine (XE). Laboratory tests revealed significant advances in fuel element technology, indicating that the high temperature and power-density levels required for the NERVA flight engine have been exceeded.

Work continued on the preliminary design of the NERVA engine based on the data produced by the NERVA technology program. Facility modifications required to test the NERVA engine using the existing ETS–1 engine test stand at the Nuclear

Rocket Development Station were further defined. Test Cell "C" will be used for NERVA reactor testing.

STATUS OF REACTOR TECHNOLOGY

The endurance goals established for the NERVA reactor technology phase of the program were accomplished with the full-power endurance demonstration of the NRX–A6 reactor (December 1967). The test of the Phoebus–2A reactor and the advances in fuel-element technology satisfied all the remaining reactor technology goals.

Phoebus-2A Reactor

The Phoebus–2A (Fig. 5–1) reactor was designed and developed by the Los Alamos Scientific Laboratory (LASL) for a reactor test program to provide technology for high-power, high-temperature rocket reactors (*19th Semiannual Report*, p. 102). Although this purpose was no longer primary when the thrust level of the proposed NERVA engine was reduced to 75,000 pounds, the Phoebus–2A test program continued to be used to obtain data on reactor technology. The major experiment of the Phoebus–2A test program was conducted on June 26, 1968, (*19th Semiannual Report*, p. 102). On July 18, the reactor was restarted for a series of experiments at low and intermediate power levels to provide essential performance data for a wide range of operating conditions. The reactor operated over a range of power levels up to 3670 megawatts, and for a total time of approximately 30 minutes. The tests were highly successful and all required data were obtained.

Fuel Element Materials Research

The results of tests of improved fuel elements (*19th Semiannual Report*, p. 104) indicated that the temperature and thus specific impulse performance requirements for the NERVA flight engine have been achieved.

The Pewee Reactor Program

Two major milestones were achieved in the Pewee reactor program. The first involved completing modifications at Test Cell "C" for Pewee-reactor testing. This work consisted primarily of installing a new liquid hydrogen feed-system turbopump and making minor changes in certain lines and valves to accommodate the reduced-flow requirements. The second milestone achieved was the completion of power tests on the Pewee-1 reactor. (Fig. 5–2).

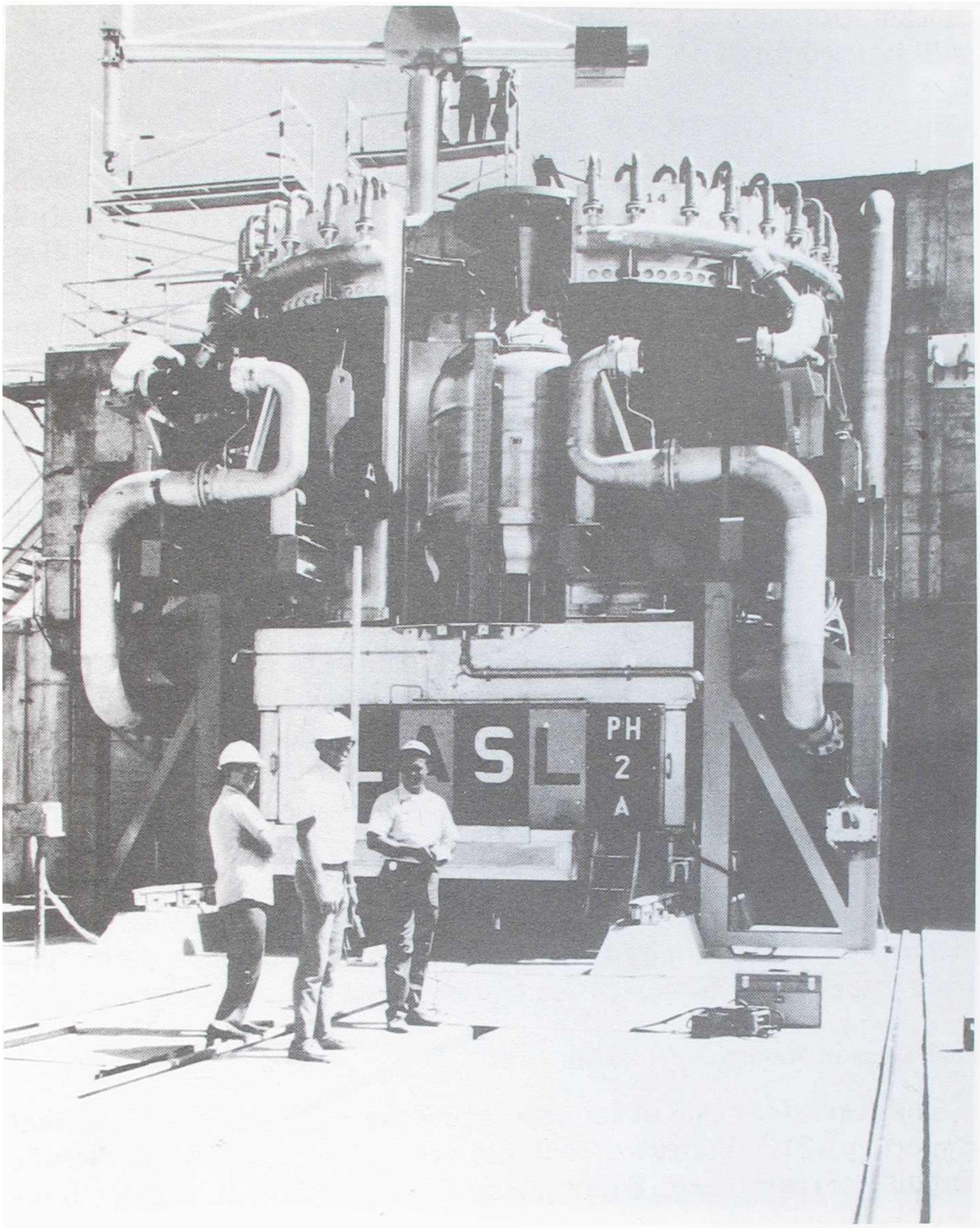


Figure 5–1. The Phoebus–2A reactor.

The major experiment of the Pewee–1 test program was conducted in December. During it, the reactor was operated at significant power levels for about 1-1/2 hours. Two separate cycles at power levels over 500 megawatts consumed more than 40 minutes of the operation. Such power levels were about half those of previous KIWI and NERVA technology reactors. The reactor oper-

Figure 5–2. The Pewee–1 Reactor.

ated stably and reached a temperature of 4140°F (4500°R), the highest operating temperature yet achieved in the nuclear rocket program. In addition, power densities were higher than ever achieved before. The December test was the second power operation of the Pewee–1; the first was conducted in November at part power for 40 minutes to determine the overall operating characteristics of the Pewee reactor design.

STATUS OF NERVA ENGINE SYSTEM TECHNOLOGY

In the NERVA engine system technology phase, major emphasis was placed on preparing for testing of the ground-experimental engine, the XE, at the NRDS. (Fig. 5–3)

The XE engine is an experimental system designed to duplicate the arrangement of components and to function like a flight engine. Earlier, a "breadboard" engine consisting of similar components, arranged for convenience on a reactor test car, was tested in the first demonstration of a nuclear rocket engine operating as a self-contained power plant. The breadboard engine was tested with the exhaust nozzle pointing up, as in previous tests of reactors, and the hot hydrogen exhaust was expelled directly into the atmosphere.

The XE engine is designed to be tested in the downfiring position and under simulated altitude conditions to approximate the operation of a rocket engine in a space environment. ETS–1 at NRDS provides these test conditions. (The checkout of ETS–1 is described in the *19th Semiannual Report*, p. 106.)

As planned, the XE engine was installed in ETS–1 in October. Preliminary checks and tests conducted to assure that the engine and stand were ready for operation were completed in early December, and then the first experiments in the XE engine test program—an initial criticality check and calibration run—were conducted.

After these experiments, the engine was temporarily removed from the test stand to the Engine Maintenance, Assembly, and Disassembly (E–MAD) building. Following other test events at the site, the engine was reinstalled and testing resumed.

STATUS OF NERVA ENGINE DEVELOPMENT

The NERVA development effort will provide a flight engine with approximately 75,000 pounds thrust and a specific impulse of 825 seconds, capable of performing a wide variety of advanced missions likely to be called for in the future space program (*19th Semiannual Report*, p. 106).

Preliminary planning and design work for development of the engine continued; areas of primary interest were determining engine requirements, evaluating design alternatives, and conducting preliminary design studies. The primary engine requirements are high performance, manned rating, high reliability, and safety. Other design requirements include the ability to withstand a space vacuum for relatively long periods both before and after

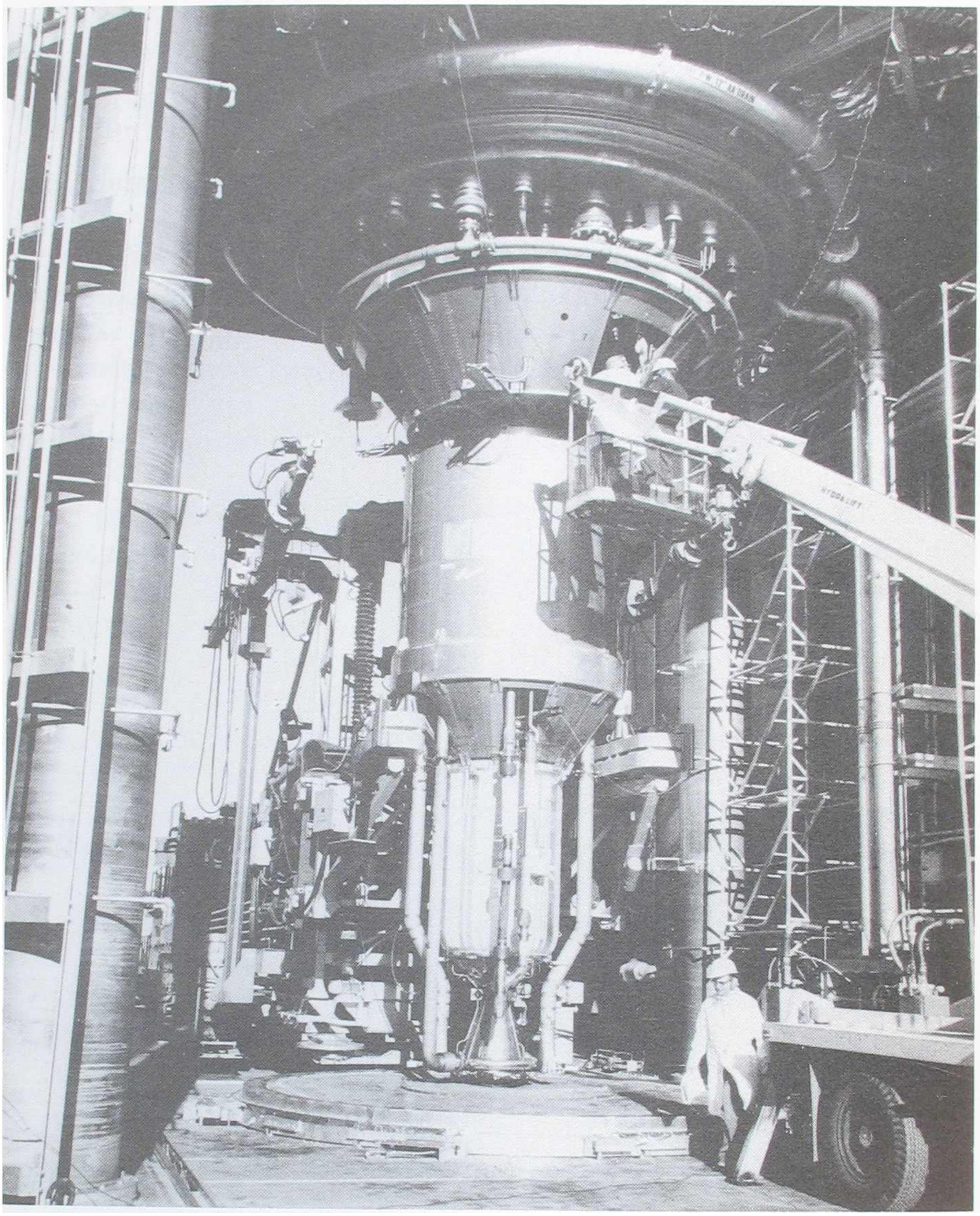


Figure 5–3. Ground Experimental Engine (XE).

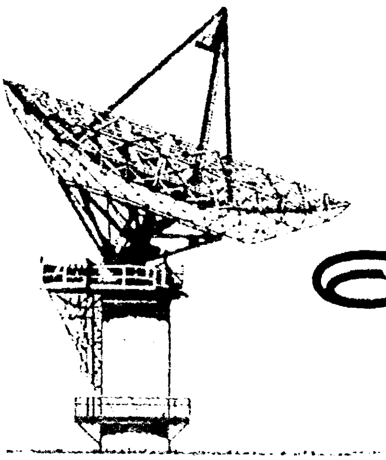
firing and adequate shielding to protect both the propellant and the crew.

The NERVA program provides for a series of reactor and engine tests, which include qualification tests supported by component development to demonstrate performance and reliability. This testing and the supporting analysis and documentation will provide a propulsion system suitable for vehicle application.

Test Cell "C" will be used to conduct all NERVA reactor tests, and the NERVA engine will be tested in ETS–1. However, the hot hydrogen exhaust system, propellant plumbing, and altitude simulation system of ETS–1 will have to be modified to permit full-power testing of the engine.

ADVANCED NUCLEAR ROCKET CONCEPTS

In this area, experimental and theoretical work was continued on two advanced ideas: the light bulb concept and the coaxial flow concept (*19th Semiannual Report,* p. 106).



6

TRACKING AND DATA ACQUISITION

The NASA tracking and data acquisition networks again supported a large number of space missions, including earlier launched spacecraft and fourteen launched during this period. Among the major missions were Pioneer IX, Orbiting Astronomical Observatory (OAO) II, Radio Astronomy Explorer (Explorer XXXVIII), Apollo 7, and Apollo 8.

The December launches alone illustrate the wide variety of space flight projects supported by the networks: An international cooperative project (HEOS–I); a satellite for the Environmental Science Services Administration (TOS–F); a commercial communications satellite for ComSat (INTELSAT III); a NASA scientific satellite (OAO–II); and the Apollo 8 mission.

MANNED SPACE FLIGHT NETWORK

The Manned Space Flight Network played a vital role in supporting the first manned Apollo mission, Apollo 7. (Fig. 6–1) Launched October 11, this earth-orbital eleven-day flight placed many first-time support requirements on the network. One such requirement was the real-time reception and relay of television transmissions from the astronauts.

After a highly satisfactory performance, extensive network checkouts and simulations were begun in preparation for the first manned lunar mission, Apollo 8. Such realistic simulations, designed to assure constant operational readiness of facilities, equipment, and personnel, are conducted before each Apollo flight and contribute significantly to the reliability of the network.

The success of the Apollo 8 mission, launched December 21, stressed the importance of the network in support of manned space flight projects. The mission clearly demonstrated the net-

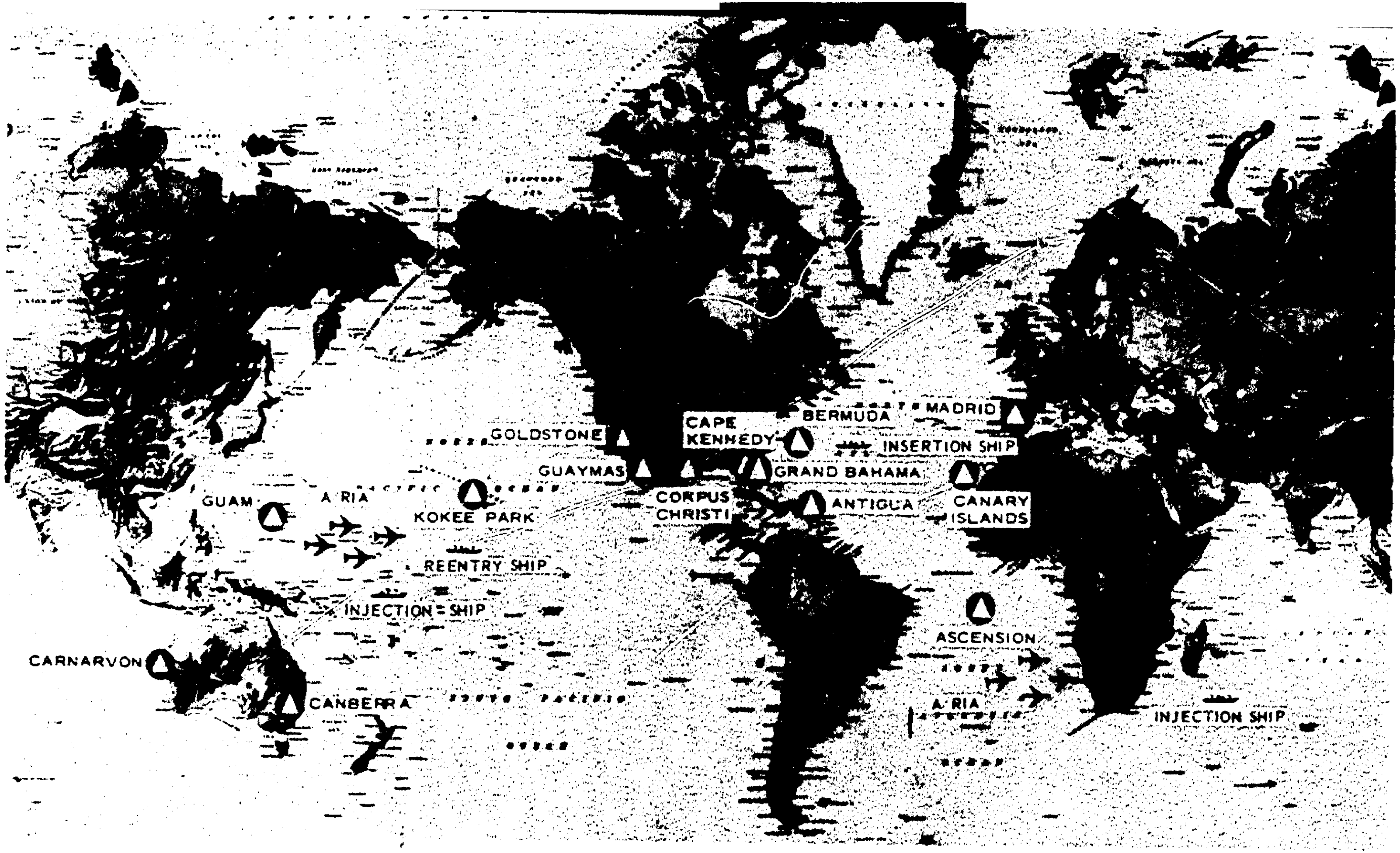


Figure 6–1. The Manned Space Flight Network.

work's ability to track and communicate with spacecraft at lunar distances, a prerequisite for a successful manned lunar landing. Voice communications with the astronauts were excellent throughout the mission, and the telemetry received by the network provided data essential to mission control in its assessment of launch vehicle, spacecraft, and astronaut functioning.

The Unified S-Band System—a sophisticated electronic tracking, command, and telemetry system installed in the network specifically for Apollo lunar mission navigation and control—operated in an outstanding manner. (Fig. 6–2) Actually, it exceeded the flight project's requirements for tracking accuracy and communications quality. This accuracy contributed significantly to the Apollo 8 spacecraft's precise navigation to and from the moon. The network's performance during this mission conclusively demonstrated that the navigational accuracies required for the lunar landing mission can be achieved.

The quality of in-flight television from the Apollo 8 spacecraft was noticeably better than that from Apollo 7. This was a result of the network improvement program in which the capability of the network is continuously updated to incorporate important new advances.

Besides improving the network's tracking, communications, and television capabilities, NASA began work aimed at reducing the time required for the network to switch its mode of support from one flight mission to the next. Such time reduction is very important to future requirements for the network to support both Apollo Applications multi-spacecraft rendezvous missions and experiment packages left on the lunar surface by Apollo astronauts. The improvement is necessary also to allow for the network's cross-support of future unmanned planetary missions. The turnaround time must be much less than the network's present capability permits.

SATELLITE NETWORK

The Satellite Network also continued to carry a substantial workload. (Fig. 6–3) This is the network which supports all of NASA's scientific and application satellites. In addition, these facilities furnish support to a wide variety of space projects conducted by other government agencies, by private industry, and through cooperative international programs. The network participated in the Apollo mission by providing priority support to the orbiting ATS–III and IMP–IV spacecraft so that their vital proton monitoring information could be sent to the Mission Con-

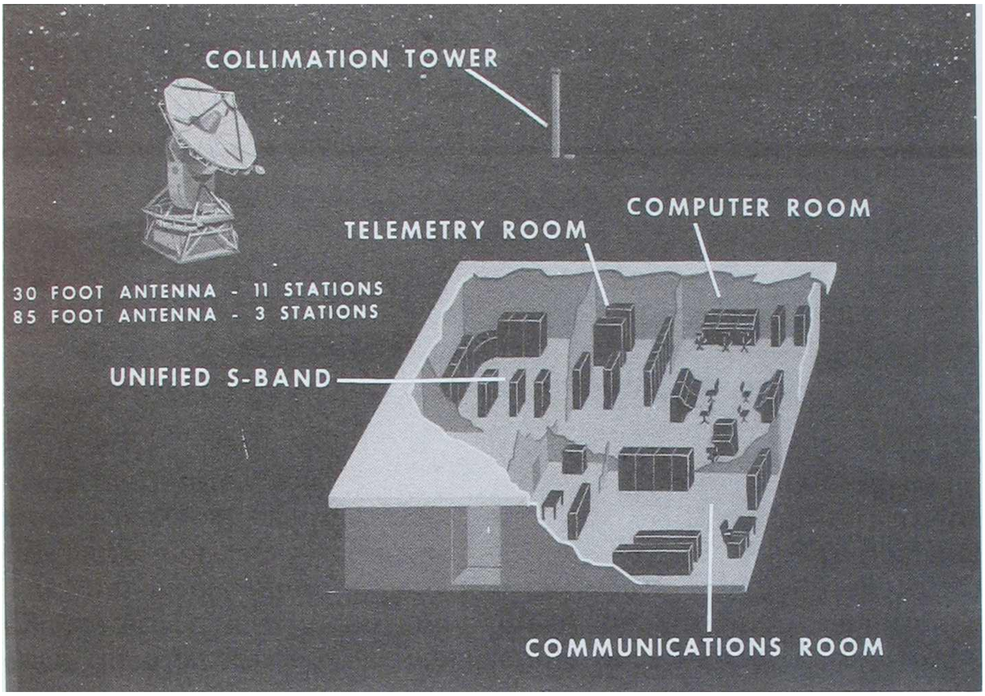


Figure 6–2. Typical Apollo Unified S–Band Station.

trol Center at Houston, and the Space Disturbance Forecast Center at Boulder, Colorado, during the flight.

In terms of the total number of satellites supported, the Satellite Network bears the heaviest workload of all the NASA tracking and data acquisition facilities. The eight successful satellites launched during the report period, together with the still active satellites in orbit, require around-the-clock operation of the network.

Although the number of satellites to be supported has an effect on the workload of the network, another significant factor is the nature and complexity of the new satellites. Most noticeable are the growing requirements to send data to the satellite from the ground. These "up" data are more than commands; they are much like a conversation between the ground and the spacecraft. A particular order is given and the satellite's response is telemetered to the ground. Here, the data are analyzed and appropriate changes are issued. All this takes place in essentially real time, thereby committing both command and telemetry equipment to the spacecraft for the entire pass period.

Two of the satellites launched during the period, the Radio Astronomy Explorer (RAE) and the Orbiting Astronomical Obser-

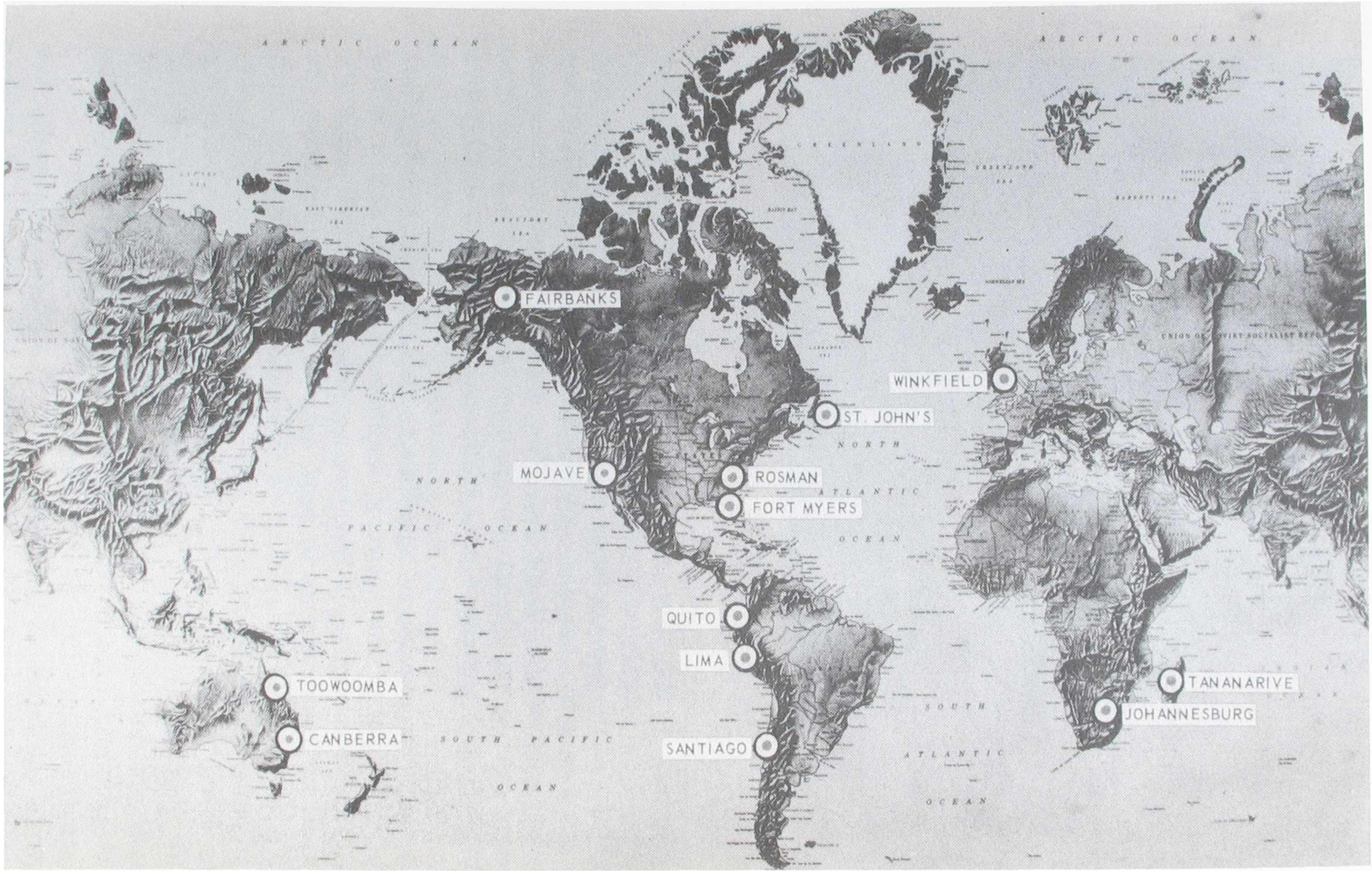


Figure 6–3. The Satellite Network.

vatory (OAO), typify this mode of operation in that they place very demanding requirements on the network for real-time command and control of the spacecraft.

The prime experiment on Explorer XXXVIII (RAE) required the deployment, in orbit, of the spacecraft's two antenna booms to a maximum length of 750 feet each. The antennas were successfully extended by a series of radio signals originated at the project control center and transmitted via the network tracking stations. After each command transmission, the network monitored the spacecraft's response and relayed these data and pictures of the boom tips back to the control center.

The booms were extended so precisely that very little motion was imparted to the spacecraft proper. At present, pictures of the antenna booms are taken only once a month, evidence of the small amount of whipping which the 750-foot booms are experiencing. At period's end, the spacecraft measured 1,500 feet from tip-to-tip—about 5 times longer than any object previously placed in space. The real-time command and control capability contributed significantly to the success of Explorer XXXVIII and was a major technological achievement by NASA.

OAO–II, launched December 7, is the most complex scientific satellite flown to date. Because this spacecraft is literally flown from the ground, it placed unprecedented support requirements on the network for real-time commands. The entire mission is under the control of a computer program having approximately 250,000 instructions. The computer continuously monitors hundreds of spacecraft status points and compares them against its own predicted values. It computes and issues the gimbal angles for the on-board star trackers so that the observatory can lock on to the proper stars among the 50,000 which OAO will ultimately study. Every attempted change of the spacecraft's position and condition is analyzed by the computer to prevent improper or impossible operations.

During the first 3 weeks of the mission, more than 40,000 commands were issued to OAO. The network was receiving data which should provide astronomers with their first detailed ultraviolet map of the stars.

DEEP SPACE NETWORK

During the report period, the Deep Space Network (Fig 6–4) provided substantial support to the Pioneer Program. Pioneer IX, launched on November 8, added to the workload of the network

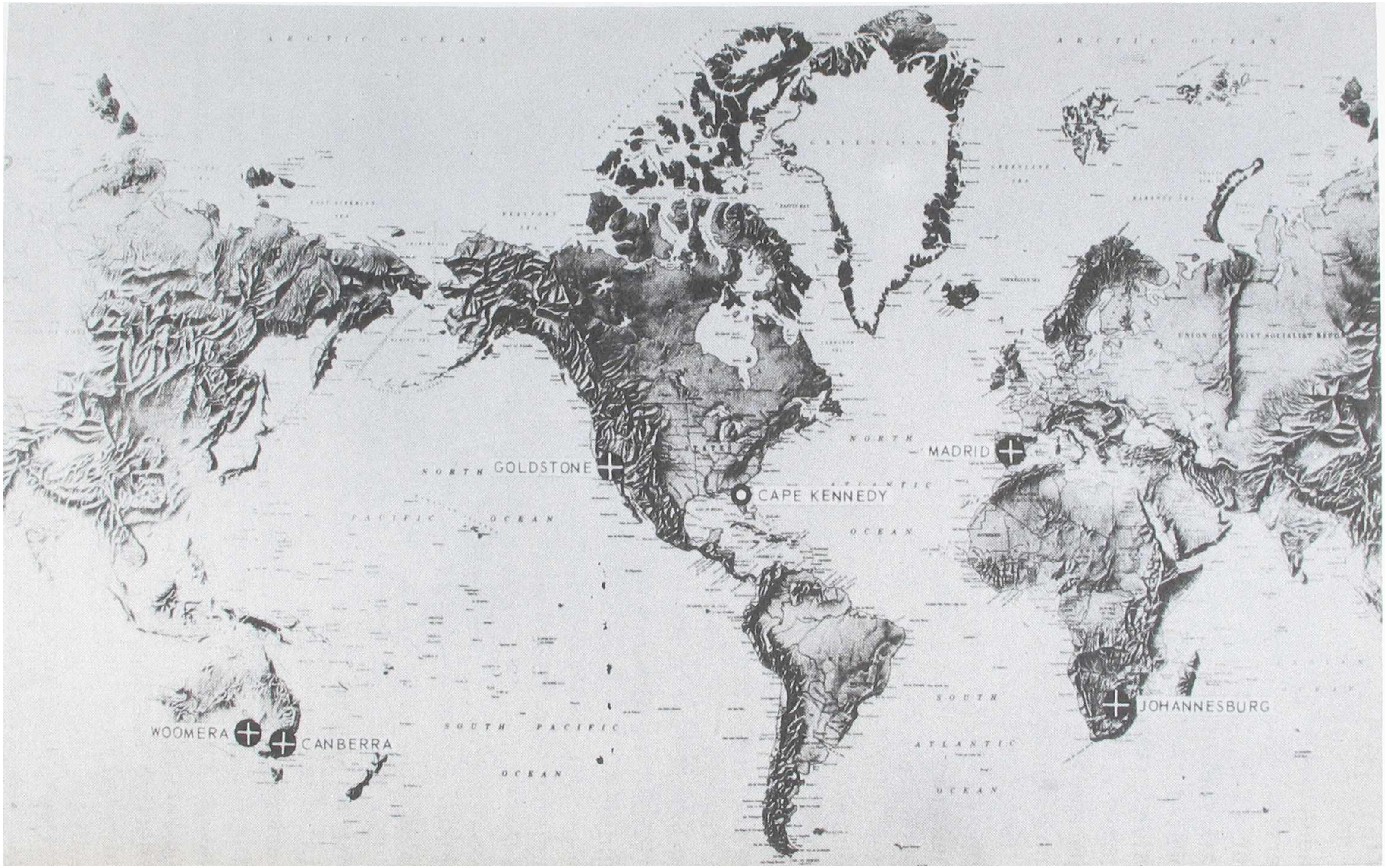


Figure 6–4. The Deep Space Network.

which supported, throughout the period, the on-going Pioneer VI, VII, and VIII missions.

The Pioneer spacecraft are now providing scientists with four independent space stations located in the ecliptic plane and are serving, along with other satellites, as "solar weather stations" in our solar system. The network's capability to track and acquire data simultaneously from at least three of the Pioneer spacecraft, located around the sun, makes it possible to determine the angular spatial distribution and the flow behavior of solar fields and particles. The ability to acquire and correlate data from these spacecraft within a short period of time is greatly expanding knowledge of the solar system.

In late November, the network supported a "first time" science opportunity offered by Pioneer VI. Launched in December, 1965, the spacecraft had moved to a position opposite the sun from the earth, more commonly referred to in astrophysics as superior conjunction. Since the Pioneer spacecraft antenna transmits a linear polarized signal, the propagation of the signal through the corona of the Sun enabled indirect measurement of its magnetic properties by determining the extent of Faraday rotation upon the signal. These measurements (now being analyzed) were received by the 210-foot Goldstone antenna during both the entrance and the exit phase of the Pioneer VI superior conjunction.

While the network was supporting the Pioneer missions, its equipment was being augmented to support the dual Mariner '69 spacecraft on their flyby mission to Mars. The added equipment, made necessary because of new telemetry coding techniques used in the design of the spacecraft, will allow considerably more data to be returned to the ground. For example, through the use of the Goldstone 210-foot antenna, NASA expects to obtain high quality TV pictures of Mars as each spacecraft approaches the planet.

The Goldstone 210-foot antenna (Fig. 6–5) in conjunction with an 85-foot antenna, conducted first-time radar observations of the asteroid Icarus (*19th Semiannual Report*, p. 117). The remarkable receiving capability of the 210-foot antenna made possible the experiment which provided the first quantitative information on the characteristics of the asteroid. Preliminary analysis of data, based upon assumptions that the asteroid's radar reflective surface is similar to those of the Moon and Venus, indicated that Icarus is rotating once every 2½ hours and has a radius of about ¼ mile.

Also during the period, the network participated in radio astronomy experiments. NASA used the 85-foot and 210-foot an-

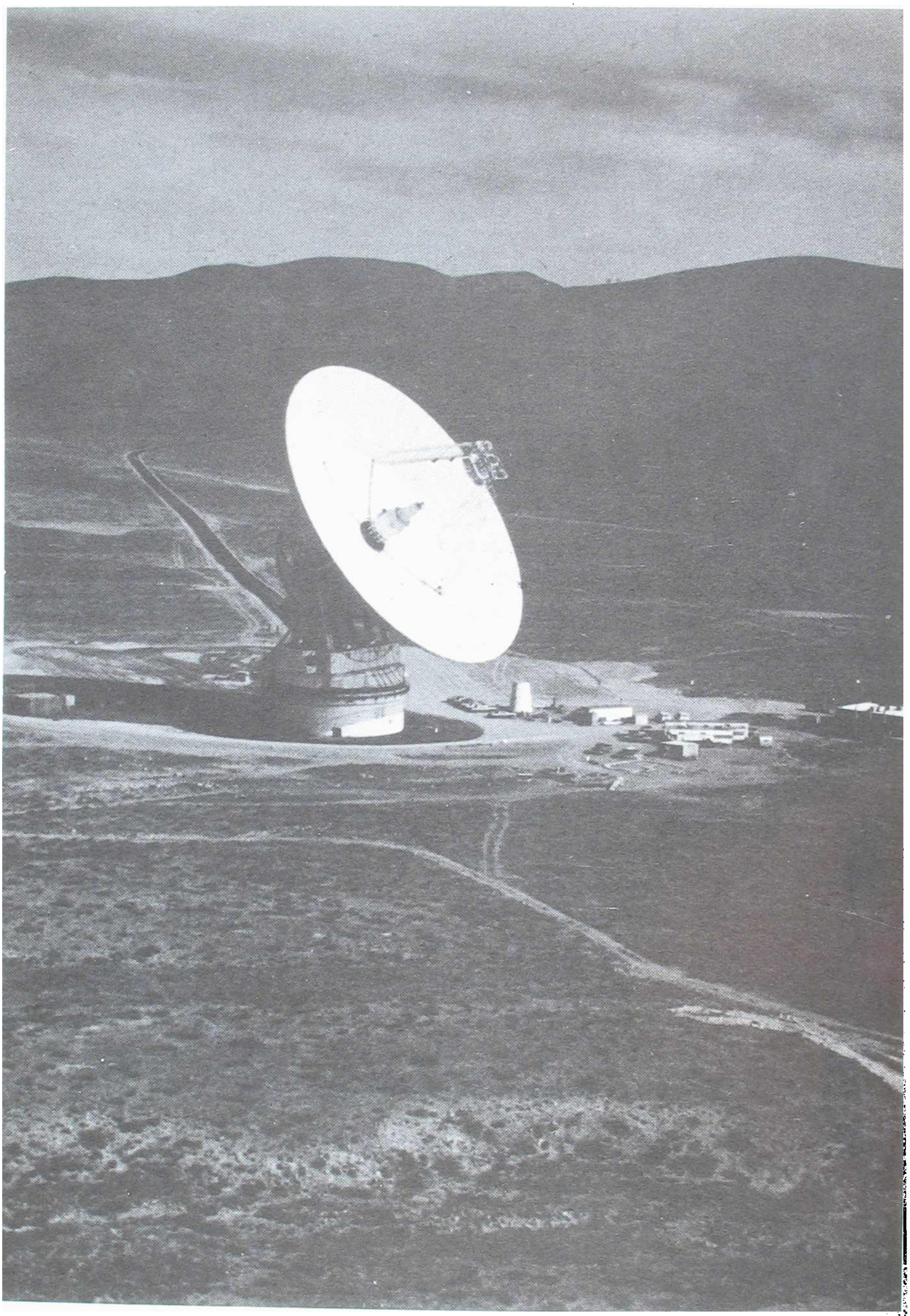


Figure 6–5. The Goldstone 210-foot diameter antenna.

tennas at Goldstone to receive radio signals generated from pulsar sources—those recently discovered astrophysical sources which mysteriously transmit precise radio pulses. In addition, wide baseline interferometer radio astronomy experiments were conducted by using the 85-foot antennas at Goldstone and in Australia.

The 210-foot antenna also supported the Apollo 8 lunar mission. In addition to the three 85-foot Deep Space Network stations which provided joint support to the Apollo missions, the 210-foot antenna was used to make sure that monitors received any marginal spacecraft transmissions from the vicinity of the moon.

In early December, NASA initiated procurement action for two 210-foot antennas planned for construction in Spain and Australia. These antennas, together with the Goldstone 210-foot antenna, are neeeded to meet the flight requirements of the future planetary missions, such as the Viking and the Jupiter-bound Pioneer flyby missions. The planned procurement schedule calls for these antennas to be operational in 1973.

NASA COMMUNICATIONS SYSTEM

The NASA Communications System (NASCOM) is a worldwide network of operational communications lines and facilities. (Fig 6–6) This network carries mission-related information for all NASA programs and for projects of other agencies supported by

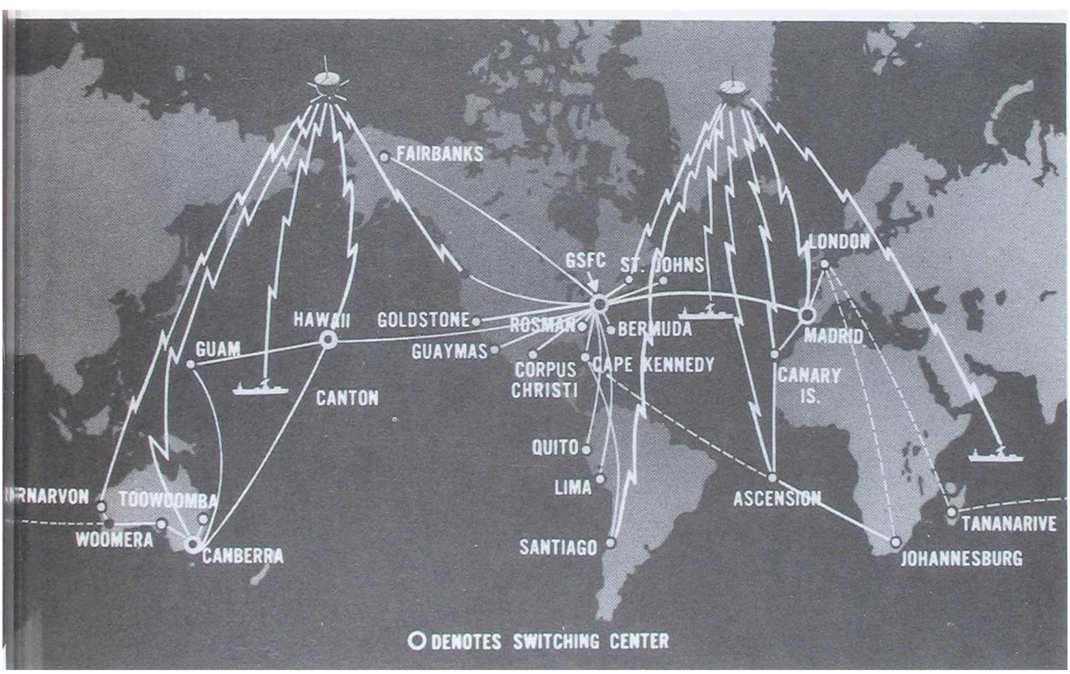
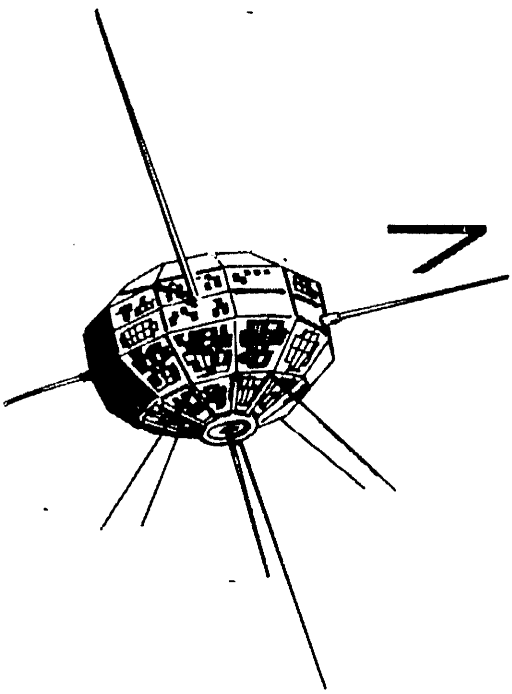


Figure 6–6. NASA Communications Network.

NASA. It connects foreign and domestic tracking stations, instrumentation ships, launch areas, test sites, and mission control centers. NASCOM consists of circuits provided by land lines, underseas cables, high frequency radio, and communications satellites.

During this period, NASA established special diverse communications routes at the Manned Space Flight Network stations to support the manned Apollo missions. The communications services for the Apollo 7 and 8 missions were the most reliable routes available, whether by satellite, cable, or land line. The diverse routes provided back-up service to the tracking stations to assure continuous program support in case the primary service failed or malfunctioned.

Also becoming part of NASCOM were new, highly reliable submarine cable circuits between Capetown and Ascension Island and new communications satellite service to the tracking station in Santiago, Chile. These replaced existing but less reliable high frequency radio communications. In addition, new equipment was being installed in the network to automatically monitor and test high-speed data lines. This equipment should assure full use and reliability of the data system.



7 INTERNATIONAL AFFAIRS

NASA's international cooperative projects and support programs became more diversified during the period and foreign participation in these programs increased.

COOPERATIVE PROJECTS

Cooperation with foreign space research institutions and regional space organizations was highlighted by NASA's launching of the ESRO I (Fig. 7–1) and HEOS I satellites built by the European Space Research Organization; by an agreement with Germany on a project to release an artificial ion cloud at an altitude of approximately 20,000 miles above the earth; by agreements with Mexico and Brazil for earth resources survey experiments; by continuing sounding rocket work; and by the selection of additional foreign experimenters to take part in studies of lunar surface samples. In all, seven new cooperative agreements were completed with Brazil, Germany, Mexico, Norway, and Sweden.

Canada

On September 29, the Canadian-built Alouette I satellite completed its sixth year of successful operation in orbit. Alouette II, which was launched in November, 1965, completed its third year of successful performance. These satellites sound the ionosphere from above to measure hour-to-hour electron densities of the ionosphere, to determine electron densities at the spacecraft altitudes, to monitor VLF noise in the 1–10 kc/s range, and to measure

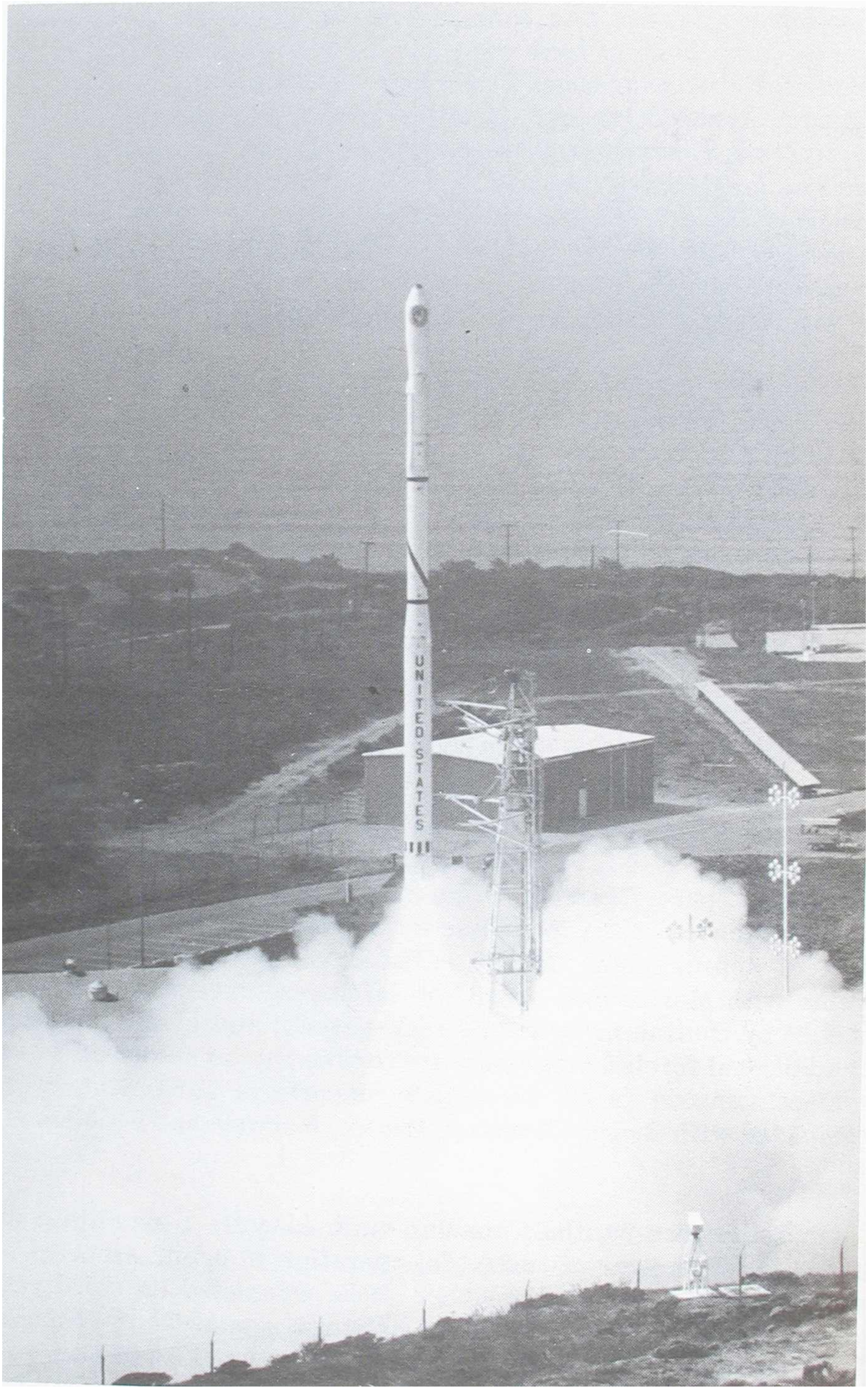


Figure 7–1. ESRO I launching from the Western Test Range, October 3, 1968.

primary cosmic ray particles outside the Earth's atmosphere. Alouette I is daily establishing new longevity records for successful spacecraft performances in orbit.

European Space Research Organization (ESRO)

The NASA launching of the ESRO I satellite on October 3 was a high point in the almost five years of active cooperation between NASA and the European Space Research Organization. This launching, conducted from the Western Test Range on a Scout vehicle, culminated an effort initiated by a Memorandum of Understanding between NASA and ESRO dated July 8, 1964. ESRO I was designed and built in Europe and carried eight experiments from Denmark, Norway, Sweden, and the UK to study the aurora borealis and related phenomena in the polar ionosphere. Although called ESRO I, it was the second of two cooperative satellite projects for which NASA has provided a Scout launch vehicle and the launching. ESRO II, a solar astronomy and cosmic ray satellite, was successfully launched from the Western Test Range on May 16, 1968, and was returning useful data.

The first NASA launching of an international scientific satellite on a cost reimbursable basis took place from Cape Kennedy on a Thor-Delta vehicle. ESRO's Highly Eccentric Orbit Satellite (HEOS) I, launched successfully on December 5, was returning data on interplanetary magnetic fields and solar and cosmic ray particles outside the magnetosphere. (Fig 7–2.)

France

The benefits of NASA's international cooperative projects were indicated at the conclusion of the FR–1 satellite project. When NASA launched this French-built and funded spacecraft in December, 1965, the prospect was that data would be received over a three month period, the design lifetime of the spacecraft. Thirty-three months later, in August, 1968, FR–1 finally failed to respond to commands. At least 19 scientific publications have resulted to date from this cooperative study of VLF radio emissions.

Work continued on the EOLE project, under which NASA will launch a French-built satellite in a cooperative project to test the feasibility of a satellite/balloon system to gather weather data on a global scale.

Germany

In December, NASA and the German Ministry for Scientific

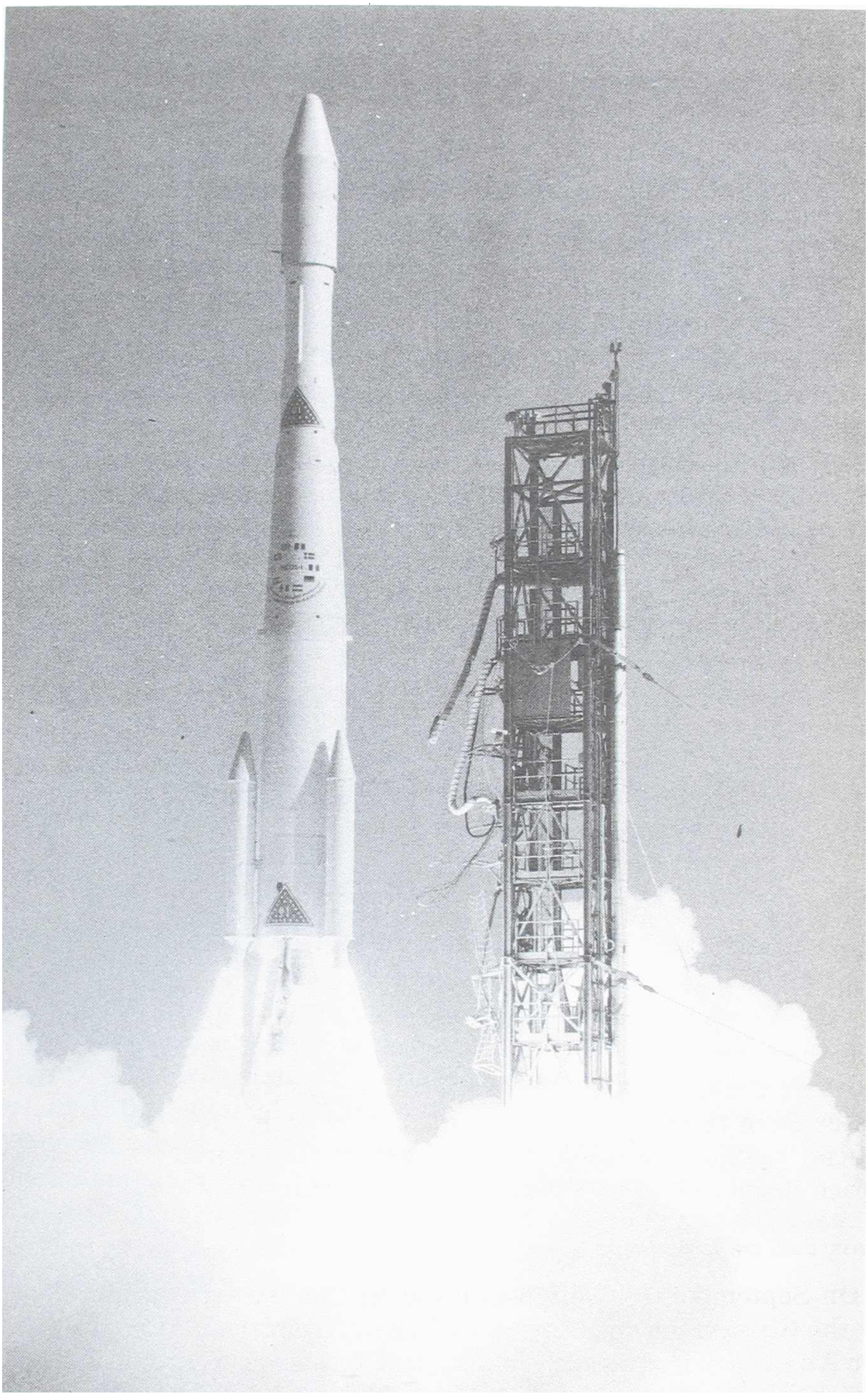


Figure 7–2. Launching of HEOS–I from Cape Kennedy, December 5, 1968.

Research reached agreement on a cooperative project under which NASA is to launch a German-developed barium-ion cloud payload. This payload will be released at an altitude of approximately 20,000 miles, where it will form a cloud that will be visible from most of the southern United States and northwestern South America. It will be photographed in various wave lengths as it expands and eventually dissipates along the earth's magnetic lines of force. This will permit the measurement of magnetic and electric fields, simulate the action of the solar wind on an ionized comet trail, and give basic new data on behavior of an ion cloud in a collisionless plasma.

Mexican Use of APT

In early 1968, NASA and the Mexican Space Commission agreed to a project in which Mexico would operate an Automatic Picture Transmission (APT) set loaned by NASA. The purpose would be to supply current cloud pictures to interested Mexican Government agencies. Mexico agreed to combine the APT data with meteorological data obtained from conventional sources, to establish an effective communications network with user agencies for disseminating the data, and to report on a broad "systems" approach to managing APT data.

The immediate usefulness of this approach was shown in September when hurricane Naomi passed over Mexico. Naomi's rains severely taxed the capacity of a dam under construction above the cities of Torreon and Gomez Palacios. An immediate decision was necessary on whether to release water and flood Gomez Palacios or keep the dam closed and risk having the water from continuing rains burst the dam and flood both cities. After urgent analysis of the APT cloud-cover pictures, the responsible officials concluded that the breakup of the hurricane cloud pattern warranted keeping the dam closed. The rains stopped. Both cities were spared, and the water from the dam was saved for future irrigation use. For this crucial application of APT weather satellite data, the Mexican Space Commission received a special government citation.

Swiss Balloon Experiment

On September 18, a high-altitude balloon experiment developed by the Observatory of Geneva was flown from the National Center for Atmospheric Research facilities at Palestine, Texas. The flight, which was fully successful, was undertaken as a cooperative project between NASA and the Swiss Committee for Space Research. The payload developed by the Observatory of Geneva was designed to conduct stellar near-ultraviolet observations. The balloon lifted the 375-pound payload to an altitude of about 136,000 feet.

Earth Resources Survey

Following up on agreements-in-principle achieved last year with Brazil and Mexico, the U.S. has now exchanged diplomatic notes with both countries, completing arrangements for cooperative earth resources survey programs. In these programs, techniques and systems are to be developed for obtaining and using earth resources data from aircraft.

Lunar Surface Sample Projects

As of the end of 1968, NASA had selected 35 foreign investigators from eight countries and 20 institutions to conduct experiments on lunar surface material to be returned in project Apollo. The countries represented are Australia, Belgium, Canada, Finland, Germany, Japan, Switzerland, and the United Kingdom. Among the approved experiments are investigations in minerology and petrology, chemical and isotope analyses, physical properties, and biochemical and organic analyses.

Orbiting Astronomical Observatory (OAO-A2)

As of December, nine scientists in Argentina, France, Germany, the Netherlands and the United Kingdom had expressed interest in obtaining "guest observer time" on OAO–A2, which was successfully orbited December 7.

Sounding Rocket Projects

Sounding rocket experiments remain a primary source of information on a great number of phenomena not yet understood, as well as on subjects such as meteorology which require constant monitoring.

During the period, sounding rocket experiments were launched in cooperation with Argentina, Brazil, Canada, India, Norway, Spain, and Sweden. In addition, agreements for new cooperative sounding rocket projects were concluded with Brazil, Germany, and Sweden.

Among the investigations performed were measurements of meteoroid flux in the upper atmosphere, studies of the dynamics of the auroral ionosphere, coordinated launchings to study the structure and behavior of the atmosphere, investigation of discrete X-ray sources in the southern hemisphere, and studies of polar cap absorption events and the D-region of the ionosphere.

UNITED NATIONS

The Administrator of NASA served as Chairman of the U.S. Delegation to the United Nations Conference on the Exploration and Peaceful Uses of Outer Space held in Vienna, Austria, in August. The U.S. technical presentation, which NASA arranged at the request of the Department of State, featured forty-nine papers and lectures addressed specifically to the two themes of the Conference: the practical benefits of space activities, and the opportunities for international cooperation. Both themes had special reference to the needs of developing countries.

The Assistant Administrator for International Affairs served as Alternate U.S. Representative to the United Nations Committee on Peaceful Uses of Outer Space during its meeting in New York October 15–18, 1968.

OPERATIONS SUPPORT

As in the past, NASA continued to obtain operations support from abroad. An agreement with Mauritius was concluded on September 3, permitting NASA to build a parking apron at Plaisance Airfield to accommodate the staging and operation of Apollo/Range Instrumentation Aircraft (A/RIA). A number of countries approved operational overflights of territory under their jurisdiction by A/RIA in support of Apollo missions. The government of Thailand approved the temporary stationing of a BC–4 camera team to make geodetic satellite observations under the National Geodetic Satellite Program (NGSP). There are now 33 temporary BC–4 camera sites under the NGSP in foreign countries from which the PAGEOS satellite has been or is being observed. The eleventh meeting of the international Ground Station Committee, which was established in 1961 to coordinate participation of other countries in NASA experimental communications by satellite, was held in Paris October 29–31, 1968.

PERSONNEL EXCHANGES, EDUCATION AND TRAINING

During the second half of 1968, over 3,000 foreign nationals from 91 locations visited NASA facilities for scientific and technical discussions or general orientation.

Under the NASA International University Fellowship Program, 53 students from ten nations were engaged in graduate study at 19 American universities. They were supported by their national space research sponsors or by ESRO. This program is administered for NASA by the National Academy of Sciences.

One hundred and fourteen postdoctoral and senior postdoctoral associates from 23 nations carried on advanced research at NASA centers, including the Jet Propulsion Laboratory. This program, also administered by the National Academy of Sciences, is open to both U.S. and foreign nationals.

Forty scientists, engineers, and technicians from Brazil, Germany, India, and Mexico—here at their own expense—received training in space technology at the Goddard Space Flight Center and the Manned Spacecraft Center in connection with cooperative projects.

8 UNIVERSITY PROGRAMS

NASA's university project research is aimed at meeting the research needs of NASA program offices and field centers. It is supplemented by the Sustaining University Program, which supports multidisciplinary research and other university activities important to NASA's mission, but broader in scope than most program office research efforts. All elements of the NASA university program are developed and administered so as to provide maximum benefit to NASA and at the same time strengthen the participating universities. Through the end of June 1968, NASA had invested a total of about $480* million in university project research, and another $204 million in the Sustaining University Program.

SUSTAINING UNIVERSITY PROGRAM

Sustaining University Program grants to universities allow considerable local control over the selection of specific research tasks. Grants for research are step funded; other activities, including training, are full funded.

Multidisciplinary Research

During this period, efforts were made to develop university programs using the multidisciplinary approach to problems related to

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

national aeronautics and space objectives. Activities were developed with universities near NASA Centers that enable faculty and students to use unusual and expensive NASA facilities and equipment. In the 1969 fiscal year (July '68–June '69), with only $5 million allocated for the support of multi-disciplinary research, it will not be possible to add new funds to all of the 50 grants. Thirty universities will continue in the program, while 20 were notified that additional funding beyond the current three-year agreement period was not anticipated due to lack of funds.

NASA initiated a pilot program to enable small developing institutions near NASA Centers to become acquainted with research opportunities at the Centers. A few institutions near NASA Centers were given small grants to investigate the capabilities of participating regional colleges and the research problems at various Center laboratories.

Administration and Management Research

Six universities, in addition to the National Academy of Public Administration, participate in this program, and all six reported worthwhile progress in research and education. Three universities—Southern California, Pittsburgh, and Syracuse—had public administration traineeships closely integrated with their research programs, and NASA was providing support for trainees in administration and management.

A new program emphasizing technology transfer was initiated at the Drexel Institute of Technology. Several projects, such as a study of NASA project managers and a study of the problems of training scientists and engineers for management positions, were also approved for study by the National Academy of Public Administration.

Engineering Systems Design

This program, a cooperative pilot effort in graduate engineering education at five universities (*19th Semiannual Report,* p. 130) supports trainees and faculty research. The first group of 23 trainees started their second year. Many of them completed their course work and took their qualifying exams. Faculty and students visited a number of the NASA Centers in the summer of 1968 in search of possible systems design projects. This exposure to large systems design activity was useful to both faculty and students and will be the basis for continuing working relationships.

Four schools started work on their projects:

Stanford: Design of an unmanned, automated Antarctic geophysical stations;
Improved metal forming technique with feedback forming;
Design of an improved premature-baby incubator.

Georgia Tech: Continental intercity transportation system.

Cornell: Unmanned satellite to Jupiter.

Purdue: Satellite surveillance system for severe storms, particularly tornadoes;
Space laboratory for industrial processing;
V/STOL transportation system.

The second group of 25 students started training in September, and some are expected to become members of the teams working on the above projects.

Special Training

This heading includes the Summer Faculty Fellowship Program in research and one in engineering systems design as well as summer institutes for undergraduates and predoctoral trainng grants (*19th Semiannual Report,* p. 130–31). During the summer of 1968, thirteen universities and nine NASA Centers cooperated in offering research and study opportunities to about 250 faculty members in the research part of the program. Three 11-week Summer Faculty Fellowship Programs in engineering systems design were conducted at Stanford University with the cooperation of the Ames Research Center, the University of Houston in cooperation with Rice University and the Manned Spacecraft Center, and Old Dominion College in cooperation with the College of William and Mary and the Langley Research Center. About 60 faculty members worked on projects such as a preliminary design of a manned lunar laboratory, a satellite servicing vehicle, and an educational television satellite sytsem.

The program of summer institutes for outstanding undergraduates continued. About 160 nationally selected undergraduates received six weeks of specialized training at four universities in space sciences and technology. Support of advanced training in aerospace medicine was continued at Harvard University and Ohio State University, where a few medical doctors received advanced training in the environmental problems of man in space.

Although no new regular predoctoral training grants for study in space-related sciences and technology have been awareded since June 1967, the existing grants will not terminate until August 31,

1970. As of December 30, 1968, 2,099 trainees were receiving support through the program at 152 universities in 50 states and the District of Columbia, and 1,383 graduate students had received Ph.D. degrees in the program. Areas of study and number of degrees were as follows:

Area	*Number of Ph.D.'s*
Physical Sciences	704
Engineering	482
Life Sciences	138
Behavioral Sciences	50
Other	9
	1,383

Resident Research Associateship Program

This program (*19th Semiannual Report,* p. 131) continued its activities with 167 associates carrying on advanced research in a wide variety of fields including physics of planetary atmospheres, magnetospheric geometry, solar physics, space astronomy, applied mathematics, electrical engineering, biophysics, microbiology, extreme environments, aerodynamics, mechanical engineering, and physical metallurgy. Researchers were distribued among NASA Centers as follows:

Center		*Participants*
Goddard Space Flight Center		77
Greenbelt, Maryland	57	
Institute of Space Studies, N.Y.	20	
Ames Research Center		39
Marshall Space Flight Center		10
Langley Research Center		13
Manned Spacecraft Center		10
Jet Propulsion Laboratory		13
Electronics Research Center		5
Total		167

Research Facilities

Addition structures at the University of Minnesota and at the University of Florida were completed and occupied by researchers, bringing to 30 the number of completed buildings, and increasing gross space on university campuses by over a million square feet. This is enough to accommodate some 3,200 university scientists, engineers, and others engaged in research in aerospace science and technology.

Table 8–1 summarizes the status of the seven remaining active grants, two of which requested construction bids during the period.

Table 8–1. Research Facilities in Process (December 31, 1968)

Fiscal Year awarded	Institution	Topic	Area (1,000 SF)	Percent complete	Cost ($1,000)
1965	Case Western Reserve	Space Engineering	69	99	$2,226
	Rochester	Space Sciences	35	90	1,000
	Stanford	Space Engineering	65	85	2,080
			169	......	$5,306
1966	Wisconsin	Space Science & Engineering	58	95	$1,694
	Washington	Aerospace Research	40	60	1,500
	Kansas	Space Technology	56	Bid	1,800
			154	......	$4,994
1968	National Academy of Sciences.	Lunar Science Institute	17	Bid	$ 580
Total			340	......	$10,880

RESEARCH GRANTS AND CONTRACTS

At the time of this report, approximately 1,300 project-oriented university grants and contracts resulting from the funding of unsolicited proposals were active. The activities reflect the interests and capabilities of investigators in areas related to the NASA mission.

The Office of University Affairs continued its efforts to ensure agency-wide program coordination and consistency in its dealings with universities, while gradually decentralizing some responsibility for university activities to the field centers. Basic policy guidelines and criteria for approval of foreign travel were distributed, and a senior policy advisory council was established representing NASA Centers and offices with substantial university involvement. Also, steps were taken to establish a computer-based system to provide prompt and complete programmatic and managerial information on the total NASA university program. System specifications were defined, input and output mechanisms established, and operational procedures were being developed.

Step Funding

Step funding, a method of ensuring stability of support for long-range academic research, was initiated by NASA in 1959 and further developed within the Sustaining University Program's multidisciplinary research grants.

A step-funded grant obligates funds for the support of a research project at the full level for the first year, 2/3 of that level for the second year, and 1/3 of full level for the third year. At the beginning of the second year, supplemental funds equal to one year of full support are awarded and spread over the following three years. When a decision is made to cease support of a step-funded grant no further funds are added, but the project still has a two-year phase-out period at reducing levels, which enables the research to be concluded in an efficient and orderly manner. Two-hundred grants operating on a step-funded basis were in effect.

9 INFORMATIONAL AND EDUCATIONAL PROGRAMS

The substantial progress made in NASA's scientific and technical information program was matched by advances in its educational programs and services. Far reaching effects of the Agency's technology utilization program were evident from the benefits many nonaerospace businesses, universities, and non-profit institutions were deriving from the use of information on Government sponsored aerospace research and development.

EDUCATIONAL PROGRAMS and SERVICES

NASA provided audiovisual materials, consultants, exhibits, field trips, publications, and speakers to summer workshops serving over 10,000 teachers through more than 170 programs in 45 states and Puerto Rico. The workshops, funded by local districts, states, or the Federal Government, introduced background materials in aeronautics and space activities for classroom use and for developing new curricula. (NASA participated at the request of workshop directors.)

The six NASA award winners from the International Science Fair in Detroit—accompanied by a teacher of their choice—visited an Agency field installation which they chose. Winners came from California, Hawaii, New Mexico, Texas, and Michigan. (*19th Semiannual Report*. p. 135.)

Spacemobiles

In 7,160 presentations before school children and educational and civic groups, NASA's spacemobile lecture-demonstration teams spoke on space science and exploration to 1,227,509 persons. Also, an estimated 12,526,622 people were reached through 82 radio and television programs. In addition, spacemobiles manned by local lecturers trained by NASA spacemobile specialists, were operated in Austria, Brazil, Colombia, Holland, Israel, and the Philippines.

Motion Pictures and Publications

Six new NASA informational-educational films and a new filmstrip were completed and released for loan to schools, civic and professional organizations, and TV stations. The films and 17 new educational publications are described in appendix N.

Television and Radio

Apollo Digest, a series of 30 five-to-ten-minute films on various aspects of the Apollo manned space flight program, was released for network and local television station news and documentary productions in December. TV stations used them before and during the Apollo 8 mission. The films were also made available for speakers, exhibits, spacemobile presentations, and other uses. The series is described in a brochure available from Television Productions/Services, Code FP, NASA Headquarters, Washington, D.C. 20546.

Also, prints of other NASA films provided, upon request, to television networks and stations were seen by millions of viewers throughout the country. Special release was made of *The Flight of Apollo 7* film to requesting television stations, and of the film *America In Space: The First Decade.* In addition, special audiovisual materials (films, film clips, prints of *Apollo Digest* films, graphics, and prints of NASA's *Aeronautics and Space* TV series) were distributed to television networks and stations during the Apollo 8 mission. They were used by the three major American TV networks, and, overseas, by the British Broadcasting Corporation, the British ITV network, the West German TV network, and others.

The Agency's television series *Aeronautics and Space Report* was distributed monthly to hundreds of requesting stations. These five-minute films included short features on a wide range of NASA projects and activities.

Twenty-six weekly five-minute taped programs on the *Space Story* were distributed to radio stations coast to coast. *NASA Special Reports*, a monthly 15 minute-program, was also sent to radio stations nationwide. In addition, taped interviews with

NASA field installation staff members and one minute-taped informational announcements, *NASA Space Notes*, were widely distributed to radio stations periodically.

SCIENTIFIC and TECHNICAL INFORMATION

In its scientific and technical information program, NASA developed software for the new Agency-wide network of remote consoles for "on-line" information retrieval (NASA/RECON); further expanded its current-awareness announcement service (NASA/SCAN) to meet the needs of NASA contractors and other Government agencies; and set up an experimental program to apply "user charges" for certain document services.

A detailed statement on progress in the RECON and SCAN (*S*elected *C*urrent *A*erospace *N*otices) computerized information storage and retrieval systems was published in the *19th Semi-annual Report*, p. 136. The administrative change applied to the user charges is described in the following paragraphs.

User Charge Program

Cooperating with the Clearinghouse for Federal Scientific and Technical Information of the Department of Commerce, NASA has established this experimental program of user charges for certain document services, which were previously available without charge to Government agencies, contractors, and others directly engaged in aerospace activities. The program roughly parallels a charge system recently instituted by the Defense Documentation Center for the Department of Defense, and is consistent with principles being developed by the Committee on Scientific and Technical Information for uniform Federal practices in this area. It transfers to the Clearinghouse the responsibility for satisfying, at established prices, requests for "hard" (facsimile) copies of unclassified-unlimited documents announced through NASA's information system. Unchanged are primary distribution of NASA publications, secondary (request) distribution of all documents in microfiche form, and the distribution of classified or limited documents. This NASA-Clearinghouse arrangement will be reviewed in June 1969, its impact tentatively evaluated, and its terms revised as necessary.

Technical Publications

Several of the Agency's special publications, issued during the last six months of this year, are listed in appendix O.

TECHNOLOGY UTILIZATION

NASA continued to work toward an increased public awareness of the potential benefits from capitalizing on the results of Government-sponsored aerospace research and development for nonaerospace applications. The Agency furthered its experiments to improve various systems for identifying, acquiring, evaluating, documenting, and disseminating new technical information derived from the research and development which it sponsors. It also moved to assure that scientists and engineers in its laboratories play an increasingly vital role in acquiring and disseminating new technical information.

Regional Dissemination Centers

The far-reaching effects of the Technology Utilization Program on the Nation's economy, were indicated by the fact that over 230 companies used the information services of NASA-sponsored Regional Dissemination Centers on a routine basis, while several hundred others took advantage of the availability of the data to serve special industrial needs. For example, two companies were established to manufacture and market products adapted from techniques originating in aerospace research and development. One manufactures electronic controls for industry; the other a new thermosetting plastic developed at Lewis Research Center.

Tech Briefs

About 2,000 industrial inquiries a month resulted from the sale of NASA's *Tech Briefs*. To relieve the technology utilization staff at the field center from answering these inquiries, and so that there would be more time for identifying and documenting new technology, agreement was reached with the Clearinghouse for Federal Scientific and Technical Information to reproduce and sell *Tech Brief* technical support packages. The packages were designed to provide the inquirer with all available information on the new technology announced in a *Tech Brief*; over 100 different packs were available for sale. (Technical support packages for *Tech Briefs* issued before November 1968 will be furnished, free of charge, by the NASA center originating the technology.)

Interagency Cooperation

The Atomic Energy Commission and NASA increased the scope of their joint program to identify, document, and report new technology through NASA-AEC *Tech Briefs*. Also, AEC arranged to make its computer programs available on a limited basis through the Computer Software and Management Information Center (COSMIC) at the University of Georgia. In addition, the Department of Defense and NASA agreed that DOD will make computer programs and documents available to scientists and engineers through this information center.

The Office of State Technical Services of the Department of Commerce and NASA cooperated closely in separate programs to make new technological information available to industry and others able to benefit from its applications. NASA and its contractors helped the Small Business Administration (SBA) conduct seminars and workshops. The SBA booklets, *Tech Aids*—featuring technology from NASA's research and development programs—continued to stimulate numerous inquiries from small business.

In addition, several meetings were held with the Law Enforcement Assistance Administration, Department of Justice, to explore ways in which aerospace technology might be applied to solve the problems of law enforcement. NASA also cooperated with the Bureau of Reclamation (Department of the Interior) to apply aerospace technology to the needs of researchers in weather modification, and the Federal Water Pollution Control Administration (Department of the Interior) and the Agency began a similar effort in water pollution.

Biomedical Application Teams

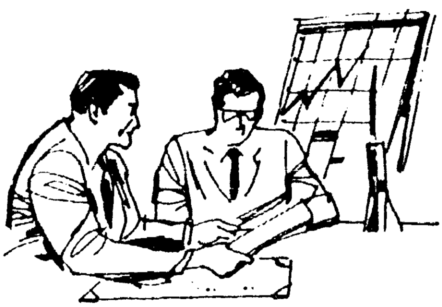
The three NASA-sponsored Biomedical Application Teams identified over 400 problems involving medical researchers at hospitals and institutes which might be solved through the application of aerospace technology. Eighty-nine transfers of this technology were made and potential solutions were found for 46 more problems. The teams also worked with the Social Rehabilitation Administration (SRA), Department of Health, Education and Welfare, to apply aerospace technology to problems pinpointed by researchers at SRA Rehabilitation Centers.

HISTORICAL PROGRAM

The NASA Historical Program continued to produce annual chronologies of aeronautical and astronautical events, contract and inhouse histories, histories of field installations, special histories, and management studies. *Venture Into Space: Early Years of Goddard Space Flight Center* was published (SP-4301, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402). *Aeronautics and Astronautics, 1967*, and chronologies of Projects Gemini and Apollo were in press. Manuscripts being reviewed included histories of Langley Research Center, Ames Research Center, and Projects Vanguard and Gemini, a Project Ranger chronology, and a monograph on the Manned Space Flight Network.

A preliminary account of NASA during the Johnson Administration was prepared as the Agency contribution to the Departmental Histories Project. This survey narrative and extensive documentation will be deposited in the Lyndon B. Johnson Presidential Library.

10 SUPPORTING ACTIVITIES



NASA continued to stress the need for improving the efficiency and effectiveness of its managerial and other supporting activities. It placed primary emphasis on making maximum use of its personnel force; on improving its financial management efforts; on holding down the costs of research, development, and related services obtained from private industry; and on giving even greater impetus to its programs of cooperation with other government departments and agencies.

PERSONNEL

During the period, employee-management cooperation and personnel training activities were emphasized, and the Federal Women's Program was given continued support. The Agency presented awards and citations to individuals for their significant contributions to the space program. Meanwhile, the personnel force was reduced by approximately 2,000 employees.

Employee-Management Cooperation

NASA continued its activities in the government-wide program for Employee-Management Cooperation in the Federal service (Executive Order 10988). It granted exclusive recognition within an activity-wide bargaining unit, less professionals, to Local 2498, American Federation of Government Employees (AFL-CIO) at the Kennedy Space Center. It approved the collective bargaining agreement between the Ames Research Center and Local 997, National Federation of Federal Employees (Independent). And an alleged unfair labor practice charge filed by Lodge 892, International Association of Machinists and Aerospace Workers (AFL-CIO) against the Langley Research Center was remanded to the union since local administrative procedures for redress had not been exhausted.

Training Activities

Agency-wide seminars were carried on to provide specialized training for program and project teams, and to promote management improvement and uniform treatment of NASA policy. Courses in "Procurement Management," "Contract Administration," "Contractor Performance Evaluation," "Termination, Settlement, and Negotiation," and "Written Communications for Executives" were conducted for NASA employees.

A 64-hour first-line supervisory training course was developed. Three pilot sessions were conducted, with evaluation and shakedown sessions to continue. Techniques and subject matter in the course were being tested as standards for first-line supervisor training.

Sixteen NASA executives were selected for the CSC Federal Executive Institute. Additionally, NASA installations continued their cyclic programs such as graduate education; cooperative education; apprentice, science, and engineering lectures; and a wide variety of management and skills training.

Status of Women Program

During the period, NASA took a number of positive steps in support of the Federal Women's Program. At MSFC, a female employee was appointed to a position in the Chief Counsel's office and made legal advisor to the NASA Exchange, MSFC Branch. At Goddard Space Flight Center, two women were appointed to positions in the personnel Classification Branch. And at Wallops Station, a female employee was made the Public Affairs Officer.

For the first time at KSC, a woman served as Instrumentation Controller on tests at Apollo/Saturn launch complexes. This position requires manning a console in the firing room for the duration of facilities tests, launch vehicle tests, or space vehicle tests.

At MSFC, two women completed work for the Master's degree. One of these, studying in fluid mechanics and structural electricity, was working toward a doctorate. And at Lewis Research Center, twenty of the enrollees in on-site college credit courses were women.

NASA Awards and Honors

The following personnel were awarded and presented the Distinguished Service Medal:

James E. Webb.—For outstanding leadership of America's space program from 1961 to 1968 as Administrator of the National Aeronautics and Space Administration. Mr. Webb provided the clear vision, driving energy and management skill which, in the space of seven years, moved the United States forward to a position of leadership in space and aeronautics. More than any other individual, he deserves credit for the great achievements of the United States during the first decade of space exploration.

Edmond C. Buckley.—In recognition of his distinguished career in both NACA and NASA and for his outstanding contributions in the fields of ground instrumentation facilities for aircraft and space flight programs.

Paul G. Dembling.—In recognition of his sustained and excellent professional service and his outstanding leadership as a lawyer and administrator.

Alexander H. Flax.—For distinguished service to the United States in aeronautics and space. His outstanding contributions and those of the Air Force research and development organization under his leadership have materially advanced the development and applications of aeronautical and space technology.

Exceptional Scientific Achievement Medals were presented to the following personnel:

G. Mervin Ault	LeRC
Edmond E. Bisson	LeRC
John C. Evvard	LeRC
Richard M. Goldstein	JPL
Otto A. Hoberg	MSFC
Hans H. Hosenthien	MSFC
Robert D. Jastrow	GSFC
Lewis D. Kaplan	JPL
Mark R. Nichols	LaRC
William A. Page	ARC
John A. Parker	ARC
Alan Rembaum	JPL
Conway W. Snyder	JPL

Twenty-nine Exceptional Service Medals were authorized and were presented to the following:

Mac C. Adams	Hqs
Walter F. Boone	Hqs
Donald D. Buchanan	KSC
Richard L. Callaghan	Hqs
Robert M. Crane (Posthumous)	ARC
R. Walter Cunningham	MSC

Robert J. Darcey	GSFC
Philip Donely	LaRC
Robert C. Duncan	ERC
Donn F. Eisele	MSC
Fred H. Felberg	JPL
Arnold W. Frutkin	Hqs
Paul F. Fuhrmeister	LaRC
Harry H. Hamilton	LaRC
Alfred S. Hodgson	Hqs
Herman E. LaGow	GSFC
Alvin R. Luedecke	JPL
Glynn S. Lunney	MSC
Robert J. McCaffery	GSFC
Mildred V. Morris	Hqs
Boyd C. Myers	Hqs
Rocco A. Petrone	KSC
Isom A. Rigell	KSC
Arthur Rudolph	MSFC
William R. Schindler	GSFC
Walter M. Schirra, Jr.	MSC
Albert F. Siepert	KSC
Hubert Ray Stanley	WS
Michael J. Vaccaro	GSFC

Key Executive Personnel Changes

During the period, a number of key executive personnel changes occurred within NASA. One new official was appointed, four were reassigned, two retired, two resigned, and two died. On August 5, Philip N. Whittaker was appointed as Assistant Administrator for Industry Affairs, coming to this Agency from the IBM Corporation. Dr. John E. Duberg was appointed as Associate Director of the NASA Langley Research Center (July 14), moving to the new position from his previous assignment as an Assistant Director of the Center.

Mr. Boyd C. Myers, II, was appointed as Deputy Assistant Administrator for Administration (July 14), within Headquarters; previously, he had been Deputy Associate Administrator for Advanced Research and Technology (Operations). On August 1, Mr. Bruce T. Lundin was appointed Deputy Associate Administrator for Advanced Research and Technology; Mr. Lundin had been Deputy Director for Development, NASA Lewis Research Center. And on November 16, Dr. H. Julian Allen was appointed as a Special Assistant to the Associate Administrator for Advanced

Research and Technology. For the preceeding four years, Dr. Allen had been Director, Ames Research Center.

On October 7, Mr. James E. Webb retired from the position of Administrator, NASA. He had held this post since his appointment on February 14, 1961. On November 30, Dr. Floyd L. Thompson retired from the position of Special Assistant to the Administrator. Earlier, Dr. Thompson had been Director of the Langley Research Center.

Bernard L. Dorman resigned from the position of Assistant Administrator for Industry Affairs (July 26). On September 6, Robert C. Duncan resigned as Assistant Director for Systems, NASA Electronics Research Center. Harold T. Luskin, Director, Apollo Applications Programs, Office of Manned Space Flight, died on Octover 25, and on September 4, Mr. Robert M. Crane, Assistant Director for Development at Ames, died.

Status of Personnel Force

The following figures represent total employment (including temporaries) for the periods ending June 30, 1968, and December 31, 1968.

	June 1968	*December 1968*
Headquarters	2310	2213
Ames Research Center	2197	2050
Lewis Research Center	4583	4397
Langley Research Center	4219	4024
Flight Research Center	622	574
Electronics Research Center	950	844
Space Nuclear Propulsion Center	108	105
Goddard Space Flight Center	4073	3800
Wallops Station	565	504
NASA Pasadena Office	79	72
Marshall Space Flight Center	6935	6505
Manned Spacecraft Center	4956	4629
Kennedy Space Center	3044	2966
Total	34,641	32,683

INVENTIONS AND CONTRIBUTIONS BOARD

The Space Act of 1958 provided for the establishment of the Inventions and Contributions Board. As one of its functions, the Board reviews petitions from NASA contractors for waiver of rights to inventions made during the performance of NASA contracts. It then recommends that the Administrator grant, deny, or take other action on such petitions. The Board also evaluates scientific and technical contributions made by NASA employees, by contractor employees, and by members of the general public. (The membership of the Board is set forth in app. I.)

Petitions for Patent Waivers

A contractor may petition for waiver of rights to an individual invention made during the performance of a NASA contract after the invention is reported. Upon recommendation of the Board during this reporting period, the Administrator granted 61 waivers of individual inventions and denied 11 (listed in app. J).

A contractor may also petition for a "blanket" waiver of rights to all inventions which may be made during the performance of work on a NASA contract. The petition may be submitted prior to the execution of a contract, or during the 60 day period immediately after the contract is issued. For this reporting period, the Administrator granted 20 blanket waivers and denied 5. In 4 cases, where the petition was received prior to execution of the contract, action was deferred and the waiver was not granted. (See app. K)

Whenever a petition for waiver of patent rights is denied, the petitioner has the right to an oral hearing before the Board. Two oral hearings were convened during the period July 1—December 31, 1968. Subsequently, a waiver was granted in one case and the second case is now under consideration by the Board.

When a waiver is granted, the Government retains a royalty-free license to the invention. Each contractor to whom a waiver is granted agrees to report annually on the status of commercialization of the invention. If the contractor does not take action to develop and place the invention on the market, NASA may, under certain circumstances, void the waiver. If such action is taken, NASA may then take title to the invention so that licenses can be granted to companies who may wish to develop the invention for commercial purposes.

Monetary Awards for Contributions

The Board evaluates all inventions made by NASA employees or NASA contractor employees for which a U.S. patent application is filed. By authority of Section 306 of the Space Act, a minimum award of $50 is made to each inventor upon filing of the patent application. For those inventions which are found to have special merit, a supplemental award can be made in an amount which depends upon the significance of the invention. These awards are granted by the Administrator following recommendation of the Board. (App. L.) During this reporting period, minimum awards were made to 10 inventors for 7 inventions, and supplemental awards were made to 41 contributors for 23 inventions and contributions.

Also, the Board evaluates all innovations reported by NASA or NASA contractor employees which are published as Tech Briefs. A minimum of $25 is awarded to each employee and each innovation is eligible for consideration for a supplemental award. Minimum awards for Tech Briefs were made to 247 emp oyees for the reporting of innovations that were subsequently published and distributed as NASA Tech Briefs.

Under the authority of the Government Employees' Incentive Awards Act of 1954, the Board made awards to 58 NASA employees for 38 inventions for which patent applications were filed (listed in app. M). Total awards which were granted by the Board or granted by the Administrator following the Board's recommendation amounted to a total of 356 individual awards for 215 contributions (total amount—$31,175).

Nearly all awards made under the Board's cognizance have been for inventions or innovations resulting in Tech Briefs. However, many contributions of significant value to space and aeronautic programs consist of scientific discoveries which advance the state of knowledge but for which the Board has received no applications for awards. A recently published revision of the Board's regulation specifically provides for awards for such discoveries. This revision should stimulate more applications for such contributions.

FINANCIAL MANAGEMENT

During this period, NASA gave special attention to ways of improving the performance of the financial management function. Three functional reviews of field installations were completed, and three more were in process December 31, 1968. The Agency used a self-evaluation technique in these reviews—the installations were provided with a check list and asked to review and evaluate their own performance. Their evaluation was then compared to information available in Headquarters from independent sources, and on-site validation was made by Headquarters representatives. This approach sharply reduced the amount of time Headquarters personnel had to be in the field; and it enabled installation personnel to make a systematic review of their own operations, to make corrections and improvements, and to develop plans for such improvements prior to Headquarters on-site review. All of this contributed to the end purpose of the reviews, i.e., improvement of agency-wide financial management operations.

Additionally, the Agency began to study ways in which financial and other data regularly reported for program or other management purposes can be used in functional management of accounting and related operations. To this end, a number of approaches were being explored (average grades of employees involved, percentages of professional personnel, lag between costs and disbursements, volume of outstanding travel advances and the like). While such efforts did not result in the establishment of standards, gross measurements were being produced which should be useful in making more detailed inquiries and studies.

Financial Management Conference

The Fourth Annual Financial Management Conference, held at Kennedy Space Center October 16—18, brought together financial management and program resources representatives from all of NASA's field installations and Headquarters to discuss problems and techniques of mutual concern. Topics discussed at this conference were aimed at improving the Agency's financial management procedures and making them more responsive to management's needs.

Financial Reporting of Contractor-held Property

In response to a request from the U.S. General Accounting Office, NASA published and distributed "Financial Reporting for Government-Owned/Contractor-Held Property and Space Hardware" (NHB 9500.2). This Handbook required contractors and subcontractors to make financial reports to the Agency covering the two major areas of Government-owned property held by them. It also provides for disclosure of NASA's major investments in such as real and personal property, special test equipment, and materials inventories; and space hardware relating primarily to certain equipment and components thereof fabricated for use in Agency programs. The Handbook expanded previous reporting requirements to include special test equipment. It also provides for a new report covering completed space hardware items, related systems and subsystems, spare parts and components, and certain work-in-process efforts.

Cost Comparison Studies (Support Services)

NASA Centers and Headquarters made a number of cost studies, comparing the costs of performing support services under contract with the cost of performing equivalent services in-house. Review of these studies was made a part of the general procedures in connection with proposed new procurement actions. They also became part of the review of existing support services contractual relationships.

Financial Reports, December 31, 1968

Table 10–1 shows fund obligations and accrued costs incurred during the six months ended December 31, 1968. Appended to the table is a summary by appropriation showing current availability, obligations against this availability, and unobligated balances as of December 31, 1968.

Table 10–1—Status of Appropriations as of December 31, 1968
(In thousands)

Appropriations	*Six months Ended December 31, 1968* Obligations	Accrued Costs
Research and Development:		
Apollo	$1,255,260	$1,200,370
Apollo applications	75,727	74,936
Advanced missions	2,963	877
Gemini	(175)	81
Completed missions	14	18
Physics and astronomy	66,813	63,973
Lunar and planetary exploration	34,527	30,959
Launch vehicle procurement	44,704	52,293
Bioscience	19,161	18,694
Space applications	57,105	38,819
Space vehicle systems	11,691	13,986
Electronics systems	10,560	15,946
Human factor systems	6,726	7,547
Basic research	8,393	9,329
Space power and electric propulsion systems	18,836	23,253
Nuclear rockets	17,620	22,245
Chemical propulsion	11,890	14,824
Aeronautics	31,699	32,432
Tracking and data acquisition	168,690	140,047
Sustaining university program	1,003	15,307
Technology utilization	1,817	1,735
Operations	(38)	(26)
Reimbursable	22,822	28,120
Total, research and development	1,867,808	1,805,765
Construction of facilities	16,996	22,023
Administrative operations	324,493	326,935
Totals	$2,209,297	$2,154,723

Appropriation Summary	*Current Availability*[1]	*Total Obligations*	*Unobligated Balance*
Research and development	$3,691,721	$1,867,808	$1,823,913
Construction of facilities	104,969	16,996	87,973
Administrative operations	650,020	324,493	325,527
Totals	$4,446,710	$2,209,297	$2,237,413

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

Table 10–2 shows NASA's consolidated balance sheet as of December 31, 1968, as compared to that of June 30, 1968. Table

10–3 summarizes the sources and applications of NASA's resources during the six months ended December 31, 1968. Table 10–4 provides an analysis of the net change in working capital disclosed in Table 10–3.

Table 10–2—Comparative Consolidated Balance Sheet December 31, 1968 and June 30, 1968
(In millions)

Assets	*December 31, 1968*	*June 30, 1968*
Cash:		
Funds with U.S. Treasury	$3,859.6	$1,996.2
Accounts receivable:		
Federal agencies	20.8	18.0
Other	3.4	1.4
	24.2	19.4
Inventories:		
NASA-held	38.7	35.3
Contractor-held	317.5	294.2
	356.2	329.5
Advances and prepayments:		
Federal agencies	10.5	12.3
Other	31.7	16.4
	42.2	28.7
Deferred charges	9.0	—
Fixed assets:		
NASA-held	3,334.2	3,134.0
Contractor-held	709.2	692.7
Construction in progress	500.5	585.6
	4,543.9	4,412.3
Other assets	59.6	—
Total assets	$8,894.7	$6,786.1
Liabilities:		
Accounts payable:		
Federal agencies	$ 124.8	$ 127.4
Other	553.5	541.0
	678.3	668.4
Accrued annual leave	34.4	34.4
Total liabilities	712.7	702.8
Equity:		
Net investment	4,290.4	4,070.8
Undisbursed allotments	3,083.4	1,965.5
Unapportioned and unallotted appropriation	923.5	141.6
	8,297.3	6,177.9
Less reimbursable disbursing authority uncollected	(115.3)	(94.6)
Total equity	8,182.0	6,083.3
Total liabilities and equity	$8,894.7	$6,786.1

Table 10–3—Resources Provided and Applied
Six Months Ended December 31, 1968
(In millions)

Resources Provided			
Appropriations:			
Research and development			$3,370.3
Construction of facilities			21.8
Administrative operations			602.9
Total appropriations			3,995.0
Revenues			31.9
Total resources provided			$4,026.9

Resources applied	*Total Costs Six Months Ended December 31, 1968*	*Less: Costs Applied to Assets*	
Operating costs:			
Research and development	$1,805.7	$240.1	$1,565.6
Construction of facilities	22.0	22.0	—
Administrative operations	326.9	7.6	319.3
Total	$2,154.6	$269.7	
Total operating costs			1,884.9
Increase in fixed assets:			
NASA-held			200.2
Contractor-held			16.5
Construction in progress			(85.1)
Total increase in fixed assets			131.6
Property transfers and retirements—net			43.3
Increase in working capital (Table 10–5)			1,967.1
Total resources applied			$4,026.9

Table 10–4—Net Change in Working Capital
Six Months Ended December 31, 1968
(In millions)

	December 31, 1968	*June 30, 1968*	*Increase or (Decrease)*
Currents assets:			
Funds with U.S. Treasury	$3,859.6	$1,996.2	$1,863.4
Accounts receivable	24.2	19.4	4.8
Inventories	356.2	329.5	26.7
Advances and prepayments	42.2	28.7	13.5
Deferred charges	9.0	—	9.0
Other assets	59.6	—	59.6
Total current assets	4,350.8	2,373.8	1,977.0
Current liabilities:			
Accounts payable	678.3	668.4	9.9
Working capital	$3,672.5	$1,705.4	
Increase in working capital			$1,967.1

COST REDUCTION PROGRAM

NASA's internal cost reduction program yielded savings of $45,160,000, and its contractor cost reduction program reduced costs by approximately $120,000,000 during the second half of 1968. NASA established an internal cost reduction goal of $125 million for Fiscal Year 1969.

The Agency's cost reduction program includes two major efforts to improve internal and contractor efficiency. The internal cost reduction program encompasses ten field installations and all of the principal Headquarters program and staff offices. The NASA contractor cost reduction program includes 36 of the Agency's major contractors who voluntarily participate in the formal reporting program. There is no overlapping or duplication between the two programs, although the concepts, standards, and criteria are quite similar. In addition to the formal contractor reporting system, the NASA Procurement Regulation requires that in responding to requests for proposals for procurements in excess of $1 million, offerors must provide information on their cost reduction programs. Similarly, the cost reduction activity is one of the factors used in periodically setting fees under cost-plus-award fee contracts.

The NASA Cost Reduction Board is responsible for the overall administration of the program and for evaluating its effectiveness. It establishes necessary policies, regulations, and procedures. It also establishes, reviews, and evaluates Agency cost reduction goals in coordination with the program offices. The Board is comprised of the Associate Deputy Administrator, the Associate Administrator for Organization and Management, the Assistant Administrator for Industry Affairs, and the Deputy Associate Administrator (Management) for the Office of Manned Space Flight.

The staff of the Cost Reduction Office continued to evaluate the management and operation of both field installation and contractor cost reduction programs. The staff also conducted intensive reviews of quarterly cost reduction reports from more than twenty internal reporting activities and of semiannual reports from the 36 NASA major contractors. The Agency then used feedback reports and staff meetings to critique management at the reporting levels on the results of these reviews.

During the latter part of this period, the Bureau of the Budget disseminated the NASA Cost Reduction Program plans, procedures, and criteria to other government agencies for comments as to their acceptability for general use as a standard system.

CONTRACT ADJUSTMENT BOARD

The NASA Contract Adjustment Board considers requests by NASA contractors for equitable contractual relief under Public Law 85–804, when no administrative legal remedy is available to such contractors. The Board's procedures are published in Title 41, Code of Federal Regulations, Part 18–17. (Members of the Board are listed in app. F.)

During this reporting period, the Board acted on two requests by contractors. In one case, the relief requested was granted in part. In the other case, the Board denied a request by the contractor for reconsideration of an earlier decision.

The case in which relief was partially granted involved a mutual mistake by the Government and the contractor in failing to foresee certain state-of-the-art engineering problems which became apparent only after the contract was executed. After studying the case, the Board authorized an increase in the contract price. The Board also had four 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.

BOARD OF CONTRACT APPEALS

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

Eleven new appeals were filed with the Board during this period, and the Board disposed of 21 appeals (most of which were filed before July 1, 1968). On December 31, 1968, the Board had 38 appeals pending on its docket.

PROCUREMENT AND SUPPLY MANAGEMENT

NASA took a number of actions to improve its procurement practices and supply management. As one example, it revised its procedure for negotiating final overhead rates, thus reducing the backlog of completed contracts held open for administrative purposes. Cost reimbursement type contracts on which performance has been completed cannot be closed out until the final overhead rates have been established. In some cases, this may take two or more years after final performance and may result in a large number of contracts being held open for fiscal and administrative purposes.

In July, NASA developed a new procedure which will replace the six-month limitation with a restriction on the total number of overhead dollars involved per twelve-month period. When this change becomes effective, installations will be able to accelerate the close-out of a large number of contracts that could not have been processed under the previous system. For example, one NASA Center reported that it has scheduled 200 contracts for close-out under the new procedure. It is too early to estimate the savings that will result, but they should be significant.

In another area of effort, NASA revised its contract clause for service contracts exceeding $2,500. The new clause incorporates procedures for contractor compliance with the new safety and health standards to protect service employees.

In another action, NASA and DOD continued a joint effort to revise and expand existing contract administration agreements and to consolidate them into a single new agreement. This effort should promote maximum NASA use of DOD contract management resources. It is consistent with the policy of promoting uniform policies and procedures in the field administration of NASA and DOD contracts.

Also, NASA participation in DOD reviews of major DOD contract administration activities having substantial NASA workload continued. This participation assured NASA that the contract administration services performed by DOD for NASA (at an estimated FY 1969 cost to NASA of $27 million) are satisfactory.

In a fifth area of effort, NASA increased the number of screening requests being processed through the Defense Industrial Plant Equipment Center. Acquisitions of idle DOD industrial plant equipment for NASA use exceeded $1 million in the last six months.

Finally, to improve financial management of Government property, NASA contractors are now required to include in their semiannual financial reports the value of Government-owned space hardware which may be used on more than one program.

Incentive Contracting

NASA started the period with 115 industrial contractors engaged in incentive contracting under 285 active contracts valued at approximately $6.7 billion. Because of the research and development nature of the programs, and because of the degree of technical and cost uncertainties, most of the contracts were cost-reimbursement types. The predominant type was Cost-Plus-Incentive-Fee (CPIF). The second largest grouping was the Cost-Plus Award-Fee (CPAF) type.

NASA continued to play a leading role in the development of advanced procedures for Government-wide use of CPAF contracts (using subjective evaluations of performance for fee determination purposes). As of December 31, 76 NASA contractors were working under 132 active CPAF contracts valued at $2.1 billion, and the total number of incentive contracts was 258; these were valued at $7.1 billion.

NASA continued its study of extracontractual influences in Government contracting. An interdisciplinary team of university research specialists was in the second year of its study of motivational influences which should be considered in developing incentive profit structures. Preliminary findings of the study were being incorporated in drafts of a new NASA/DOD Incentive Contracting Guide being developed for release during 1969.

Summary of Contract Awards

NASA's procurement for this report period totalled $1,979 million. This is $224 million less than was awarded during the corresponding period of 1967.

Approximately 85 percent of the net dollar value was placed directly with business firms, 4 percent with educational and other nonprofit institutions, 4 percent with the California Institute of Technology for operation of the Jet Propulsion Laboratory, 6 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 58 percent of the funds placed by NASA under the Jet Propulsion Laboratory contract resulted in subcontracts or purchases with business firms. In short, about 93 percent of NASA's procurement dollars was contracted to private industry.

Sixty-nine percent of the total direct awards to business represented competive procurements, either through formal advertising or competitive negotiation. An additional 8 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 23 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 $70 million, or 4 percent of NASA's direct awards to business. Most of the awards to business however, were for large continuing research and development contracts for major systems and major items of hardware which are generally beyond the capability of small business firms on a prime contract basis. Of the $236 million of new contracts of $25,000 and over awarded to business during the six months, small business received $21 million, or 9 percent.

In addition to the direct awards, small business received substantial subcontract awards from 85 of NASA's prime contractors participating in its Small Business Subcontracting Program. Total direct awards plus known subcontract awards aggegated $160 million, or 9 percent of NASA's total awards to business during the period.

Geographical Distribution of Prime Contracts

Within the United States, NASA's prime contract awards were distributed among 43 States and the District of Columbia. Business firms in 40 States and the District of Columbia, and educational institutions and other nonprofit institutions in 40 States and the District of Columbia, participated in the awards. One percent of the awards went to labor surplus areas located in 12 States.

Subcontracting

Subcontracting effected a further distribution of the prime contract awards. NASA's major prime contractors located in 23 States and the District of Columbia reported that their larger subcontract awards on NASA effort had gone to 844 subcontractors in 41 States and the District of Columbia, and that 77 percent of these subcontract dollars had crossed state lines.

Major Contract Awards

Among the major research and development aggregate contract awards by NASA during this six month period were the following:

1. North American Rockwell Corp., Downey, Calif. NAS9–150. Design, develop and test Apollo command and service module. Awarded $281 million; cumulative awards $3,296 million.

2. Grumman Aircraft Engineering Corp., Bethpage, N.Y. NAS 9–1100. Development of Apollo lunar module. Awarded $190 million; cumulative awards $1,773 million.

3. The Boeing Company, New Orleans, La. NAS8–5608. 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 $138 million; cumulative awards $1,337 million.

4. North American Rockwell Corp., Downey, Calif. NAS7–200. Design, develop, fabricate and test the S–II stage of the Saturn V vehicle and provide launch support services. Awarded $107 million; cumulative awards $1,237 million.

5. McDonnell Douglas Corp., Santa Monica, Calif. NAS7–101. Design, develop and fabricate the S–IVB stage of the Saturn V vehicle and associated ground support equipment and provide launch support services. Awarded $65 million; cumulative awards $1,023 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 $53 million; cumulative awards $723 million.

7. Chrysler Corporation, New Orleans, La. NAS8–4016. Fabricate, assemble, checkout and static test Saturn S–IB stage; provide product improvement program and space parts support; modify areas of Michoud Plant assigned to contractor; provide launch support services. Awarded $26 million; cumulative awards $484 million.

8. The Boeing Company, Washington, D.C. NASW–1650. Apollo/Saturn V technical integration and evaluation. Awarded $26 million; cumulative awards $78 million.

9. Bendix Corporation, Owings Mills, Md. NAS5–10750. Maintenance and operation of the Manned Space Flight Network. Awarded $26 million; cumulative awards $53 million.

10. International Business Machines Corp., Huntsville, Ala. NAS 8–14000. Fabrication, assembly and checkout of instrument units for Saturn I and V vehicles. Awarded $25 million; cumulative awards $291 million.

11. North American Rockwell Corp., Canoga Park, Calif. NAS 8–18734. Fabrication and delivery of F–1 engines; provide supporting services and hardware. Awarded $25 million; cumulative awards $129 million.

12. General Motors Corp., Milwaukee, Wisc. NAS9–497. Guidance computer subsystem for Apollo command and service module. Awarded $21 million; cumulative awards $362 million.

13. Bendix Corporation, Kennedy Space Center, Fla. NAS10–1600. Apollo launch support services at Kennedy Space Center. Awarded $18 million; cumulative awards $94 million.

14. 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 $16 million; cumulative awards $627 million.

15. International Business Machines Corp., Houston, Texas. NAS 9–966. Design, develop and implement real time computer complex for Integrated Mission Control Center at the Manned Spacecraft Center. Awarded $15 million; cumulative awards of $129 million.

16. Federal Elctric Corp., Kennedy Space Center, Fla. NAS10–4967. Provide communications, instrumentation and computer operations support services for KSC facilities. Awarded $15 million; cumulative awards $31 million.

17. Aerojet-General Corp., Sacramento, Calif. SNP–1. Design, develop and produce a nuclear powered rocket engine (NERVA). Awarded $14 million; cumulative awards $464 million.

18. Trans World Airlines, Kennedy Space Center, Fla. NAS 10–1242. Provide base support services at Kennedy Space Center. Awarded $14 million; cumulative awards $96 million.

19. Martin Marietta Corp., Denver, Colo. NAS8–24000. Payload integration for the Apollo Applications Program. Awarded $14 million; cumulative awards $25 million.

20. Grumman Aircraft Engineering Corp., Bethpage, N.Y. NAS 8–25000. Lunar module modifications for the Apollo Applications Program. Awarded $13 million; (new contract).

Major Contractors

The 25 contractors receiving the largest direct awards (net value) during the period were the following:

Contractor & Place of Contract Performance	Thousands
1. North American Rockwell Corp. *Downey, Calif.	$444,325

	Contractor & Place of Contract Performance	*Thousands*
2.	Grumman Aircraft Engrg. Corp. Bethpage, N.Y.	221,877
3.	Boeing Company *New Orleans, La.	169,307
4.	McDonnell Douglas Corp. *Santa Monica, Calif.	93,084
5.	General Electric Company. *King of Prussia, Pa.	88,509
6.	Bendix Corp. *Owings Mills, Md.	74,430
7.	Int'l Business Machines Corp. *Huntsville, Ala.	53,226
8.	Radio Corporation of America *Camden, N.J.	33,076
9.	TRW, Inc. *Houston, Tex.	29,109
10.	Chrysler Corp. *New Orleans, La.	26,832
11.	General Motors Corp. *Milwaukee, Wisc.	20,789
12.	Federal Electric Corp. *Kennedy Space Center, Fla.	18,843
13.	Sperry Rand Corp. *Houston, Tex.	17,899
14.	Aerojet-General Corp. *Sacramento, Calif.	16,556
15.	Martin Marietta Corp. *Denver, Colo.	16,117
16.	Lockheed Aircraft Corp. *Houston, Tex.	14,032
17.	Trans World Airlines, Inc. *Kennedy Space Center, Fla.	13,830
18.	LTV Aerospace Corp. *Dallas, Tex.	13,501
19.	Catalytic-Dow (Joint Venture) Kennedy Space Center, Fla.	12,809
20.	Philco-Ford Corp. *Houston, Tex.	11,153
21.	United Aircraft Corp. *Windsor Locks, Conn.	9,586

Contractor & Place of Contract Performance	Thousands
22. General Dynamics Corp. *San Diego, Calif.	8,459
23. Singer-General Precision, Inc. *Houston, Tex.	8,351
24. ILC Industries, Inc. Dover, Del.	7,500
25. Service Technology Corp. *Houston, Tex.	6,761

* 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

The number of man days lost because of strikes on construction contracts at all NASA Centers decreased from 2,066 during the first half of 1968 to 885 during the last half of the year. At Cape Kennedy, the man days lost decreased from 645 in the first half to 106 during the second half of 1968. Man days lost on industrial contracts during the period amounted to 3,519 as compared with 3,475 during the preceding period.

Advance planning prevented strikes from impacting on NASA programs because through procedures were put into effect to isolate contractor labor disputes from interfering with work of other on-site contractors, and alternative production techniques were used to continue production requirements during a strike.

RELATIONSHIPS WITH OTHER GOVERNMENT AGENCIES

Largely through the Aeronautics and Astronautics Coordinating Board (AACB) and its panels, NASA and the Department of Defense continued to exchange information, and to review and coordinate the aeronautical and space programs. They also initiated certain new studies during the period.

Through the AACB, NASA and DOD reviewed the proposed facilities construction programs outlined in the FY '69 budget; reviewed large ground test facilities considered necessary to carry out foreseeable aeronautical programs in the next ten- to fifteen-year period; surveyed the coordination and exchange of information in the navigation satellite area; initiated launch vehicle studies to determine the future needs; established a policy relating to biological in-flight experiments and the manned space flight program; and reviewed the instrumentation aircraft and ship requirements in support of the Apollo Program and DOD programs.

NASA continued to use military detailees, although fewer were assigned during this period than during previous ones. Almost 300 individuals were on detail in the last half of 1968. Of these, 89 were from the Department of the Army, 26 from the Navy Department, and 183 from the Air Force. Ten NASA employees were assigned to DOD organizations.

NASA developed informal relationships with the Department of Health, Education, and Welfare for consideration of areas of mutual interest. These involve the role communications satellite technology might play in advancing educational and cultural objectives, such as instructional TV in schools, public TV, and medical education for practicing physicians. The Office of Education was expected to evaluate the educational aspects of proposals for using ATS satellites for educational demonstrations or experiments.

Aside from arrangements with the Department of Transportation on matters involving aeronautical research, NASA was working closely with that agency in connection with development of navigation satellites and related space technology that might be useful for various transportation applications.

NASA advised the Federal Communications Commission on some of the technical aspects of communications satellite systems, including launch vehicle capability and costs. This Agency also participated actively in the work of the President's Task Force on Communications Policy.

PATENT PROGRAM

Through its patent licensing program, NASA attempts to encourage the maximum use of its inventions for public benefit. While such inventions would be applicable to new products and services, they are equally valuable in contributing to the Nation's continued economic growth. To aid industries and interested parties in using these inventions, NASA issued patent licensing regulations under which its patented inventions may be licensed to industry.

The Agency of course prefers non-exclusive licensing on its patents so that the widest possible use may be made. However, it does on occasion grant an exclusive license when this added incentive appears necessary to have the invention developed for commercial use. As of the end of this reporting period, NASA held title to 780 U.S. patents. It had granted 171 nonexclusive licenses and three exclusive licenses to American companies to use Agency-owned inventions.

Foreign Patent Program

Since NASA began its foreign patent program four years ago, it has filed 228 patent applications in the Patent Offices of foreign countries, and 95 patents have been issued to date. During the past six months, NASA negotiated its first royalty-bearing foreign patent license.

An exclusive license for the manufacture in Japan of the invention described in Japanese Patent No. 484, 436, "Interconnection of Solar Cells," was granted to Nippon Electric Company, Ltd. In return, Nippon will pay NASA, for deposit in the U.S. Treasury, an initial sum of $2,000 together with a fixed royalty of one per cent of the fair market value of the units covered by the patent claims. The license was negotiated and granted under the authority of the NASA Foreign Patent Licensing Regulations, published in the Federal Register on August 18, 1966.

Domestic Licensing Program

On September 20, NASA granted an exclusive, irrevocable, royalty-free license to the Hubbard Scientific Company, Northbrook, Illinois, for an invention covered by a patent issued to this Agency. The invention, which was not available on the commercial market, is a flight path simulator developed at the Jet Propulsion Laboratory for visually indicating flight paths of vehicles between Earth, Venus, and Mercury (U.S. Patent No. 3,196,558). Under the license, Hubbard receives the exclusive right to make, use, and sell the invention on the commercial market for a period of five years. In consideration of the license, Hubbard has agreed to spend a minimum of $3,000 during the first year in an attempt to commercialize the invention. Hubbard plans to use the invention as an educational training device for schools and universities. This is the fourth exclusive license granted by NASA for patented inventions resulting from its aeronautical and space activities.

Appendix A

Congressional Committees on Aeronautics and Space

(July 1–December 31,1968)

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
MARGARET CHASE SMITH, Maine
BOURKE B. HICKENLOOPER, Iowa
CARL T. CURTIS, Nebraska
LEN B. JORDAN, Idaho
MARK O. HATFIELD, Oregon
CHARLES E. GOODELL, New York

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
THOMAS N. DOWNING, Virginia
JOE D. WAGGONNER, Jr., Louisiana
DON FUQUA, Florida
GEORGE E. BROWN, Jr., California
EARLE CABELL, Texas
JACK BRINKLEY, Georgia
BOB ECKHARDT, Texas
ROBERT O. TIERNAN, Rhode Island
BERTRAM L. PODELL, New York
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, Florida
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 31,1968)

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

DEAN RUSK
Secretary of State

CLARK M. CLIFFORD
Secretary of Defense

THOMAS O. PAINE, *Acting 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, 1968)

DR. THOMAS O. PAINE	Acting Administrator
Vacant	Deputy Administrator
DR. HOMER E. NEWELL	Associate Administrator
WILLIS H. SHAPLEY	Associate Deputy Administrator
HAROLD B. FINGER	Associate Adminstrator for Organization and Management
WILLIAM E. LILLY	Assistant Administrator for Administration
PHILIP N. WHITTAKER	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
DR. ALFRED J. EGGERS, Jr	Assistant Administrator for Policy
JACOB E. SMART	Assistant Administrator for DOD and Interagency Affairs
VADM. CHARLES E. WEAKLEY, USN (Ret.)	Assistant Administrator for Management Development
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 Adminstrator 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: 936-7101)

Appendix D

Current Official Mailing Addresses for Field Installations

(December 31, 1968)

Installation and telephone number	Official	Address
Ames Research Center; 415-961-1111	Dr. H. Julian Allen, Acting Director.	Moffett Field, Calif. 94035.
Electronics Research Center; 617-494-2000.	Mr. James 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; 301-982-5042.	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; 305-867-7113.	Dr. Kurt H. Debus, Director	Kennedy Space Center, Fla. 32899.
Langley Research Center, 703-722-4645	Dr. Edgar M. Cortright, 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-HU3-3111.	Dr. Robert. Gilruth, Director	Houston, Tex. 77058.
George C. Marshall Space Flight Center; 205-877-1000.	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 29300, New Orleans, La. 71029.
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, Lompoc, 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.

Appendix E

NASA's Historical Advisory Committee

(December 31, 1968)

Chairman: MELVIN KRANZBERG, Western Reserve University and Executive Secretary of the Society for the History of Technology

MEMBERS

RAYMOND BISPLINGHOFF, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology
JAMES LEA CATE, Department of History, University of Chicago
EARL DELONG, Dean, School of Government and Public Administration, The American University
A. HUNTER DUPREE, Department of History, Brown University
JOE B. FRANTZ, Department of History, University of Texas
LOUIS MORTON, Department of History, Dartmouth College
ROBERT L. PERRY, Economics Division, The RAND Corporation
Executive Secretary: EUGENE M. EMME, NASA Historian

Appendix F

NASA's Contract Adjustment Board

(December 31, 1968)

Chairman	E. M. SHAFER
Members	ERNEST W. BRACKETT
	FRANK J. SULLIVAN
	MELVYN SAVAGE
	WILLIAM E. STUCKMEYER
Counsel to Board	DANIEL M. ARONS

Appendix G

NASA's Board of Contract Appeals

(December 31, 1968)

Chairman	ERNEST W. BRACKETT
Vice Chairman	MATTHEW J. MCCARTIN
Members	WOLF HABER
	DONALD W. FRENZEN
	DANIEL M. ARONS
	JOHN B. FARMAKIDES
	(Vacancy)
Recorder	(MRS.) EVELYN M. KIRBY

Appendix H

NASA's Space Science and Applications Steering Committee

(December 31, 1968)

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Secretary:
MARGARET B. BEACH

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ROLL D. GINTER
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VINCENT L. JOHNSON
URNER LIDDEL
DOUGLAS R. LORD
JESSE L. MITCHELL,
ORAN W. NICKS
ORR E. REYNOLDS
LEE R. SCHERER
MORRIS TEPPER

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E. MARGARET BURBIDGE—University of California at San Diego
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LAURENCE FREDRICK—University of Virginia
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KENNETH GREISEN—Cornell University

FREDERICK T. HADDOCK—University of Michigan
WILLIAM F. HOFFMAN—Goddard Institute for Space Studies
DONALD C. MORTON—Princeton University
THORNTON PAGE—Wesleyan University/Manned Spacecraft Center

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JOHN V. HARRINGTON—Massachusetts Institute of Technology
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JOHN L. HULT—RAND Corporation
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SAMUEL G. LUTZ—Hughes Aircraft Company
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JAMES H. SASSER—Manned Spacecraft Center
HELLMUT SCHMID—Environmental Science Services Administration
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URHO A. UOTILA—Ohio State University
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WILLIAM B. HANSON—Southwest Center for Advanced Studies
ROBERT W. KNECHT—Environmental Science Services Administration
GERALD S. LEVY—Jet Propulsion Laboratory

Meteorology Subcommittee

Chairman:
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Secretary:
GEORGE P. TENNYSON—NASA Headquarters

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PHILIP D. THOMPSON—National Center for Atmospheric Research
RAYMOND WEXLER—Allied Research Associates

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WILLIAM W. KELLOGG—National Center for Atmospheric Research
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ILYIA POPPOFF—Ames Research Center
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Secretary:
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PAUL GAST—Lamont Geological Observatory
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Secretary:
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EDWARD L. CHUPP—University of New Hampshire
HERBERT FRIEDMAN—Naval Research Laboratory
EDWARD GIBSON—Manned Spacecraft Center
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EDWARD P. NEY—University of Minnesota
WILLIAM H. PARKINSON—Harvard College Observatory
PETER A. STURROCK—Stanford Univerxity
RICHARD TESKE—University of Michigan
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HAROLD ZIRIN—California Institute of Technology
JACK ZIRKER—University of Hawaii

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Secretary:
JOSEPH F. SAUNDERS—NASA Headquarters

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NELLO PACE—University of California at Berkeley
C. LADD PROSSER—University of Illinois
ALGERNON G. SWAN—Kirtland Air Force Base
HANS-LUKAS TEUBER—Massachusetts Institute of Technology
CORNELIUS A. TOBIAS—Donner Laboratory

Appendix I

NASA's Inventions and Contributions Board

(December 31, 1968)

Chairman	ERNEST W. BRACKETT
Vice Chairman	LEONARD RAWICZ
Director of Staff	FRANCIS W. KEMMETT
Members	MELVIN S. DAY
	C. GUY FERGUSON
	HARVEY HALL
	ARTHUR D. HOLZMAN
	ROBERT E. LITTELL
	JOHN B. PARKINSON
	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, 1968)

Invention	Petitioner	Action on petition
(Complementary Micropower Transistor) Complementary J-K Flip-Flop Using Transistor Logic.	Texas Instruments, Inc	Granted.
(Complementary Multiple Emitter Micropower) High Speed, Low Power Magic Gate.	do	Do.
Process for Fabricating Integrated Circuits Having Matched Complementary Transistors and Product.	do	Do.
Monolithic Circuit and High Q Capacator	do	Do.
Flame Resistant Silicone Composition	North American Rockwell Corp	Do.
Novel Polyelectrolytes	California Institute of Technology.	Do.
Shielding Method and Device for Polycrystalline and Epitaxy Growths.	TRW, Inc	Do.
Pulsed Laser Holocamera	do	Do.
Three Axis Torque Measuring Fixture	The Bendix Corporation	Do.
Method of Applying Intermittent Electrical Insulation	Avco Corp	Do.
A Vortex Pressure Amplifier with Discontinuous Chamber Surface for Stabilization Purposes.	Bendix Corp	Do.
Hydraulic Drain Means for Servo Systems	California Institute of Technology.	Do.
Electric Arc Light Source Having Undercut Recessed Anode.	Giannini Scientific Corp	Do.
High Current Single Diffused Transistor	Westinghouse Electric Corp	Do.
Laser Device	Massachusetts Institute of Technology.	Do.
Polymeric Compositions and Their Method of Manufacture.	California Institute of Technology.	Do.
Double Doped Alkaline Earth Fluoride Photochromic Material.	Radio Corp of America	Do.
Positive and Negative Work Cylinder	North American Rockwell Corp	Do.
Continuity Tester for Multilayer Boards	TRW, Inc	Do.
Sychronization System for TDMA	ITT Corp	Denied.
Avalanche Effect Transistor Frequency Divider	California Institute of Technology.	Granted.
Improved Lithium Niobate Crystal Method and Efficient Harmonic Generator.	Union Carbide Corp	Do.
Synchronization System for MESA	International Telephone and Telegraph Corp., ITT Federal Laboratories Division.	Denied.
Locking Mechanism	North American Rockwell Corp	Granted.
High Temperature Stable Adhesives	Singer-General Precision, Inc	Do.
Vapor Fed Liquid-Metal Cathode	Hughes Aircraft Co	Do.
Pin-Installation	North American Rockwell Corp	Do.
Squeeze Film Bearnings	Bendix Corp	Do.

Invention	Petitioner	Action on Petition
Beam Alignment	Singer-General Precision Systems, Inc.	Granted.
Hermetically Sealed Relay	Raytheon Co	Do.
Method for Producing Dimensionally Stable Photo-sensitive Resist Pattern.	CBS Laboratories	Do.
Method for Producing Reliable Contacts b/n Resistors & Low Sensitivity Materials.	CBS Laboratories	Do.
Method for Restoring the Electrical Properties of Ion Bombarded Semi-conductor Devices.	----do	Do.
Klystron Amplifier Employing Helical Distributed Field Buncher Resonators and a Coupled Cavity Extended Interaction.	Varian Associates	Do.
Monochromator	Farrand Optical Co., Inc	Do.
Waveshaping Circuit Apparatus	IBM Corp	Do.
Digital Deflection Sensor	General Telephone and Electronics Laboratories, Inc.	Do.
Stripper for Insulated Wire	Computing and Software, Inc	Do.
Deployable Lattice Column	Astro Research Corp	Do.
Inverter with Means for Base Current Shaping for Sweeping Charger Carrier from Base Region.	Airtronics, Inc	Denied.
Thermoelectric Generator Mount	North American Rockwell Corp./Atomics International Division.	Granted.
Scan Conversion Video Tape Recorder	California Institute of Technology.	Do.
Delay Flop Switching	Panametrics, Inc	Do.
A High-Strength Whisker-Reinforced Metallic Mono-filament.	General Technologies Corp	Do.
Efficient Radiation Cooled Beam Collector for Linear Beam Devices.	Varian Associates	Do.
Separator for Alkaline Electric Batteries	The Borden Co	Do.
Separator for Alkaline Electric Batteries	----do	Do.
Separator for Alkaline Electric Batteries	----do	Do.
Storage Battery	----do	Do.
Membrane	----do	Do.
Polyimide Polymers	TRW, Inc	Do.
Polyimide Molding Power Compositions	----do	Do.
Reinforced Structural Plastics	----do	Do.
Separator for Alkaline Electric Batteries	The Borden Co	Do.
Separator for Alkaline Electric Batteries	----do	Do.
Method and Apparatus for Cryogenic Wire Stripping	B. D. Babb (Employee of Hayes International Co.)	Denied
Inorganic Non-Reciprocal Optical Filter	Hartman Systems Co., Inc	Do.
Low Power Analog Switch	Westinghouse Electric Co	Granted.
Automatic Frequency Discriminators and Control for a Phase-Lock Loop Providing Frequency Preset Capabilities.	Motorola, Inc	Denied.
Sealed Cabnetry	----do	Do.
Digital Frequency Discriminator	----do	Do.
Electrohydrodynamics Apparatus and Method	Massachusetts Institute of Technology.	Granted.
High Temperature Nickel-Base Superalloy	TRW, Inc	Do.
Graphical Display System	Massachusetts Institute of Technology.	Do.
Turbine Stator Vance with Film Cooled Leading Edge	Curtiss-Wright Corp	Denied.
Aluminum-Steel Composite	Harvey Aluminum Inc	Granted.
Use of and Method for Introducing Oxygen as an Additive into a Thermionic Converter.	Thermo Electron Corp	Do.
In Situ Hafnium-Tantalum Composities	IIT Research Ins	Do.

Invention	Petitioner	Action on petition
Device for Obtaining Separation of Oxgyen	General American Transportation Corp.	Granted
Transformer Regulated Self-Stabilized Chopper	United Aircraft Corp. Hamilton Standard Division.	Do.

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, 1968)

Contract Description [1]	Petitioner	Action on petition
Analytical Study Program to Develop the Theoretical Design of Traveling Wave Tubes.	Hughes Aircraft Co	Denied.
Research on the Effective Implementation of Guidance Computers with Large Scale Arrays.	....do	Granted.
R&D of an Improved Quadrupole Mass Spectrometer	Earth Sciences, A Teledyne Co	Do.
Development of a Thin Film Temperature Sensor for Upper Atmospheric Soundings.	Atlantic Research Corp. and Victory Engineering Corp./ Joint Venture.	Do.
Fabricate and Develop Mark II, A Critical Tasks Tester and Test Plan.	Systems Technology, Inc	Do.
Modification of Goddard Range and Ranger Radar Systems.	General Dyamics/Electronics Division.	Denied.
Investigate the Thrust Vector of an Electron Bombardment Ion Engine.	Hughes Aircraft Co	Granted.
Program for Development of High Temperature Electrical Materials.	Westinghouse Electric Corp	Do.
High Temperature (LM) Mercury Cathode Ion Thrustor	Hughes Aircraft Co	Do.
Development of Improved Solar Cell Electrical Contacts	Singer-General Precision Systems Inc.	Do.
Linear Beam Tube Having a Beam Collector Cooled by Radiation Through an Infrared Window.	Varian Associates	Do.
Feasibility Study of ABVAC-Absolute Vacuum Density Calibration.	TRW, Inc	Do.
Development of an Improved Extra-vehicular Space Suit Thermal Insulation.	Arthur D. Little, Inc	Denied.
Fabricate, Assemble, and Test Flight Telemetry System and Operational Support Equipment.	Texas Instruments, Inc	Granted.
Investigation of Laminated Convection Film Cooled Vanes.	Aerojet-General Corp	Denied.
Determining the Feasibility of Chemical Vapor Deposition Process for the Production of Disperiod-Strengthened Chrominum Alloys.	Texas Instruments Inc	Do.
Augmentor Wing Large-Scale Model Tests [2]	DeHavilland Aircraft of Canada, Ltd.	Granted.
Development of Long Life Jet Engine Thrust Bearings	Mechanical Technology Inc	Do.
Design, Develop, Fabricate and Test a 0–4 MHZ Video Tape Recorder/Reproducer to be Used on Long Life Missions on Earth Orbiting Satellites.	Radio Corp. of America	Do.

[1] Waiver before execution of contract.
[2] Waiver of license rights.

Contract Description [1]	Petitioner	Action on petition
Design Plan for Feasibility Model of a Video Instrumentation Recorder/Reproducer System (VIRRS).	Ampex Corp	Granted;
Magnetic Head/Tape Interface Study	IIT Research Ins	Do.
Cleaning Services for Spacecraft, Launch Vehicles and Ground Support Equipment.	The Dow Chemical Co	Do.
Neutron Radiographic Viewing System	Zenith Radio Corp	Do.
Development of Multimodal Fixtures and Multiple Input Concepts as Substitutes for High-level Acoustic Testing.	Bolt, Beranek and Newman, Inc.	Do.
Design and Install General Purpose Motion Simulator	General Precision Systems, Inc	Do.
LSI Complementary MOS-FET Scratch Pad Memories	Radio Corp. of America	Do.

Petitions Deferred

Analog Integrated Microsystems, Inc. (AIM, Inc.) (BW-1039)
Westinghouse Electric Company (BW-985)
Texas Instruments, Incorporated (BW-969)
Texas Instruments, Incorporated (BW-996)

Appendix L

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

(July 1—December 31,1968)

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

Contribution	Inventor(s)	Employer
Flexible, Repairable, Pottable Material for Electrical Connectors.	Philip C. Crepeau, Robert A. Dunaetz.	Hughes Aircraft Co.
Pulse Activated Polarographic Hydrogen Detector.	John N. Harman III	Beckman Ins.
Bonding Graphite	Richard Faulkner	Radio Corp. of America.
Excitation and Detection Circuitry for a Flux Responsive Magnetic Head.	David A. Ehrenfeld	Kinelogic Corp.
Self Balancing Strain Gage Transducer.	Billy D. Babb	Hayes International Corp.
Transistor Drive Regulator	Richard J. Ravas	Westinghouse Electric Corp.
Latch Ejector Unit	Stuart K. Edleson	LTV Aerospace Corp.
Silicide Coatings for Refractory Metals.	Ray T. Wimber, Alvin R. Stetson, Arthur G. Metcalff.	International Harvester Co.
Collapsible Nozzle Extension for Rocket Engines.	Warren E. Darrow Jr., Billy C. Ursery.	Brown Engineering.
Locking Mechanism	Edward Prono, Wesley R. Kirk	North American Rockwell Corp.
Doped Silicon Carbide Diode for Increased Light Output.	Leonard B. Giffiths, Abraham I. Mlavsky.	Tyco Laboratories Inc.
Optical Beam Deflector	Vernon L. Fowler, William Watson, John Schlafer.	General Telephone and Electronics Laboratories.
Remote Local Oscillator Frequency Multiplier.	Charles H. Currie, William W. Graham.	Scientific Atlanta Inc.
Portable Hermetic Work Chamber	Joseph L. LeBlanc, Herbert M. Goldstein.	Grumman Aircraft Engineering Corp.
Automatic Closed Circuit Television Welding Arc Guidance Control.	William A. Wall, Jr., Douglas L. Stephens.	NASA/George C. Marshall Space Flight Center and Hayes International Corp.
Synthesis of Zinc Titanate Pigment and Coatings Containing Same.	Daniel W. Gates, Gene A. Zerlaut, Frederick O. Rogers.	NASA/George C. Marshall Space Flight Center and Illinois Institute Technology Research Institute.
Precision Electronic Control for Orbital Tube Flaring Machines.	Clayton Loyd, John R. Rasquin, Hubert E. Smith, Charles D. Stocks .	NASA/George C. Marshall Space Flight Center.
Theory of a Refined Earth Figure Model and Theory of a Refined Earth Figure Model with Applications.	Helmut C. L. Krause	Do.
Polymide Bonded Solid Lubricants	Keith E. Demorest, Mahlon E. Campbell, Vernice Hopkins.	NASA/George C. Marshall Space Flight Center and Midwest Research Institute.

Contribution	Inventor(s)	Employer
Method and Apparatus for Ballasting High Frequency Transistors.	George J. Gilbert	Radio Corp. of America.
Bimetallic Power Controlled Actuator.	Franklin L. Murphy	Jet Propulsion Laboratory.
Noninterrupted Digital Counting System.	Robin A. Winkelstein	Do.
Absolute Cavity Radiometer	James M. Kendall, Sr., Joseph A. Plamondon, Jr.	Do.
A Polarimeter for Transient Measurement.	Alan R. Johnston	Do.
Fluid Lubricant System	Joseph C. Heindl, Robert J. Belanger.	Thompson Ramo Wooldridge, Inc., TRW System, Inc.
Thrust Dynamometer	Siegfried Hansen	Hughes Aircraft Corp.
Frequency Shift Keyed Demodulator.	Steven Teitelbaum, Charles Staloff.	Radio Corp. of America.
Load Cell Protection Device	Ernest T. Hillberg	North American Rockwell Corp.
Method and Apparatus for Cryogenic Wire Stripping.	Billy D. Babb	Hayes International Corp.
High Resolution Developing of Photosensitive Resists.	Charles J. Taylor	Westinghouse Electric Corp.

Space Act Section 306 Awards Summary

(July 1–December 31, 1968)

TYPES	NUMBER OF CONTRIBUTIONS	NUMBER OF AWARDEES	AMOUNT OF AWARDS
Tech Brief awards of $25	147	247	$6,175
Patent application awards of $50	7	10	500
Contribution awards of $250 or more	23	41	12,400
Totals	177	298	$19,075

Appendix M

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

(July 1–December 31, 1968)

Contribution	Inventor(s)
Goddard Space Flight Center:	
Complementary Regenerative Switch	LEONARD KLEINBERG
Optical Tracker	EDWARD J. DEVINE
Protein Sterilization Method	EMMETT W. CHAPPELLE and EDWARD RICH
Frangible Electro-chemical Cell	JOSEPH M. SHERFEY, GERALD HALPERT, and JOSEPH G. HAYNOS
Facsimile Video Remodulation Network	CHARLES H. VERMILLION
Diversity-Locked Combining System	VINCENT J. DILOSA and CHARLES R. LAUGHLIN Jr.
Input Impedance and Low Output Impedance	CIRO A. CANCRO and PAUL J. JANNICHE Jr.
Method and Apparatus for Battery Charge Control	THOMAS J. HENNIGAN, KENNETH O. SIZEMORE, and NELSON H. POTTER
Resettable Monostable Pulse Generator	NORMAN M. GARRAHAN
John F. Kennedy Space Center:	
Digital Notch Filter	BENJAMIN Z. MEERS Jr.
Langley Research Center:	
Spectrograph Alignment System	REGINALD J. EXTON
Vibrating Structure Displacement Measuring Instrument	BRUCE FLAGGE
Logic and Gate for Fluid Circuits	RICHARD F. HELLBAUM
Imidazopyrrolone/Imide Copolymers	VERNON L. BELL Jr. and GEORGE F. PEZDIRTZ
Omnidirectional Multiple Impact Landing System	JOHN R. MCGEHEE
Cryogenic Liquid Level Sensor	JOSEPH D. PERDUE
Space Suit Pressure Stabilizer	DONALD E. BARTHLOME
Payload/Burned-Out Motor Case Separation System	NATHAN D. WATSON
Fringe Counter for Interferometers	WILLIAM E. HOWELL and KAZMERE C. ROMANCZYK
Tube Fabricating Process	JOHN G. DAVIS Jr.
Steering System	UPSHUR T. JOYNER

Contribution	Inventor(s)
Lewis Research Center:	
Spiral Groove Seal	LAWRENCE P. LUDWIG
Gas Core Nuclear Reactor	FRANK E. ROM
Gaseous Control System for Nuclear Reactors	EDWARD LANTZ and HARRY W. DAVISON
High Strength Tungsten Alloys	WILLIAM D. KLOPP, PETER L. RAFFO, WALTER R. WITZKE, and LESTER S. RUBENSTEIN
Ion Thrustor Accelerator System	BRUCE A. BANKS and SHIGEO NAKANISHI
Single Grid Accelerator System	PAUL M. MARGOSIAN and SHIGEO NANANISHI
Process for Glass Coating an Ion Accelerator Grid	BRUCE A. BANKS
Refractory Metal Fiber Nickel Alloy Composites.	DONALD W. PETRASEK, ROBERT A. SIGNORELLI, JOHN W. WEETON, and GERALD B. BEREMAND
George C. Marshall Space Flight Center	
Harness Assembly	DAN H. DANE
Swivel Support for Gas Bearing	HELMUTH PHAFF
Air Cushion Lift Pad	DAN H. DANE and HERMAN T. BLAISE
Printed Circuit Assembly and Method of Fabrication	WILLIAM A. BOSHERS
Ratchet Mechanism	DAN H. DANE
System for Maintaining a Motor at a Predetermined Speed	CLAYTON LOYD
Positive DC to Positive DC Converter	EUGENE H. BERRY and FRANK J. NOLA
Handle Combination	LEWIS R. COKER and CHARLES A. MACKAY
Wallops Station:	
Safe-Arm Initiator	LOYD C. PARKER

Appendix N

EDUCATIONAL PUBLICATIONS and MOTION PICTURES

(July 1–December 31, 1968)

NASA released the following new educational publications during the last six months of this year. They are available to the public, without charge, from the Special Events Division, FGC–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

Address by Dr. Homer E. Newell, Associate Administrator, NASA, on "Some Thoughts on the Space Program and Education" delivered before the National Association of Secondary School Priciplas, Atlantic City, N.J., February 13, 1968. (*Speaking of Space and Aeronautics,* vol. iv, no. 5, 15 pp.)

Address by Dr. Newell on "Current Program and Considerations of the Future for Earth Resources Survey" delivered at the Fifth Symposium on Remote Sensing of Environment at the Institute of Science and Technology, University of Michigan, Ann Arbor, April 16, 1968. (*Speaking of Space and Aeronautics,* vol. iv, no. 7, 16 pp.)

Address by Dr. Arnold K. King, Vice President for Institutional Studies, The University of North Carolina, Chapel Hill on "Space Exploration and Its Effects on Education" delivered at the National Association of Secondary School Principals annual convention, Atlantic City, N.J., February 12, 1968. (*Speaking of Space and Aeronautics,* vol. iv, no. 6, 8 pp.)

International Cooperation In Space.—An eight-page description of developments (since 1962) in the many-sided program for international cooperation in space exploration established by NASA. Prepared for the Conference on the Peaceful Uses of Outer Space, Vienna, Austria, August 1968.

America In Space: The First Decade.—A series of illustrated booklets commemorating NASA's 10th Anniversary (1958–68). Not intended as comprehensive histories, these are overviews of some important activities, programs, and events written for the layman in terms of the several science disciplines. In addition to the following titles, booklets on propulsion, spacecraft power space life sciences, aeronautics, Space Age by-products, and materials were being prepared.

"Space Physics and Astronomy" (EP–51, 22 pp.).—Progress in studies of cosmic rays; energetic particles; magnetic fields; ionospheres; radio, solar, and cometary physics; planetary atmospheres; astronomy; and interplanetary dust.

"Exploring the Moon and Planets" (EP–52, 26 pp.).—Summary of the Mariner Program of fly bys of Mars and Venus, and lunar exploration by the Ranger, Orbiter, and Surveyor spacecraft.

"Putting Satellites to Work" (EP–53, 26 pp.).—Brief descriptions of satellites used for communications, weather forecasting, and navigation, and to investigate the earth's shape and gravitational field. Future Earth Resources Technology Satellites are also mentioned.

"NASA Spacecraft" (EP–54, 26 pp.).—The Agency's manned and unmanned spacecraft.

"Spacecraft Tracking" (EP–55, 18 pp.).—Outline of NASA's tracking and data acquisition networks.

"Linking Man and Spacecraft" (EP–56, 18 pp.).—Communications links between earth based-stations and spacecraft.

"Man In Space" (EP–57, 30 pp.).—Progress in space flight from pre-Sputnik days to the beginning of the Apollo manned lunar missions.

NASA Facts (Organization Series)

A series covering the functions and organization of each NASA center.

John F. Kennedy Space Center.—A look at the major launch facilities of the U.S. space program in Florida. 8 pp.

Lewis Research Center.—Description of NASA's propulsion research center at Cleveland, Ohio. 4 pp.

Langley Research Center.—Survey of NASA's primary aeronautics research center at Hampton, Va. 4 pp.

NASA Facts (Science Series)

Series designed for Elementary, Junior High, and High School teachers to use in explaining basic science concepts in space exploration.

Solar Cells.—Description of the major source of electricity for of the unmanned spacecraft of NASA and how that energy is produced. 4 pp.

Orbits and Revolutions.—A simple mathematical description of the two terms and their application to the space program. 4 pp.

NASA Facts (General)

Mariner Spacecraft—The story of NASA's instrumented spacecraft flights to Mars and Venus, and the results of these scientific missions, 12 pp.

Motion Pictures*

NASA also released these motion pictures during the same period. They may be borrowed, without charge other than return mailing and insurance costs, from 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.)

America in Space: The First Decade (HQ–183–1968).—color, 28 min., 16mm. Pictorial review of the U.S. space program, 1958–68. Summarizes, in layman's language, the accomplishments in major areas of space research and discovery including aeronautics, rocketry, scientific satellites, weather and communications spacecraft, manned space flight, and advanced research. (Alexander Scourby, narrator.)

Apollo Mission Highlights (AD–1).—1968, color, 12 min., 16mm. Overview of plans for the Apollo lunar landing mission. Explains briefly the techniques of the flight, how astronauts will explore the moon, and how scientists will study lunar rock samples returned to earth.

Debrief: Apollo 8 (HQ–188–1969).—color, 28 min., 16mm. The story of man's first journey to the moon. Shows highlights of the Apollo 8 mission from lift-off to recovery, with emphasis

* The Agency loaned 28,986 film prints for direct projection (non-TV) showings. Audiences included 1,725,884 students and teachers, 202,298 members of civic groups, and 309,077 members of professional or other organizations. NASA's central film depository released 18,056 feet of motion picture footage requested by producers of educational and documentary motion pictures and telecasts. An additional 606,206 feet of stock footage was catalogued and stored for a total of 8,902,350 feet.

on lunar and earth photography. Includes comments on the mission by prominent Americans. (Narrated by Actor Burgess Meredith.)

The Flight of Apollo 7 (HQ–187–1968).—color, 14 min., 16mm. The major achievements of the first manned flight of a Saturn V/Apollo vehicle, including the launching, on-board activities of the astronauts, and spacecraft reentry and recovery.

Nuclear Propulsion in Space (HQ–152–1968).—color, 24 min., 16mm. Describes the principle of the nuclear rocket, and shows its possible future uses for such missions as a manned flight to another planet. Also compares nuclear, chemical, and electrical propulsion systems. (Filmstrip of the same title available—color, 77 frames, silent, with script).

Radio Astronomy Explorer (HQa–186–1968).—color, 30 min., 16mm. Illustrates the design and function of the Radio Astronomy Explorer (XXXVIII) satellite which studies radio waves emitted by the sun, the earth, and the planet Jupiter.

Appendix O

TECHNICAL PUBLICATIONS

(July 1—December 31, 1968)

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.

The Zodiacal Light and the Interplanetary Medium (NASA SP-150).—J. L. Weinberg, editor. Proceedings of an international symposium sponsored by the International Astronomical Union, the American Institute of Aeronautics and Astronautics, and NASA, held January 30–February 2, 1967, at the University of Hawaii in Honolulu. Papers presented dealt with current research on the zodiacal light and the interplanetary medium in the following broad areas: photometric observations, particle collection and impact, meteor observations, scattering properties, dynamics, the solar wind, and origin and evolution. 430 pp. GPO $3.00.

Third Symposium on the Role of the Vestibular Organs in Space Exploration (NASA SP-152).—Proceedings of the third symposium on the inner ear held at the U.S. Naval Aerospace Medical Institute, Pensacola, Florida, January 24–26, 1967, under the auspices of the National Academy of Sciences-National Research Council Committee on Hearing, Bioacoustics, and Biomechanics. Topics discussed include man's response to the space environment, circulation of the endolymph, efferent vestibular function and anatomical considerations, blood supply to the labyrinth, and tests of the otolith function and canal function. 437 pp. GPO $3.25.

Thermal Radiation Heat Transfer. Vol. I.: The Blackbody, Electromagnetic Theory, and Material Properties (NASA SP-164).—By Robert Siegel and John R. Howell. The first of a 3-volume textbook on thermal radiation and its importance to aerospace research and design, resulting from a course developed at Lewis Research Center and taught by the authors. This volume deals with opaque materials; the second will discuss radiation exchange in enclosures both with and without convection and conduction; and the third will treat radiation in partially transmitting materials—chiefly gases. 190 pp. GPO $1.00.

Exploring Space With a Camera (NASA SP-169).—Compiled and edited by Edgar M. Cortright. This is a collection of the best photographs taken from space during the first decade of space exploration. Some were transmitted back to Earth by machines which would never return, and others were brought back by astronauts. The captions were prepared by persons intimately connected with the Nation's space effort during the 10-year period. 214 pp. GPO $4.25.

Surveyor VII: A Prleiminary Report (NASA SP-173).—This publication is a preliminary report on the last of the Surveyor missions, Surveyor VII, which was directed to land in an area of primary scientific interest—the highland area of the young ray crater, Tycho. This site provided a different kind of geological sample for comparison with mare materials studied by earlier Surveyors. The mission provided a wide variety of lunar-surface data from the alpha-scattering instrument and from the surface sampler, obtained pictures of the Earth, and performed star surveys. A special test of laser-pointing techniques was also successfully performed. 303 pp. CFSTI $3.00.

Second Conference on Sonic Boom Research (NASA SP-180).—Ira R. Schwartz, editor. Proceedings of the second conference held May 9–10, 1968, at NASA Headquarters, Washington, D.C., on the generation and propagation of sonic booms. The purpose was to review the current status of the NASA-University Program on Sonic Boom Research, to survey the current research program at NASA centers, to determine those areas of sonic boom research most pressing from the standpoint of commercial supersonic transport (SST) operation, and to determine the various avenues of research which appear to be most promising with regard to sonic boom overpressure reduction. 193 pp. GPO $1.00.

Problems and Programs on the Use of Submillimeter Waves in Space (NASA SP-182).—By Max R. Nagel. This report describes the development and the present status of the technology associated with the use of submillimeter waves in field and space applications and offers a compilation of tables, graphs, and other data on the performance of modern submillimeter components. Some of the more significant achievements and the potential of submillimeter waves in the atmospheric and astronomical disciplines and in spaceflight-related operations are discussed. Related programs currently sponsored by NASA are also reviewed. The approximate closing date for all data given is March 1968. 47 pp. CFSTI $3.00.

A Study of NASA-University Programs (NASA SP–185).—This document, prepared as a summary report by the Task Force to Assess NASA-University Programs, is based on the analysis of information gathered throughout NASA and the university community covering many different grants, contracts, disciplines, programs, and projects wherein NASA and universities have interacted. The information collected about so complex a relationship can never be complete, but the Task Force has sought to make it representative and it is believed to typify NASA-university programs with reasonable accuracy. 79 pp. CFSTI $3.00.

Progress of NASA Research Relating to Noise Alleviation of Large Subsonic Jet Aircraft (NASA SP–189).—Proceedings of a conference held at Langley Research Center, October 8–10, 1968, by NASA research centers and their contractors. Presentations were made on the following subjects: (1) Nacelle Acoustic Treatment Technology, (2) Nacelle Acoustic Treatment Application, (3) Noise Generation and Reduction at Source, (4) Operational and Environmental Considerations, and (5) Subjective Reaction. 682 pp. CFSTI $3.00.

A Numerical Least-Square Method for Resolving Complex Pulse Height Spectra (NASA SP–3044).—By J. L. Trombka and R. Schmadebeck. The authors have developed a general technique for determining the differential energy spectrum from a measurement of the pulse height spectrum, using a numerical least-square analysis method as most applicable for this analysis. Analytic methods have been successfully applied to problems in gamma-ray, X-ray, and alpha-particle spectroscopy. Bits and pieces of the technique have been published over the years, and in this publication the completed information is brought together to form a picture of the background and application of the analytic method. 170 pp. GPO $1.50.

Venture Into Space: Early Years of Goddard Space Flight Center (NASA SP-4301).—By Alfred Rosenthal. This book is a preliminary history of NASA's Goddard Space Flight Center from its antecedents through 1963. It describes the historical origins and traditions of the center as well as the projects and activities which contributed to the U.S. space program. Discussion includes early organization, budget, personnel, and programs at GSFC. 354 pp. GPO $2.50.

Effects of Low Temperatures on Structural Materials (NASA SP-5012(01)).—By H. L. Martin, P. C. Miller, A. G. Imgram, and J. E. Campbell. This revised and enlarged edition of a previous publication includes advancements in the state-of-the-art since 1964 on applicability of various metallic materials at cryogenic temperatures. These data on structural metals will be helpful to those interested in the development of gas liquification and separation, storage and handling of cryogenic fluids, low-temperature heat exchange, quick freezing, superconductivity, and medical applications for low-temperature storage and surgery. 65 pp. GPO $0.50.

Index to NASA Tech Briefs, January–June, 1968 (NASA SP-5021(07)).—Tech Briefs are short announcements of innovations and developments by NASA research centers, contractors, and subcontractors that are potentially applicable to problems arising outside as well as within the aerospace industry. This index lists those briefs published between January and June 1968. 44 pp. CFSTI $3.00.

Flat Conductor Cable Technology (NASA SP-5043).—This report covers development and fabrication of flat conductor cable system of low cost, light weight, and high reliability. Emphasis is placed on flat cable design, interconnection and termination techniques, harness fabrication, and installation methods. Also presented are flat cable and round wire cost and weight comparisons, including the results of an extensive flat cable installation exercise in a Saturn S–IVB aft skirt mockup. 49 pp. GPO $0.40.

Applications of Systems Analysis Models (NASA SP-5048).—A survey of selected systems technology applications used by NASA or developed under NASA sponsorship, including estimating costs and personnel requirements for long-range planning; management information and control techniques; mathematical simulation of a manned space mission, etc. Potential applications of these systems in such fields as urban planning, transportation, market research, public health, social welfare, and education are examined. 69 pp. GPO $0.50.

Visual Information Display Systems: A Survey (NASA SP-5049).—The examples of visual information display systems presented are mainly cited from aerospace work, but have potential utility to management. The survey is restricted to systems which are computer-connected or updated with computer-generated information. The report deals largely with console alphanumeric and graphic devices. Subjects covered include cathode-ray tubes, man-machine reactive input devices, computer systems, and checkout and control systems. 95 pp. GPO $0.60.

Development of Special-Purpose Thermocouples: A Survey (NASA SP-5050).—By C. Eugene Moeller, Michael Noland, and B. L. Rhodes. A review of the development in thermocouple technology resulting from the activities of engineers and scientists of NASA and its contractors. This survey describes (1) the solutions to problems associated with measurement of temperatures, gases, surfaces, and solids with thermocouples from near absolute zero to 5000°F; (2) devices and techniques for measuring the quantity of thermal and nuclear energy transferred from one body to another; and (3) special techniques for using and testing thermocouples. Potential applications of the NASA thermocouple developments are suggested. 94 pp. GPO $1.25.

Application of Biogeochemistry to Mineral Prospecting (NASA SP-5056).—A survey of the technologies of geology, biology, and chemistry as they apply to mineral prospecting. Plant roots can act as conduit systems for carrying metals in solution up into the plant body. The incorporation of metals into the plant system may cause physical changes in the plant which may be discernable visually or by photographic techniques. Theoretical concepts are presented including the geochemical cycle, the physiological requirements for plant growth, and their interrelationship as applicable to prospecting. Also covered is the application of aerial observation and photography to prospecting. 135 pp. CFSTI $3.00.

Selected Technology for the Electric Power Industry (NASA SP-5057).—Proceedings of a Technology Utilization conference held at Lewis Research Center September 11–12, 1968, to described technical topics from aerospace activities that might have value in the electric power industry. Program components include (1) scientific studies of space phenomena, (2) manned exploration of space, (3) applications of space flight, such as meteorology, Earth resources, navigation, and communications, and (4) extensive research and development both to support present activities and to make future undertakings possible, including advances in aeronautics. 321 pp. CFSTI $3.00.

NASA Scientific and Technical Reports for 1967: A Selected Listing (NASA SP-7029).—An annotated listing of NASA reports and journal articles announced during 1967 in *Scientific and Technical Aerospace Reports* (STAR). Included are Special Publications, Technical Reports, Technical Notes, Technical Memorandums, Technical Translations, and Contractor Reports. 414 pp. GPO $2.50.

Properties of Selected Radioisotopes. Volume I: Unclassified Literature. (NASA SP-7031.—Compiled and edited by Dale Harris and Joseph Epstein. This bibliography presents a description of the nuclear, chemical and physical characteristics, isotope production methods, and costs of the following nine isotopes: Strontium-90, Cesium-134, Cesium-137, Cerium-144, Promethium-147, Polonium-210, Plutonium-238, Curium-242, and Curium-244. 182 pp. CFSTI $3.00.

Appendix P

NASA Launch Vehicles Payload In Pounds

Vehicle	Stages	345 mile orbit	Escape	Mars/ Venus	Principal Use
Scout	4	310			Launching small scientific satellites, reentry experiments, and probes (Explorers XXXVII, XXXIX, and XL Reentry F, Radio Attenuation Measurement-C, and ESRO 1A and 2B.)
Delta	3	880	100	120	Launching scientific, meteorological, and communications satellites (TIROS IX, Orbiting Solar Observatories—OSO I thru V, Ariel, Telstar I, Relay, Syncom II, Interplanetary Monitoring Platforms—Explorers XXI and XXVIII, and Energetic particles satellite Explorer XXVI.
Thrust Augmented Delta (TAD).	3	1,900	400	325	Launching scientific, meteorological, communications, and bioscience satellites, and lunar and planetary probes (Pioneer VI, TIROS M, TIROS operational satellites OT-3 and -2, Syncom III, Commercial Communications Satellite Early Bird I, Radioastronomy Explorer, Biosatellites A-F, INTELSAT I, II, and III communications satellites, and International Satellites for Ionospheric Studies—ISIS).
Thrust Augmented Thor-Agena (TAT).	2	2,600			Launching geophysics, astronomy, and applications satellites (OGO C, D, and F, Nimbus B2 and D, and SERT II).
Atlas-Centaur	2½	9,900	2,600	1,600	Launching medium weight unmanned spacecraft (Mariner, ATS, OAO, and Pioneer).
Saturn IB	2	[1] 40,000			Launching Project Apollo spacecraft.
Saturn V	3	[1] 270,000	100,000	80,000	Do.

[1] For 100 nautical mile orbit.

Appendix Q

Major NASA Launches

(July 1–December 31, 1968)

Name, date launched, mission	Vehicle	Site [1]	Results
Explorer XXXVIII (Radio Astronomy Explorer), July 4. Satellite designed to monitor low-frequency radio signals in space.	Delta	WTR	In 3640-mile circular orbit measured radio signals of low frequencies. Also observed radiation from the sun and Jupiter. Operation of its advanced instruments and unique 1,500 foot-antenna marked substantial progress in developing instruments for radio astronomy.
Air Density Explorer (XXXIX) and Explorer XL (Injun V), Aug. 8. To continue detailed studies of the density and radiation characteristics of earth's upper atmosphere at a time of high solar activity.	Scout	WTR	One Scout launched both satellites into polar orbits (apogee 1,550 miles; perigee 435 miles.) They were operating as designed.
ATS–IV (ATS–D), Aug. 10. Satellite toe xperiment with and determine the performance of a passive gravity gradient control system using earth's gravity to stabilize the spacecraft.	Atlas Centaur	ETR	Did not achieve its planned orbit when the launch vehicle failed. Data from experiments not meaningful. Re-entered earth's atmosphere on October 17.
ESSA–VII, Aug. 16. Weather satellite launched for the Environmental Science Services Administration to replace ESSA V (orbited in April 1967) as the primary stored data satellite in the operational systems.	Delta	WTR	Launched into a circular 885 mile, near-polar orbit. Spacecraft's Advanced Vidicon Camera system was providing global cloud pictures to aid in weather forecasting and storm warnings.
RAM C–II, Aug. 22. Eight-minute ballistic flight test to obtain data on the ionized flow field about a spacecraft reentering the atmosphere at great speeds for developing methods to prevent the loss of radio signals from the spacecraft.	Scout	WI	Spacecraft launched to an altitude of about 700,000 feet. Then measured the number of electrons and ions built up around it when reentering the earth's atmosphere at 17,000 miles an hour.

[1] See footnote at the end of table.

NASA Missions—Continued

(July 1–December 31, 1968)

Name, date launched, mission	Vehicle	Site [1]	Results
Apollo 7 (AS–205), Oct. 11. The first manned flight in the Apollo program. Walter M. Schirra, Jr., commander, Donn F. Eisele, command module pilot, and Walter Cunningham, lunar module pilot.	Saturn IB	ETR	Eleven days in earth orbit (apogee 176 miles; perigee 142 miles.) Seven live telecasts and eight successful Service Propulsion firings. Rendezvous with the S–IVB stage also performed. Spacecraft recovered in the Atlantic Ocean southeast of Bermuda.
Pioneer IX, Nov. 8. To join Pioneers VI, VII, and VIII, in widely separated orbits about the sun, in investigating the interplanetary medium and solar activity and their influence on earth's environment.	Delta	ETR	Spacecraft were transmitting data to form the basis for daily reports to ESSA for studies and predictions of solar weather.
OAO–II, Dec. 7. Orbiting Astronomical Observatory II carrying 11 telescopes to study the stars. (Heaviest and most complex automated spacecraft launched by NASA.)	Atlas Centaur	ETR	In an almost circular orbit about 500 miles above the earth, observed ultraviolet radiation. All the satellite's instruments were operating as planned.
Apollo 8 (AS–503), Dec. 21. First manned lunar orbiting mission. Lunar module not to be carried, but a Lunar Test Article—equivalent in weight to this module—to be onboard as ballast.	Saturn V	ETR	First space craft to orbit men around the moon. Also, the first manned flight of the Saturn V rocket, this country's largest launch vehicle. Astronauts Borman, Lovell, and Anders recovered from the spacecraft in the Pacific Ocean on December 27.

Non-NASA Missions

Name, date launched, mission	Vehicle	Site [1]	Results
INTELSAT III–F–1, Sept. 18. Third generation commercial satellite launched for ComSat on behalf of INTELSAT for global communications. (1200 two-way circuits; design lifetime 5 years.)	Delta	ETR	Destroyed by the range safety officer 109 seconds after launch because launch vehicle malfunctioned.
Aurorae (ESRO–I), Oct. 3. European Space Research Organization satellite launched by NASA to study the Aurora Borealis (Northern Lights) and related phenomena of the polar ionosphere.	Scout	WTR	Spacecraft, designed and built by ESRO, was placed in a near polar orbit between 171 and 932 miles. Its 4 British, 3 Norwegian, and a Swedish experiment were making the planned integrated measurements of the polar ionosphere.
HEOS–I, Dec. 5. ESRO satellite to investigate interplanetary physics (particularly magnetic fields), cosmic radiation, and solar wind outside of the magnetosphere, and study earth's shock wave.	Delta	ETR	Launched into a highly elliptical orbit—apogee 138,000 miles; perigee 274 miles. Satellite's eight experiments prepared by university laboratories in Belgium, Federal Republic of Germany, France, Italy and the United Kingdom, were operating satisfactorily.

[1] See footnote at the end of table.

Non-NASA Missions—Continued

(July 1–December 31, 1968)

Name, date launched, mission	Vehicle	Site [1]	Results
ESSA-VIII, Dec. 15. Another operational weather satellite launched for ESSA. To carry two Automatic Picture Transmission Camera Systems for obtaining worldwide daily cloud photographs. (Launched to supplement ESSA-VI whose spare camera had degraded.)	Delta	WTR	All systems functioning normally. ESSA and other APT ground stations receiving excellent pictures. (Apogee 907 miles; perigee 881 miles.)
INTELSAT III-F-2, Dec. 18. Second INTELSAT III, with 1,200 circuits, orbited for ComSat on behalf of INTELSAT for worldwide communications. Designed to operate for 5 years.	Delta	ETR	Placed in synchronous equatorial orbit 22,300 miles above the Atlantic Ocean. Operating as planned. (Scheduled to begin regular commercial service in January 1969.)

[1] ETR—Eastern Test Range, Cape Kennedy, Fla.
WTR—Western Test Range, Point Arguello, Calif.
WI—Wallops Island, Va.

Appendix R

Institutions Currently Participating in NASA's Predoctoral Training Program

(December 31, 1968)

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-Mellon University
Case Western Reserve University
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 [1]
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 [1]
Georgia, University of
Hawaii, Unversity 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 [1]
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

See footnote at end of table.

New York University
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 [2]
Princeton University
Purdue University [1]
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 [3]
Southern Illinois University
Southern Methodist University
Southern Mississippi, University of
Stanford University [1,3]
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
William and Mary, College of
Wisconsin, University of
Worcester Polytechnic Institute
Wyoming, University of
Yale University
Yeshiva University

[1] Institutions receiving training grants specifically for engineering systems design.
[2] Institutions receiving training grants specifically for administration and management.
[3] Institutions receiving training grants specifically for laser technology.

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