UNITED STATES

Aeronautics & Space Activities

1968

REPORT TO THE CONGRESS

FROM

THE PRESIDENT OF THE UNITED STATES

NASA DOD AEC STATE NSF COMM. NAS SAO DOT FCC USIA ACDA

UNITED STATES

Aeronautics & Space Activities

1968

THE EARTH FROM ATS-III 22,300 MILES IN SPACE

EXECUTIVE OFFICE OF THE PRESIDENT

NATIONAL AERONAUTICS AND SPACE COUNCIL

WASHINGTON, D. C. 20502

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PRESIDENT'S MESSAGE OF TRANSMITTAL

TO THE CONGRESS OF THE UNITED STATES:

This report summarizes a year of significant achievement in aeronautics and in space—culminating in the epochal APOLLO 8 flight in December, in which three astronauts orbited the Moon ten times and returned safely to Earth. A courageous, pioneering exploration!

The outstanding success of the APOLLO 8 mission attracted world acclaim and greatly enhanced the prestige of the United States as the leading space-faring nation. The capability of the astronauts and the integrity of their space equipment justified our highest hopes.

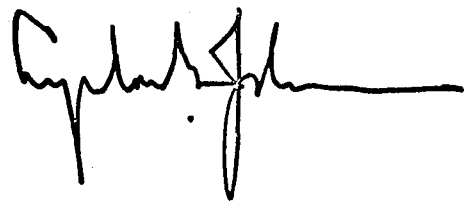
The APOLLO 8 flight was preceded by the very successful 11-day orbit of the Earth in APOLLO 7—the first manned flight test of the APOLLO spacecraft.

These great missions bring us nearer to reaching our national goal of landing men on the Moon in this decade.

Our astronauts have now flown 18 manned space missions, during which they experienced 3,215 man hours in space flight. Together with the activities of the Soviet Union, this makes a total to date of 28 manned flights and 3,846 man hours in space.

Through this investment we have obtained new products, services, and knowledge; we have enhanced our national security; we have improved our international relations; and we have stimulated our educational system.

Our Nation is richer and stronger because of our space effort. I recommend that America continue to pursue the challenge of space exploration.



THE WHITE HOUSE,
January 1969.

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CHAPTER I

U. S. AERONAUTICS AND SPACE ACTIVITIES *1968*

SUMMARY

As 1968 came to an end, America moved dramatically near its national goal of landing men on the Moon in this decade. Three U.S. astronauts became the first humans to depart from the confines of Earth's gravitational sphere of influence and venture to the close vicinity of the nearest celestial body.

Launched from Cape Kennedy on a SATURN V vehicle on December 21, the APOLLO 8 crew took their spacecraft on man's first trip to the vicinity of the Moon. They orbited the Moon 10 times, coming within about 70 miles of its surface. Returning to Earth on December 27—147 hours after lift-off—they re-entered the atmosphere and splashed down in the Pacific Ocean target area. Taken aboard an aircraft carrier, Astronauts Borman, Lovell, and Anders were found to be in excellent health.

The astronauts broadcast live television programs back to Earth while en route to the Moon, while in lunar orbit, and during their return to Earth. Those pioneering pictures were, in turn, given wide distribution throughout the world via communications satellites.

The great precision of the launching, the re-entry, and all intervening events such as injection into lunar orbit and departure from that orbit for Earth return promised success for the entire lunar program.

This great milestone in human achievement was the year's final step in a carefully planned succession of APOLLO missions. On January 22, NASA launched the APOLLO 5 payload from Cape Kennedy into Earth orbit. This unmanned launch, using the SATURN IB vehicle, was the first test of the Lunar Module, in which two astronauts are expected to descend from the mother APOLLO spacecraft for the first lunar landing sometime during 1969. The results were successful enough so that it was decided that a second such test was unnecessary.

The APOLLO 6 payload, which was launched at the Cape on April 4, was the second unmanned flight of the SATURN V/APOLLO system. The Command and Service Module re-entered from 400,000 feet, simulating the speed of a return from the Moon, and landed in good condition about 50 miles from its target point.

In the next step, on October 11, the APOLLO 7 payload went into orbit from Cape Kennedy aboard a SATURN IB, taking its three-man crew on the first manned APOLLO mission. The flight lasted almost 11 days and covered 4.5 million miles, with splashdown occurring on October 22 exactly in the planned Atlantic Ocean target area. Major features of the mission included live television transmission from space; production of drinking water as a by-product of fuel cells; and the largest number of inflight re-starts of a manned spacecraft propulsion system. The three-man flight, first for the United States, totaled 781 man-hours in space, a new record.

A thorough study of the results of the highly successful APOLLO 7 flight, together with favorable assessments of the status of the spacecraft and launch vehicle for the next flight, led to NASA's decision to fly a lunar-orbit and return mission with APOLLO 8.

Earlier, space officials had obtained much new knowledge and confidence required to proceed with the flight program from the successes in the unmanned lunar exploration programs—RANGER, LUNAR ORBITER, and SURVEYOR. The first two of these projects were completed in earlier years; the last was concluded early in 1968, when the seventh and last SURVEYOR landed on the Moon. Launched from Cape Kennedy by an ATLAS–CENTAUR vehicle on January 7, SURVEYOR VII soft-landed at its planned site near Tycho Crater on January 9. In addition to returning more than 20,000 photographs, the spacecraft took part in a laser communications experiment, detecting a tiny laser beam directed to it from Earth. The experiment indicated that lasers could be used for space communications, and for accurately measuring great distances.

NASA plans five APOLLO flights in 1969. APOLLO 9, an Earth-orbital mission scheduled for the first quarter of the year, will be the first manned flight of the complete lunar vehicle—SATURN V launch vehicle, the Command and Service Modules, and the Lunar Module. Lunar landing is expected in late 1969.

In a year during which the spotlight of space activity returned to the dramatic field of manned flight, there was also solid progress in unmanned satellite programs which are increasingly benefiting mankind through improvements in communications, weather prediction, navigation, and scientific investigations.

One new INTELSAT III spacecraft was launched by NASA for the Communications Satellite Corporation, adding to the service provided for the international consortium Intelsat. ComSat spacecraft were utilized for live TV coverage of the Mexico City Olympics to Europe and Asia, as well as elsewhere in North America, and for similar coverage of the November 7 elections. The APPLICATIONS TECHNOLOGY SATELLITE (ATS) series of NASA spacecraft were also used in communications experiments. On the military side, the Department of Defense expanded its total of operating communications satellites and ground terminals. The ATS series, in synchronous orbit 22,300 miles above the Earth, also demonstrated that it could be used to pinpoint the location of aircraft and ground vehicles, and to provide broad meteorological coverage of the globe.

A milepost was reached in the short history of meteorological satellites in May, when the 1,000,000th TIROS–ESSA cloud-cover picture was transmitted by the ESSA 6 satellite, which had been launched by NASA in 1967 for the Environmental Science Services Administration. April 1 marked the eighth anniversary of the launch of TIROS 1, the first weather satellite to send back usable cloud pictures. Two new meteorological satellites—ESSA 7 and 8—were launched during 1968. Still another use of an ATS spacecraft was proven when ESSA and NASA cooperated to use the ATS–III for taking photographs, from which films were prepared, of tornadoes and hurricanes. The same satellite was used to send weather data from the U.S. to Europe, Africa, and South America—a service which became semi-operational late in the year, and ATS–1 continued to be used for transmissions to the Pacific. Dissemination of satellite weather photographs was greatly expanded during the year, both within the U.S. and abroad.

The TRANSIT navigational satellite system, developed by the Navy and made available for civilian use in 1967, was made fully operational in 1968.

On December 7, NASA orbited its second ORBITING ASTRONOMICAL OBSERVATORY (OAO–2), the heaviest and most complex automated satellite ever launched by the U.S. The OAO–2, which carries 11 telescopes, is returning pictures of stars that were previously impossible to study by optical means.

Military space activity continued to progress, with development of the Air Force's MANNED ORBITING LABORATORY (MOL) approaching a point of peak activity. Associate contractors began exchanging test assemblies of major system components; there were successful demonstration firings of the first-stage engine of the TITAN IIIM booster for MOL; preparations were made for static-testing of the remaining liquid engines and solid motors; and construction of the launch complex at Vandenberg AFB, California, neared completion. The MOL, which will enhance the Nation's security, has no missions as a weapons system.

For the second consecutive year, a major international accord involving space activity went into effect. On

December 3, the President announced the entry into force of the international Agreement providing for the rescue and return of astronauts, and the return of space objects from foreign soil. More than 75 nations have signed the Agreement.

Despite the successes in the APOLLO program, the United States launch total in 1968 was substantially lower than in 1967, which in turn had represented a numerical drop from the two preceding years. The 64 U.S. launches that were successfully conducted, however, reflected the growing sophistication and capability of the space effort, exemplified by the unprecedented APOLLO accomplishments.

The Soviet Union, with 74 successful launches during the year, slightly exceeded its total of 67 successful payloads in 1967. On October 26, the SOYUZ 3 spacecraft with a single cosmonaut aboard was sent on a four-day Earth-orbital mission marking the first Russian manned flight since the fatal SOYUZ 1 mission in April 1967. The SOYUZ 3 rendezvoused, but did not dock with the unmanned SOYUZ 2, which had been orbited on October 25. The other major highlight of the Soviet program in 1968 was the separate launching of three unmanned ZOND spacecraft. Two of these were recovered, after circumlunar flight, one in the Indian Ocean and the other on Soviet soil after an aerodynamic glide-skip re-entry over the ocean. Some primitive forms of life were aboard at least one of the circumlunar flights.

Aeronautics activity in 1968 included the first test flights of the U.S. Air Force's C–5A, the largest military cargo aircraft, meeting its June flight schedule. Three of the aircraft have now flown 31 flights for a total flying time of about 88 hours.

On the civilian side of aeronautics, Government and airline experts reevaluated the design submitted for construction of two prototype Supersonic Transports (SST) during the year and decided that the variable-sweep wing design was not the best choice for this commercial SST. The program was therefore delayed to allow the airframe contractor to make design changes, and in September a fixed-wing design was selected. SST engine development proceeded satisfactorily. It is now hoped that protoypte aircraft construction will begin in 1969.

Advances were made in the effort to apply aeronautical technology to develop reusable spacecraft. NASA's HL–10 lifting body research vehicle completed 12 successful glide flights, and a rocket engine was used for the first time in November to propel the vehicle to higher altitude and speed.

Nuclear rocket and space power programs progressed on several fronts. There were power tests of the PHOEBUS–2A reactor; first tests of a cold-flow test engine, resembling a flight configuration, in a new test stand which partially simulates flight conditions; and first test firings of the PEWEE–1 fuel element test-bed reactor.

A summary list of major U.S. accomplishments in 1968 includes:

1. Four APOLLO missions, which steadily developed our lunar exploration capability, were climaxed at the end of the year by man's first trip out of the sphere of his familiar gravitational field and into the orbit of the Moon, and a successful return.

2. The final SURVEYOR mission completed the space program's unmanned lunar exploration activity, returned photographs and other data, and was successfully used in an experiment in laser communications.

3. The second ORBITING ASTRONOMICAL OBSERVATORY (OAO–2) was successfully orbited with an unprecedented total of 11 telescopes, and began returning previously unobtainable data on the stars.

4. The APPLICATIONS TECHNOLOGY SATELLITES performed a variety of meteorological, navigation, and communications assignments.

5. An INTELSAT III spacecraft was successfully launched by NASA for the Communications Satellite Corporation.

6. The ESSA 7 and 8 satellites were launched to maintain the operational weather satellite system established in 1966. ESSA 6, launched in 1967, transmitted the 1,000,000th TIROS–ESSA cloud-cover picture.

7. ESSA and NASA cooperated in using the ATS–III satellite to obtain closely timed pictures of tornadoes and hurricanes; films made from the pictures were used to study the development and life cycles of the storms.

8. A special facsimile transmission was added to the established U.S. network to relay Automatic Picture Transmission (APT) photographs to Weather Bureau and military ground stations, greatly increasing dissemination and operational use of satellite data. Transmission of satellite and standard meteorological data from the U.S. to APT stations in Europe, Asia, and South America via the ATS–III satellite started experimentally in July, and by October had become semi-operational. Transmissions to the Pacific via ATS–I continued.

9. NASA launched the European Space Research Organization (ESRO) Highly Eccentric Orbit Satellite (HEOS–I) into orbit for a study of interplanetary physics. It was the first foreign satellite to be launched by NASA on a reimbursable basis.

10. The military's MANNED ORBITING LABORATORY (MOL) program neared a peak of activity and construction of its launch complex approached completion.

11. The Phase I Defense Satellite Communications System was enlarged to a constellation of 22 operating satellites and 39 surface terminals.

12. The TRANSIT navigational satellite system grew to a four-satellite, fully operational system.

13. The C–5A, world's largest military cargo aircraft, made its first flights.

14. The nuclear rocket and space power programs progressed, with successful test firings of two types of reactors and a cold-flow test engine closely approaching a flight configuration.

15. In air traffic control and navigation, there was successful testing of a device to improve a controller's ability to guide aircraft around heavy storms; virtual completion of a prototype all solid-state transmitter for the VOR navigational system, which will improve reliability and reduce costs; and testing of a system of area navigation which will permit more flexible and direct navigation on instruments.

16. The international Agreement on rescue and return of astronauts, and return of space objects from foreign soil, took effect. More than 75 nations are signatories.

17. The U.S. participated in a United Nations-sponored Conference on the Exploration and Peaceful Uses of Outer Space, held in Vienna.

18. Through 1968, 21 countries were taking part in cooperative, mutually funded space activities with the United States. In addition, scientists from eight countries were engaged in cooperative sounding rocket programs, and 52 countries had APT facilities to receive cloud-cover pictures directly from U.S. satellites.

19. The United States launched a total of 61 spacecraft into Earth orbit, and three on escape trajectories.

NATIONAL AERONAUTICS AND SPACE COUNCIL

CHAPTER II

Introduction

The National Aeronautics and Space Council, established by the National Aeronautics and Space Act of 1958, has a statutory responsibility for advising and assisting the President on policies, plans, and programs of the United States in aeronautical and space activities. During 1968, the Council carried out its responsibilities in a variety of fields whose scope was both national and international. Its work encompassed both civil and military aeropace projects.

The Vice President

The Vice President, by statute, is the Chairman of the National Aeronautics and Space Council. He exercised forceful leadership in the aeronautics-space field during the year under review. As a matter of policy and practice, he emphasized the importance of bringing the benefits of the space program into early practical realization for the well-being of mankind. In the course of his duties, the Vice President continued to acquaint himself at firsthand with both the problems and the progress of our national space effort. In addition to his continuing attention to the space program, the Vice President maintained particular interest in the pressing problems of aeronautics, specifically with regards to new aircraft, improved air safety, and lessening the noise and air pollution created by jet engines. He also vigorously supported the principle of continued U.S. participation in international exhibits, such as the Paris Air Show.

International Cooperation

The United States continued to make leading contributions to space technology, space accomplishment, and international peace-building through cooperation in space. In the latter category there are now cooperative programs with some 70 nations in space enterprises. The United States has taken a leading role in the development of international treaties and agreements, and in international arrangements for sharing advances in space communications and other beneficial applications, including weather forecasting and navigation. The United States has made concerted efforts to initiate new cooperative space arrangements in order to utilize space for the advancement of our foreign policy aims.

Moreover, of major importance has been the initiative role and the follow-through participation of the United States in international treaties and agreements affecting national security in space and safety and rescue of astronauts.

Aeronautics

Early in the year, the Vice President, in a Council meeting, arranged for coordinated action by the Department of transportation, the Department of Defense, and NASA to analyze the relationship between the benefits that accrue to the Nation from aviation and the Nation's level of aeronautical research and development. This action was in response to a recommendation by the Senate Committee on Aeronautical and Space Sciences that the Council undertake such a task. Because of its direct responsibility for the evolution of national transportation policy, the Department of Transportation was assigned leadership in the study. Progress reports were received and consultations undertaken during the year.

Comparison of U.S. and Soviet Space Programs

Since the first satellite was launched some 11 years ago, the United States has, as of December 31, 1968, placed 606 spacecraft into Earth orbit or on escape missions, while the Soviet Union figure is 358 or 37% of the total effort. The United States has 3,215 man-hours in space flight, compared with 631 for the U.S.S.R., or about 83% of the total manned flight hours. Of equal significance perhaps is the fact that the United States has made major technological advances in unmanned space activity, bringing direct benefits to mankind in meteorology, communications, navigation, and observation. Moreover, the United States leads in the dissemination of scientific information obtained from space investigations, launching of the world's most powerful operational booster (SATURN V), the use of on-board nuclear power units, as well as in the number of spacecraft successfully launched.

In making this comparative analysis, however, it is essential that we derive satisfaction but no complacency from our relative status. The U.S.S.R. effort is vigorous and appears to be on a trend of increasing investment and increasing accomplishment. At existing rates, the Russians could overtake and possibly surpass the U.S.

New Goals Required

The years 1958–1968 have been filled with significant accomplishments in the space domain, and the decade ahead will present new challenges and new opportunities, none of which will be successfully dealt with if the Nation is complacent over its achievements of the past. The challenges of initiative have been well met; the determination to maintain the pace is to be tested in the coming years.

Since the greatness of a nation depends to an important degree upon mastering and putting to use technological advances, new goals and new directions must be established in space to maximize the existing and potential benefits of this new national asset. A sound basis for determining that our Nation benefits from such activity may be seen in the advances which have taken place in communications, meteorology, navigation, and Earth resources observation, as well as the spinoffs from space research in the form of new products, new services, and novel managerial techniques. Beneficial beginnings have also been achieved in the application of space-proven systems analysis to urban problems and other non-space needs.

Council Activities

During 1968 the Council and its staff dealt with a variety of aerospace problems. A number of meetings were held to coordinate the exchange of interagency information and to evaluate fiscal year 1969 and fiscal year 1970 budget plans. Continued consideration was given to post-APOLLO space goals, foreign-affairs aspects of U.S. space programs and opportunities for expanded international cooperation in outer space, coordination of the U.S. presence in major international scientific and cultural events having an aerospace content, plans and prospects for natural resources survey satellites, policy aspects of communications satellite development, planning and safety aspects of nuclear rocket and space nuclear-power projects, aeronautical research funding, aeronautical safety, and reduction of airport noise.

In brief, the Council directly and through its staff, engaged in a broad range of policy, coordinating, and informational activities. Among these were:

a. Supervised and edited the President's Annual Report to the Congress on Aeronautics and Space Activities for 1968.

b. Submitted reports to the President and the Council Chairman on significant space and aeronautics activities and plans.

c. Maintained a mutually informative relationship with both the members and their staffs of appropriate committees of the Congress on domestic and foreign aeronautics and space developments.

d. Increased public understanding of the national space program through speeches, articles, correspondence, and other public contacts.

e. Participated in analysis of, and made recommendations concerning, our national budgets for space and aeronautics.

f. Coordinated for the President the policy decisions involved in launching nuclear power units in spacecraft.

g. Helped to develop recommendations on the evolution of communications policy.

h. Furnished briefing materials, including space photographs, for use in connection with visits to Washington of high-ranking officials of other nations.

i. Participated in the planning for aeronautical and space exhibits abroad, including the Paris Air Show which is scheduled for 1969.

j. Examined the need for legislative changes affecting space and aeronautics.

k. Maintained liaison with the technological and aerospace communities.

l. Reviewed the status of space booster programs, both chemical and nuclear, and of meteorological, navigation, communication and applications technology satellite projects, including Earth resources survey satellites.

m. Reviewed and maintained continuous liaison with the national aeronautics and space programs under the cognizance of the Department of Defense and the National Aeronautics and Space Administration.

n. Visited space installations, examined facilities, and engaged in interagency as well as Government-industry meetings and briefings on new developments in aeronautics, space technology, and space benefits.

o. Maintained a current record of U.S. and Soviet space launches, developed comparisons between U.S. and U.S.S.R. space activities, and reviewed the space accomplishments and potentials of other nations.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHAPTER III

Introduction

In 1968, the National Aeronautics and Space Administration recorded a number of advances in its aeronautics and space programs. The results of the SURVEYOR program to obtain data on the Moon and its environment were particularly satisfying.

After making APOLLO improvements prompted by the January 1967 fire at Cape Kennedy, the manned space flight program made significant advances toward the lunar landing goal announced in 1961. The four APOLLO launches during the year—APOLLO 5, 6, 7, and 8—gave evidence that the anticipated lunar mission could be accomplished in 1969. The two manned missions (APOLLO 7, employing the SATURN IB launch vehicle, and APOLLO 8, using the SATURN V) showed that the hardware, the communication network, and the personnel were at the proper stage of readiness required to complete the APOLLO program.

Space sciences and applications activities included the landing on the Moon of SURVEYOR VII—the last in this series of highly productive unmanned satellites, the flight qualification of the APOLLO Lunar Surface Experiments Package which the APOLLO astronauts will leave on the Moon, and the determination that it will be feasible for the astronauts to collect and bring back to Earth lunar soil samples.

In addition, NASA orbited sophisticated APPLICATIONS TECHNOLOGY SATELLITES capable of forecasting global weather, maintaining worldwide communications, locating vehicles on and above Earth's surface, and assisting in studies of the space environment and solar phenomena.

In advanced research and technology, investigations covered a wide range of current and future needs. Very satisfactory results were achieved in laser research, particularly in its application to space communication. Studies of jet aircraft noise showed several ways of alleviating this problem. V/STOL efforts moved ahead with the start of tests of the XV–5B fan-in-wing airplane and the assignment of the tilt-wing XC–142 to the Langley Research Center for further research.

The XB–70 and the X–15 flight research programs continued, with the emphasis in the latter shifting to experiments for the Air Force. A space cabin life support system was successfully tested by simulation for a 60-day period during which four men lived and worked in a closed chamber. Lifting body research work progressed materially with the powered flight of the HL–10 in November.

The space power and electric propulsion program continued to make advances with both engine designs and performance concepts. An electric propulsion system was tested on the ATS–IV mission, even though the spacecraft failed to achieve its correct orbit. The 35–KWe SNAP–8 power conversion system was further tested, and the SNAP–27 generator reached the final stage of development. The technology was developed for an advanced solar cell array which would provide greater power while reducing hardware weight.

In the joint NASA–AEC nuclear rocket program, NERVA engine work progressed with completion of flow tests on the first ground experimental engine (XECF), hot tests on the 5,000-megawatt PHOEBUS–2A reactor, first power testing of the first PEWEE reactor, and positioning of the first "hot" ground experimental engine (XE) in the test stand for checkout. In addition, advances were made in component and stage technology.

Manned Space Flight

With the historic flight of APOLLO 8 to the Moon and back to Earth in the closing days of 1968, mankind entered a new era and the United States became a truly spacefaring nation. The 6-day lunar flight was completely successful, taking three APOLLO astronauts to within about 70 miles of the lunar surface during their 10 orbits.

The epochal mission ended on December 27 with a precision splashdown in the Pacific Ocean, completing the journey begun from the Kennedy Space Center in Florida on December 21. The flight climaxed four APOLLO missions in a year of manned space flight progress, and demonstrated impressively the capability of U.S. crews and equipment to fly into space beyond the equilibrium point of Earth's gravitational pull.

Meanwhile, preliminary steps were being made in the APOLLO Applications Program, which is intended to capitalize on the space flight capabilities this nation is developing in the APOLLO Program.

Apollo Program—The pace of the APOLLO Program accelerated during 1968 as it moved into full operational status, moving closer to the planned lunar landing missions beginning in 1969. The program proceeded toward its objectives with four APOLLO flights—two unmanned tests in January and April and two manned missions in October and December. Following the APOLLO 5 and 6 unmanned tests of the spacecraft and launch vehicle, the APOLLO 7 successfully tested the spacecraft in an Earth-orbital mission. Then APOLLO 8, the first manned launch with the SATURN V rocket, carried out man's most far-reaching exploration as a preliminary to setting foot on lunar soil in 1969.

APOLLO 5.—One of the key milestones in the APOLLO Program was achieved on January 22, with the successful flight of APOLLO 5. This unmanned mission was the first Earth-orbital flight of a Lunar Module, the vehicle designed to land two astronauts on the Moon. As a result of this test, every major piece of the APOLLO–SATURN space vehicle has now been successfully flight-tested and proven in space.

The major objectives of the flight were to verify the operation of the descent and ascent propulsion systems, including restart and Lunar Module staging; evaluate Lunar Module structure; and evaluate launch performance. All these objectives were satisfactorily accomplished.

The launch vehicle for this mission was a SATURN IB. It performed according to plan and placed the second stage and the Lunar Module into an orbit of 120 by 88 nautical miles.

Separation of the Lunar Module from the S–IVB stage was accomplished as planned, using the Lunar Module reaction control system. The planned mission sequence included two firings each of the Lunar Module descent and ascent propulsion systems.

Overly conservative programming of the Lunar Module guidance computer caused early shutdown of the first descent propulsion system burn. The engine was cut off after 4 seconds of the planned 38-second duration. Data indicated that this premature shutdown resulted when the computer sensed that the thrust had not built up to the predesignated level. Indications are that there were no problems with the engine or with the computer itself.

The premature cutoff of the burn resulted in flight controllers shifting to a previously planned alternate mission sequence. This provided for two firings of the descent engine, two firings of the ascent engine, and a separation of the two stages of the Lunar Module to simulate an aborted lunar landing, and was successfully carried out.

As the first test flight of the complex and unique Lunar Module, incorporating new systems of propulsion as well as other characteristics that distinguish this vehicle (designed to operate only in space and on the lunar surface), the efficient performance of this module was a significant achievement. Both descent and ascent propulsion systems worked satisfactorily for this critical aspect of the lunar mission, wherein these engines must function properly in order to assure the return of the astronauts to the Command Module in lunar orbit, after the expedition to the Moon's surface.

APOLLO 6.—The second unmanned flight of the SATURN V was accomplished with this mission, which was launched on April 4. Additional and redundant tests which were first performed on the near-perfect APOLLO 4 mission were undertaken on this flight.

Its primary objectives were to demonstrate the structure, thermal integrity, and compatibility of the launch vehicle and spacecraft; to confirm launch loads and dynamic characteristics; to demonstrate stage separation; to verify operation of the propulsion, guidance and control, and electrical systems; to evaluate performance of the space vehicle emergency detection system in a closed-loop configuration; and to demonstrate mission support facilities and operations required for launch, mission conduct, and Command Module recovery.

The APOLLO 6 was launched from Kennedy Space Center on schedule on April 4. The first stage operated for the planned duration of 148 seconds. Separation of the booster and ignition of the second stage also took place as planned, and the second stage operated near-normal for the first 264 seconds of a total programed time of 368 seconds. At the 264-second point, engines No. 2 and No. 3 shut down prematurely. However, the SATURN V vehicle not only maintained its stability, but the three remaining second-stage engines compensated by continuing to function until cutoff 426 seconds after ignition. The longer-than-planned burning time partially compensated for the loss of total thrust resulting from the premature shutdown of engines No. 2 and No. 3.

The second stage separated normally, followed by the third-stage ignition and operation for 170 seconds, 29 seconds longer than programed, to offset the lower second-stage thrust. The third stage placed the APOLLO spacecraft into an Earth orbit with a perigee of 96 nautical miles (n.m.) and an apogee of 196 n.m.

When attempts to restart the third-stage engine after two orbits proved unsuccessful, an alternate APOLLO mission plan was put into effect. The third stage was separated, and the spacecraft's propulsion system responded successfully to ignition commands. It operated for 7 minutes and 25 seconds, consuming most of its propellants to reach an apogee 12,000 n.m. above Earth. A second burn was not attempted.

Although the spacecraft re-entered at a speed about 4,000 feet-per-second below that planned, it nevertheless accomplished the intended test of the heat shield at lunar entry speed. It landed within 49 n.m. of the target point, and was brought aboard the recovery ship OKINAWA.

It is important to note that APOLLO 6 was a safe mission from a crew safety standpoint, in spite of the abnormal engine performance conditions.

In addition, although an alternate mission was selected because of the launch vehicle problems, data indicated that the spacecraft successfully accomplished its mission.

Anomalies on the APOLLO 6 mission were traced to three significant technical problems:

(1) The first technical problem involved the J–2 engine carried on the second and on third stages of the SATURN V. The data analysis has tracked the source of the problem to the same cause in both stages—a leak, and then a rupture, in the propellant line;

(2) The second technical problem was a "Pogo" effect, i.e., the amplitude of longitudinal oscillations, or vibrations, in the space vehicle which exceeded the design requirements for the spacecraft, during the latter part of the first stage burn;

(3) The third technical problem was an anomalous condition concerning a sheet of metal that separated from the spacecraft-LM adapter.

A course of action to correct these problems, and to demonstrate their correction, was quickly decided upon and successfully implemented. These actions included: (1) A fix to the J–2 engine (which the SATURN IB also carries in its second stage) and a demonstration of the fix, prior to certifying the manned flight of APOLLO 7, using a SATURN IB launch vehicle; (2) a fix to the first-stage "Pogo" problem on the SATURN V, and (3) a fix to the SLA anomaly, prior to certification of a manned flight on the third SATURN V, in APOLLO 8.

APOLLO 7.—The APOLLO 7 mission was one of the most successful manned space flights in the history of the U.S. space program. All primary mission objectives were completely accomplished. Every detailed test objective was accomplished, as well as three which were not originally planned.

The SATURN launched a manned APOLLO spacecraft for the first time.

This was also the first U.S. flight with a three-man crew in one spacecraft; the first flight in which the spacecraft used its own self-contained propulsion system for major maneuvers; the first flight using the advanced communications designed for deep space operations; and the first exercise of the corresponding ground communications network. It was the first space test of the TV equipment, essential for the APOLLO

Moon mission. Finally, a new on-board computer control system was used for the first time.

The APOLLO 7 space vehicle was launched from Launch Complex 34 at Cape Kennedy on October 11, within 3 minutes of the time and date established 10 weeks before. All launch events occurred as planned.

The manual control test of the launch vehicle's second stage (S–IVB) was completed as planned with the crew reporting excellent results. Separation of the S–IVB and the Command/Service Module (CSM) occurred on schedule. Transposition of the CSM and simulated docking were accomplished, with the crew maneuvering the CSM to within 4-to-5 feet of the S–IVB.

On the second day, two burns of the service propulsion system (SPS) set up the rendezvous with the S–IVB, which was completed by braking the CSM to within approximately 70 feet of the S–IVB, which was then tumbling.

On subsequent days, six additional burns of the SPS were performed, including the eighth and final burn, on the last revolution, to de-orbit the CSM.

Following a nominal re-entry, the APOLLO 7 spacecraft splashed down in the Atlantic Ocean on October 22. Splashdown occurred about 8 miles north of the recovery carrier, the U.S.S. *Essex*. The crew was picked up by a recovery helicopter.

Checkout of the spacecraft systems was a principal objective of the APOLLO 7 flight. Extensive operational checkouts of the environmental control, guidance and navigation, spacecraft electrical power, and service propulsion systems were accomplished to the extent possible in Earth orbit. Crew performance, prime and backup spacecraft systems, and ground support facilities were evaluated throughout the mission. APOLLO 7 accomplished 100% of the mission objectives.

Engineering firsts included live television from space and drinking water produced as a byproduct of the fuel cells.

The success of the mission paved the way for the decision to schedule APOLLO 8 as a lunar-orbit mission.

This fateful determination was made only after a thorough assessment of the total risks involved and the total gains to be realized in this next step toward a manned lunar landing. Satisfactory results in all of the ground tests of the APOLLO 8 spacecraft, and review of the previous APOLLO flights, led to the determination that the SATURN V was thoroughly proven for manned flight and that the APOLLO Command and Service Module spacecraft was ready for flights into deep space. It was determined that taking the APOLLO 8 deep space flight would gain engineering and operational information that would increase the confidence for a manned lunar landing during 1969.

APOLLO 8.—As a followup to APOLLO 7, the APOLLO 8 mission demonstrated an even more flawless performance in man's first flight to the Moon. All primary mission objectives were completely accomplished. Every detailed test objective was accomplished, as well as five which were not originally planned. The SATURN V space vehicle flew several systems and new configuration details for the first time, in addition to flying its first manned APOLLO Block II spacecraft.

For this first APOLLO flight to the lunar vicinity, the APOLLO mission operations team successfully coped with lunar launch opportunity and lunar launch window constraints in carrying out a perfect launch.

APOLLO 8 provided man his first opportunity to personally view the far side of the Moon, to view the entire body from only 60 nautical miles away, to view the Earth from over 200,000 nautical miles away, and to enter Earth's atmosphere through a restrictive lunar return corridor at lunar return velocity of 24,530 miles per hour.

The APOLLO 8 space vehicle was launched from Launch Complex 39 at Kennedy Space Center at 7:51 EST on December 21. Prelaunch operations and all launch events occurred as planned. The spacecraft and launch vehicle third stage were inserted into a circular parking orbit nearly 115 miles above Earth.

After more than 2 hours and 50 minutes, the third stage engine was re-ignited for more than 5 minutes, increasing the spacecraft speed to 24,200 miles per hour to place the APOLLO on a translunar trajectory. The trajectory was one that would enable the spacecraft to swing around the Moon and return to Earth automatically if the lunar orbit insertion maneuver were not performed. Twenty minutes after the burn, the third stage was jettisoned in a course that would take it into solar orbit after passing beyond the Moon.

The first midcourse correction was made at 11 hours into the flight and was so accurate that two later scheduled correctional burns during translunar coast were cancelled as unnecessary. A fourth planned burn was performed about 8 hours before reaching the Moon.

After more than 69 hours in flight, during which the space ship had passed from Earth's gravity to lunar gravitational pull, the astronauts inserted the spacecraft into an elliptical lunar orbit with a propulsion system burn. A second burn established the orbit at about 69 miles.

The crewmen conducted many landmark sightings during the 20 hours the spacecraft was in lunar orbit. Extensive photography of the Moon was carried out with both still and moving picture cameras. Real-time TV pictures of the lunar surface and the Earth were transmitted at various times during the mission. The live transmission of voice and pictures by the astronauts, particularly during the lunar orbit phase, was a spectacular highlight.

After 10 revolutions of the Moon, the transearth injection maneuver was performed with the spacecraft propulsion system so accurately that only one small midcourse correction was required. Two subsequent planned midcourse corrections were cancelled. Fifteen minutes before Earth entry, the Command Module and its crew separated from the Service Module.

Traveling at 24,600 miles per hour, the spacecraft entered Earth's atmosphere over the Western Pacific at an altitude of 400,000 feet. Six days, two hours and 51 minutes after liftoff the spacecraft splashed down, approximately 5,100 yards from the recovery ship, USS YORKTOWN. The crew was picked up by a recovery helicopter and was safe aboard the ship at 12:20 p.m. EST, December 27.

Forthcoming Launches.—Five APOLLO flights are scheduled for 1969. APOLLO 9 will see the first manned flight of the complete lunar space vehicle, the SATURN V launch vehicle, the Command and Service Modules, and the Lunar Module. This Earth-orbital flight is scheduled for the first quarter of 1969. Subsequent flights will continue the incremental testing, which is expected to lead to the lunar landing sometime in 1969.

Hardware Development and Employment—*SATURN IB.*—Two SATURN IB's (SA-204, SA-205) were launched during 1968, on APOLLO 5 and APOLLO 7. Nine SATURN IB's, including two for use in the APOLLO Applications Program, are still in test, manufacture, or in storage.

SATURN V.—Two SATURN V's (SA-502, SA-503) were launched in 1968, on APOLLO 6 and APOLLO 8. Two SATURN V's are at KSC, while 10 are in manufacture, test, or checkout.

Command and Service Module.—The Command and Service Module design was verified by the highly successful flight of APOLLO 7.

Manufacturing of Command and Service Modules 103 and 104 was completed. CSM-103 was delivered to Kennedy Space Center in August. Command and Service Modules 104 and 106 were delivered to KSC in October and November, respectively. The remaining 14 flight vehicles were in various stages of manufacture, test and checkout.

Lunar Module.—During 1968 major milestones were accomplished in the Lunar Module (LM) program.

As a result of the successful APOLLO 5 mission, NASA concluded that a second unmanned Lunar Module mission would not be required.

Mandatory changes are being implemented for the remaining 11 Lunar Modules. The first manned flight of the LM is scheduled for APOLLO 9 in the first quarter of 1969.

Apollo Lunar Surface Experiment Package.—Apollo Lunar Surface Experiment Package (ALSEP) efforts included testing the qualification model, fabricating the flight article, and testing it. Due to the time constraints during the first lunar expedition, its deployment has been scheduled for the second lunar landing. A simpler science package has been devised for the first landing.

Facilities.—Construction was completed on a major new facility, the Lunar Sample Receiving Laboratory at the Manned Spacecraft Center, and the facility was activated during 1968.

APOLLO Applications—The APOLLO Applications Program (AAP) was conceived to make optimum use of the manned space flight capability developed during GEMINI and APOLLO. The program takes advantage of the space vehicles, facilities, and organizations as they are made available by the APOLLO Program.

Because of budgetary restrictions, AAP initiated a "holding" action to bring into clear focus the entire program. The concept of a flexible "Core Program" was developed and planning was under way around a "core" of a limited number of launches that can be expanded when funds become available. These include an Orbital Workshop mission, a resupply mission, a Lunar Module/APOLLO Telescope Mount (LM/ATM) mission, and a resupply for this mission.

Long-duration Earth-orbital missions were planned for scientific, technological, medical, and human-factor purposes; and for solar astronomy studies. Experiments under consideration for AAP missions would study the useful application of space systems, meteorology, Earth resources, and communications.

Progress was made during the year on the major AAP hardware contracted for, including the Orbital Workshop, the APOLLO Telescope Mount (ATM), Multiple Docking Adapter, Airlock, and many of the experiments.

Orbital Workshop Missions.—Development of the SATURN I Workshop Mission (AAP–1/AAP–2) was a major task during the year. This mission will use the empty hydrogen tank of the S–IVB stage (after its use as a launch-vehicle stage) as the nucleus of an embryonic space station. In orbit the Workshop consists of the modified stage plus two modules: an Airlock, and a Multiple Docking Adapter.

The first Workshop Revisit Mission (AAP–3A) has been planned to use a single SATURN IB launch of the modified three-man Command and Service Module, to rendezvous and dock with the SATURN I Workshop set up in the previous mission.

Work also progressed in 1968 on the Solar Astronomy Mission (AAP–3/AAP–4). This mission will use the SATURN I Workshop as a base of operations for the manned APOLLO Telescope Mount (ATM) solar observatory.

The APOLLO Telescope Mount spacecraft is a derivative of the APOLLO Lunar Module. The descent stage is replaced by a structural rack which carries the solar astronomy instrument and other systems.

Advanced Manned Missions—Intensive study continued during 1968 in major areas of Advanced Manned Missions, leading to such ultimate goals as manned permanent space stations, lunar bases, and low-cost space transportation systems.

Space Stations.—The space station studies point to a multi-purpose, general-usage laboratory significantly more advanced than the SATURN I Workshop of the APOLLO Applications Program. The space station-laboratory would be used for a variety of disciplines including astronomy, Earth sciences and applications, industrial processes, physics, life sciences, and advanced technology.

Basic concepts have included a space station designed for two or more years of operation, for a crew of nine persons.

Low-Cost Transportation.—A low-cost transportation system development was studied in parallel with the the space station, emphasizing a more operationally efficient and cost-effective manned round-trip Earth-orbital transportation system. Logistics systems for personnel rotation, expendables resupply, and experiments and experiment module delivery—which represent a major share of the manned Earth-orbiting space station program costs—were considered.

Lunar Exploration.—The manned lunar exploration project studied in 1968, covering the effort following the APOLLO manned lunar landings, parallels the APOLLO Applications and Space Station Programs. The studies envisioned programs early in the 1970's to make maximum utilization of APOLLO hardware, as with APOLLO Applications. Improved APOLLO systems and the addition of new systems were considered, to increase stay-times on the surface, improve astronaut mobility, and increase the range of traverses. The accomplishment of 14-day missions and the utilization of highly mobile flying units and rovers with ranges up to 6.2 miles was considered feasible in the first half of the 1970's. Fourteen-day orbital survey missions were studied, considering techniques of metric photography, radar, altimetry and tracking, high-resolution photography and spectroscopy. As with the APOLLO Program, return of lunar samples to Earth was seen as an essential part of lunar surface missions. Other APOLLO follow-on surface science would be conducted with APOLLO ALSEP experimental equipment, later augmented by additional automated stations.

Lunar and Planetary Programs

SURVEYOR—On January 9 the last of the lunar soft-landers, SURVEYOR VII, landed just north of the crater Tycho on a rugged, rock-strewn ejecta blanket. This region of the Moon's surface (probably not suitable for manned landings) was chosen because it is in the lunar highlands far from the mare basins of the equatorial belt previously scouted for potential APOLLO landing sites. The area is believed to be covered with debris from deep beneath the surface thrown out when this crater was formed.

SURVEYOR VII transmitted over 20,000 pictures, performed three chemical analyses of each of three different samples, manipulated and tested the lunar soil, and provided other data. Detecting tiny one-watt laser beams projected from Earth, the spacecraft demonstrated that lasers could revolutionize communications in space, could measure considerable distances with great accuracy, and might have additional uses.

MARINER—Two spacecraft of the MARINER class are scheduled to fly by Mars next year to investigate the Martian atmosphere and surface characteristics, and to increase scientists' overall knowledge of the planet. One, launched in February, will pass the equatorial region in July; the other, launched in March, will pass a more southerly region in August so that it will be able to study the south polar cap and the surrounding region.

Tests of the flight spacecraft have proceeded as planned without major problems arising, and mission analysis and design studies have shown that they can take up to 166 "far-encounter" photographs. Covering almost all of the Martian surface, these pictures would be better than the best ever taken from Earth. The studies have also helped the principal investigators for this mission plan the most efficient use of their scientific instruments at the time the MARINERS are close to the planet, and assisted them in determining when this would be.

Following these two MARINER fly-by missions to Mars (as well as the MARINER Mars fly-by of 1964), two other MARINER spacecraft are scheduled to orbit the planet in 1971 for at least 90 days. They will measure the composition, density, pressure, and temperature of the Martian atmosphere, and transmit data on the composition of the planet's surface, its temperature, and topography. About 70 percent of the surface of Mars will be covered in some way by the various experiments aboard the spacecraft. These will include television, an infrared radiometer, an infrared interferometer spectrometer, an ultraviolet spectrometer, and a cosmic-ray telescope, in addition to experiments in dual-frequency and S-band occulation, and celestial mechanics.

Design of the spacecraft system and its subsystems was progressing from the conceptual to the detailed phase, and the two Mars orbiters may be launched by two ATLAS-CENTAUR vehicles during a 20-day period in May 1971 to arrive at the planet in November.

Also, two missions to orbit and land on Mars are planned for 1973 to provide further data on the planet's atmosphere and surface, and to detect extraterrestrial life.

Preliminary design studies of the spacecraft for these flights were completed, and scientists have proposed various experiments for them.

Space Science and Applications

Orbiting Observatories—NASA's fifth ORBITING GEOPHYSICAL OBSERVATORY (OGO–V), weighing 1,347 pounds, was launched on March 4 into a highly elliptical orbit reaching halfway to the Moon. Its instruments measure the Van Allen radiation belt, the magnetopause, and beyond these regions to an altitude of 92,000 miles. Among the 24 experiments on board, designed to provide a coordinated survey of phenomena in space, are those to investigate solar flares and X-rays, primary cosmic rays, and Earth's upper atmosphere.

Also, the second ORBITING ASTRONOMICAL OBSERVATORY (OAO–A2), weighing 4,000 pounds and carrying over 900 pounds of instruments, was launched December 7. It resembled the OAO–1—successfully orbited in April 1966—which failed to return scientific data. The two experiments aboard OAO A–2 map the celestial sphere in the ultraviolet, determine the energy distributions of the stars in the ultraviolet range, and determine the emission line intensities of diffuse nebulae in the same spectral band.

Explorer and International Satellites—In addition, five EXPLORER satellites and two international satellites were orbited.

NASA launched, in May, the international satellite IRIS or ESRO–II, designed and built by the European Space Research Organization. The spacecraft carried experiments in cosmic rays and solar X-rays from Great Britain, the Netherlands, and France. The Agency also launched, in October, the second international satellite ISIS–II, a cooperative project of Canada and the United States designed to further knowledge of ionospheric physics. The spacecraft continues the studies begun by the two Canadian topside sounders ALOUETTE I and II in 1962.

EXPLORER XXXVII, built by the Naval Research Laboratory to continue its solar studies, was orbited by NASA in March. To continue geodetic studies of the surface of the Earth, EXPLORER XXXVI (GEOS–II) was launched in January. A third EXPLORER, INJUN V (EXPLORER XL), was designed by the State University of Iowa to continue its studies of Earth's radiation belt, its magnetic field, and energetic particles. EXPLORER XL and an air density satellite, EXPLORER XXXIX, were placed into a near polar orbit by one SCOUT launch vehicle in August. EXPLORER XXXIX uses radio tracking to study air density in the atmosphere.

The orbiting of EXPLORER XXXVIII in July marked a substantial advance in developing instruments for radio astronomy in space. The spacecraft featured a new type of antenna system built like a crossed-X, which allowed each arm to extend to 750 feet, or an overall length of 1,500 feet. When each arm was played out to 455 feet (for a total of 910 feet) in July, extensive radio observations were made. In September, with its antennas extended to a total of 1,200 feet, the spacecraft met the objectives of its mission by measuring the direction and intensity of radio signals from cosmic sources in the planned frequency range. The antennas were then extended to their full length in October.

PIONEER—In their widely separated orbits about the Sun PIONEERS VI, VII, and VIII continued to investigate the interplanetary medium and solar activity and their influence on Earth's environment. Data transmitted by these spacecraft (launched in 1965, 1966, and 1967 and by PIONEER IX, launched November 8) formed the basis for daily reports to the Environmental Science Services Administration for studies and predictions of solar weather. The activity of the Sun affects not only long-range radio communications but the weather on Earth.

Sounding Rockets and Balloons—During the year almost 100 rockets were launched at altitudes between 25 and 125 miles in studies of astronomy and space physics. The launchings were in the United States and in Canada, Norway, Brazil, and India.

Also, about 50 high-altitude balloons, flying above 95% of Earth's atmosphere, were able to carry heavier scientific instruments than the rockets (or satellites) for more comprehensive investigations of various phenomena in space.

BIOSATELLITES—Scientists have completed their analyses of the results of the biological experiments recovered from the two-day flight of BIOSATELLITE II in September 1967. Additional ground control studies of the effects of vibration and acceleration on life forms of the same species as those orbited in this satellite confirmed that weightlessness and weightlessness combined with an onboard radiation source were primarily responsible for the changes observed in most of the organisms tested on the BIOSATELLITE.

BIOSATELLITES D and F—to be put in 30-day orbits in 1969 and 1970—will carry highly instrumented pigtailed monkeys to investigate the effects of weightlessness on the central nervous system, the cardiovascular system, and the general metabolism, and on performance and behavior. The flight spacecraft for these missions has undergone qualification tests and fully instrumented monkeys were tested for their month in space. Experiments were being developed and tested for the 21-day BIOSATELLITES C and E, which will involve studies of rats, plants, and human cells.

APPLICATIONS TECHNOLOGY SATELLITES—The cameras aboard APPLICATIONS TECHNOLOGY SATELLITES I and III (ATS–I and –III) supply unique meteorological cloud-cover pictures for research and operational use. Among the backup services which they provided to the Communications Satellite Corporation in 1968 were television coverage of the Eucharistic Congress in Bogota, Columbia, the Olympic games, the World Series, and the launches of Project APOLLO.

ATS–I, launched in December 1966 over the Pacific, and ATS–III, in November 1967 over the Atlantic, are in orbits 22,300 miles above the Earth.

The launch vehicle for ATS–IV, launched in August of this year, failed to operate correctly. This spacecraft, still attached to the vehicle's second stage, re-entered Earth's atmosphere in October.

Other APPLICATIONS TECHNOLOGY SATELLITES to be orbited are ATS–E in 1969, ATS–F in 1972, and ATS–G in 1973.

Communications Satellites—ECHO I, the passive reflector balloon seen by millions since it was orbited on August 12, 1960, re-entered the atmosphere off the coast of Chile this May and burned up.

Although its design life was only 18 months, the first commercial communications satellite—EARLY BIRD or INTELSAT–I, launched by NASA for ComSat in April 1965—was still operating. Three in the INTELSAT–II series, orbited during 1967, continued in commercial service, extending satellite coverage to over two-thirds of the world. Larger and more powerful than INTELSAT–I, they are designed to operate for three years. INTELSAT–II transmits telephone and telegraph messages, data facsimile, black and white or color TV, and supports Project APOLLO.

In September and December NASA launched the first two of five INTELSAT–III satellites. The spacecraft in the September launch failed to achieve the planned orbit when its launch vehicle failed. The INTELSAT–III satellites are larger, with greater capacity than the INTELSAT–II, and are designed to operate for five years.

ComSat has contracted for INTELSAT–IV satellites—an advanced version of INTELSAT–III. The first of these four INTELSAT–IV spacecraft is scheduled for a late 1970 launching.

INTELSAT–IV will be a larger, more sophisticated satellite than the third INTELSAT with 5,000 to 6,000 two-way voice circuits and greater operational flexibility than any of the INTELSATs launched to date. It will operate for seven years. NASA will provide ComSat with launch services for INTELSAT–IV similar to those provided for INTELSAT–I, –II, and –III. This 2,452-pound spacecraft (INTELSAT–II weighed 357 pounds, INTELSAT–III 640 pounds) will have to be launched by either a larger ATLAS–CENTAUR or a TITAN–AGENA.

Also, in response to requests from the FCC and ComSat, NASA provided technical advice on stabilization systems for INTELSAT–IV and reviewed and commented on the specifications for this satellite.

Navigation-Traffic Control Satellites—NASA used its Omega Position Location Experiment, OPLE—flown on ATS–III (and operating along with the Navy's Omega position location system)—to come within two to five miles of locating an airplane in flight; within less than a mile of pinpointing a moving car; and within one to five miles of locating a ship. OPLE, 22,300 miles above Earth, also tracked a balloon used for meteorological research during its 200-mile, 10-hour flight.

Meteorological Satellites—NIMBUS II (launched in May 1966) was still responding to commands and its TV cameras continued to transmit some pictures.

NIMBUS B (NIMBUS III) was planned to test instruments measuring the atmosphere's vertical temperature profile. Its launching was unsuccessful when its launch vehicle failed. NIMBUS B–2 is scheduled to repeat this mission in the spring of 1969. Other launches include NIMBUS–D in 1970, NIMBUS–E in 1972, and NIMBUS–F in 1973.

TIROS–M, representing the next generation of operational weather satellites, will replace the Improved TIROS Operational Satellites developed and launched by NASA for the Environmental Science Services Administration (ESSA). To be launched in the second quarter of 1969, it will determine if one spacecraft with redundant systems can provide both global recorded and local direct-readout cloud-cover data day and night. Two spacecraft in the present TIROS Operational Satellite (TOS) series are needed for this daytime capability only.

NASA orbited two of these TOS spacecraft for ESSA in 1968. Both of them (ESSA 7 and 8) supplied global recorded data. ESSA 8 was launched because random failures in a redundant TV camera and a tape recorder within two weeks of launch left ESSA 7 without spare systems. ESSA 6 (launched in November

1967) continued to provide daytime, direct local-readout cloud-cover data. Also, ESSA–II, –III, and –V still operated and were providing limited picture coverage. (ESSA–II and –III were launched in 1966; ESSA–V in 1967.)

Meteorological Sounding Rockets—In addition, NASA launched 47 research sounding rockets of the NIKE-CAJUN class to obtain data at altitudes between 20 and 60 miles and to develop experiments for providing new kinds of meteorological data. To supply meteorological data and develop reliable, less expensive techniques in making the routine measurements needed for aerospace operations and research, 110 HASP or ARCASONDE rockets were launched.

Earth Resources Survey Program—In cooperation with the Departments of Interior, Agriculture, Commerce, and Navy, NASA continued to investigate the possible use of space-acquired data in surveying the world's natural resources. In these studies two types of aircraft flew special cameras, infrared imagers, microwave radiometers, radar, and other remote sensors over a network of ground test sites providing geoscientists with Earth resources information. One of these supplied data from flights up to 15,000 feet; another from flights up to 30,000 feet. Seventeen flight missions were conducted over 63 test sites during 1968.

NASA also will use an airplane loaned to it by the Air Force (the Air Weather Service) to test some of its remote sensors at altitudes above 40,000 feet.

The potential of surveying Earth resources by means of satellites is under coordinated study. It is anticipated that increasing attention will be given to this technology for this purpose.

Geodetic Satellites—GEOS–II (EXPLORER XXXVI) was launched on January 11. Data were being provided by all of its instruments—Doppler and optical beacons, laser detector, and range-range rate transponders. In addition, data were still being obtained from the large passive balloon satellite. PAGEOS–I, orbited in June 1966.

All of this information was being applied to the National Geodetic Satellite Program to set up a unified world geodetic reference system and define precisely Earth's gravitational field.

Other Launch Experience—During 1968 SCOUT orbited three EXPLORER satellites and two ESRO international spacecraft, carried out the Re-entry F and RAM C–B experiments, and launched a spacecraft for the Defense Department.

THOR-DELTA launched two spacecraft of the EXPLORER class, PIONEER IX, two meteorological satellites for the Environmental Science Services Administration, and the HEOS I scientific satellite for the European Space Research Organization (ESRO).

AGENA orbited two spacecraft. OGO–V was launched by an ATLAS/AGENA using the first Improved ATLAS, SLV–3A. (This marked the completion of the phase-out of the ATLAS-AGENA with the transfer of the launch facilities to the Air Force.)

THORAD-AGENA experienced its first failure on a NASA mission when one carrying the third NIMBUS spacecraft veered off course and was destroyed by the range safety officer.

ATLAS-CENTAUR was used to launch SURVEYOR VII, the last of NASA's spacecraft to soft land on the Moon, and an ORBITING ASTRONOMICAL OBSERVATORY (OAO A–2). However, this vehicle failed in launching the APPLICATIONS TECHNOLOGY SATELLITE–D when the CENTAUR stage failed in its second burn restart, to prevent the spacecraft from achieving its planned orbit.

Advanced Research and Technology

BASIC AND APPLIED RESEARCH

Fluid Dynamics—In sonic boom research, progress was made in understanding propagation of the pressure wave from an aircraft maneuvering through a nonuniform atmosphere. Analytical techniques and a number of computer programs for predicting the boom were developed, and simple, inexpensive prediction methods were being devised for testing against the more sophisticated computer programs. Theoretical studies of aircraft configurations with some lift distributed toward the nose indicated that sonic boom could be reduced significantly without apparent penalty in cruise performance; the theoretical concepts were being evaluated in the wind tunnel.

Research was started on the basic fluid dynamic mechanisms of noise generation in turbulent supersonic exhaust jets, and a preliminary theory for predicting noise was being devised. In studying the basic mechanisms of noise reduction it was found that a shroud-induced secondary-flow mixes with the supersonic exhaust so as to convert the flow to subsonic, thus reducing noise without a thrust penalty. The fluid dynamic details of the flow were being studied.

The gas dynamic laser concept offers the possibility of obtaining high-power system output (megawatts rather than the kilowatts of more conventional lasers). Consequently, a new research program was established to investigate a number of such techniques, and a molecular laser concept and an electric arc expansion laser were proven experimentally.

Applied Mathematics—Mathematical techniques developed for precise analysis of the motions of the Lunar Orbiters were used in the discovery of Mascons, very dense mass concentrations which apparently exist some 50 miles below the lunar surface. The location of the Mascons was indicated by variations from the expected circular orbits of the spacecraft. The gravity anomalies were plotted on a map of the Moon's surface and proved by statistical correlation analysis to correspond to locations of several of the large circular lunar seas. The latter may have been produced by collision with iron asteroids, now deeply buried beneath the surface, which would account for the densely concentrated subsurface masses. The same mathematical techniques should be applicable to the analysis of data collected by future planetary orbiters.

Electrophysics—The discovery at the Electronics Research Center that the electrical output of certain semiconductors, such as gallium antimonide, was very sensitive to applied pressure led to the development of a minute (3/32-inch diameter by 1/32-inch. height) transducer which transforms pressure into an electrical signal. Mounted in a cardiac catheter which was inserted into the left ventricle of the heart of an anesthetized dog, the transducer provided details of the variation of blood pressure during the heart pumping cycle. Additional research was under way to develop a completely self-contained transducer which will not require any external power supply. Such sensitive transducers can be used to measure small pressure variations in spacecraft as well as for medical diagnosis.

Materials—A cobalt-tungsten-iron alloy was developed which maintains its magnetic properties and strength at temperatures in the 1200° to 1400° range. It will make possible lighter and more compact power generation equipment for spacecraft as well as more efficient electric generators and motors for use on Earth.

Other materials work includes the development of a glass composition twice as stiff as most current industrial fiberglass composites. This development may provide a basis for a new family of glass fibers, the development of the Pyrrone polymers into resins for fiberglass laminates having better mechanical properties than those currently used, and also development of the Pyrrone polymers as foam materials having densities in the 30–40 lb. per-cubic-foot-range, high compressive strengths, and potential applications in aircraft structures and in spacecraft ablative nose cones.

Aeronautics

Aircraft Aerodynamics—Progress was made on methods of reducing the sonic boom generated by supersonic configurations and the shock-induced boundary-layer separation on wings at transonic speeds.

Aircraft Structures—Preliminary analytical and experimental studies at Langley Research Center indicated that weight reductions of 25–50 percent may be achieved with aluminum or titanium structures reinforced by bonding high-strength boron or carbon filaments at selected locations. A program was initiated to develop and evaluate this information and to provide engineering data needed for the design phase.

Air-Breathing Propulsion—Advanced inlet and exhaust nozzles previously tested in the design stage on small models in the wind tunnel were installed on one of two nacelles added to an F–106 aircraft and were flown at or near the speed of sound. The other nacelle, to be subjected to the same flight conditions, will be used as a standard reference. Purpose of the tests is to provide information on the interactions between the propulsion system and the air frame.

Aircraft Operating Problems—In research on ways of modifying warm fog to improve visibility, theoretical studies and laboratory tests indicated that seeding with salt crystals of very small and carefully controlled size, was effective. In field tests, natural dense fogs were seeded with salt from an agricultural spray airplane flying just above the fog. Swaths over 200 yards wide were cut into a 300-foot-deep dense fog. Clearing occurred a few minutes after seeding and lasted for up to 20 minutes.

Research efforts continued on methods of improving aircraft directional control and braking on wet and slush-covered runways. Various runway surface textures and materials as well as tire tread patterns were investigated in the laboratory. After laboratory tests indicated that transverse grooves cut into the runway surface can be effective, the NASA Wallops Station runway was resurfaced and grooved, and various aircraft were used as test vehicles. No degradation in aircraft braking and controllability occurred on landing or rollout on the grooved surface, even when wet or flooded.

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

Aircraft Noise Alleviation—Research on ways of modifying turbofan nacelles to minimize engine fan-compressor noise indicated that it is technically feasible to reduce noise significantly near the approach path of jet aircraft.

The program to develop a "quiet engine" for airplanes moved forward with the issuance of a request for proposals by NASA. The goal of the "quiet engine" program is to produce a turbofan demonstrator engine capable of operating at a noise level at least 15 to 20 decibels below present engines powering four-engine commercial jet aircraft.

Supersonic Transport—In the National Supersonic Transport Program, NASA supported the intensive configuration design-improvement program, particularly in studies related to the SCAT 15F design; in addition, the NASA wind tunnels at Ames and Langley were used extensively in a revised test program agreed upon between the FAA and the SST contractor.

V/STOL Aircraft—The V/STOL Transition Research Tunnel at the Langley Research Center is approximately 50% complete anad is expected to be in operation by the latter part of 1969. The test section is designed to provide more accurate aerodynamic data on advanced V/STOL aircraft models by avoiding or reducing the tunnel-wall effects encountered by such models in conventional wind tunnels.

The Ames Research Center began tests of the XV–5B fan-in-wing airplane. These tests, together with wind-tunnel-model tests of other lift-fan VTOL configurations will provide data required by designers of aircraft embodying this concept, which is considered one of the more promising for high-performance civil and military transport applications.

Another VTOL concept—also considered potentially useful for transport applications—is the tilt wing, on which the NASA has conducted very extensive research since 1949. To continue this research, the XC–142, the largest non-helicopter VTOL aircraft built in this country, was assigned to the Langley Research Center for further evaluation of the tilt-wing concept specifically, and to investigate generally the landing operation of V/STOL transports, particularly in poor visibility.

NASA–USAF XB–70 Flight Research Program—The XB–70 completed 13 flights in 1968 under NASA funding and management responsibility. The flights sought data on dynamic loads; stability, control, and handling qualities; engine-inlet matching; ground-based and airborne simulator validation; and general performance of large supersonic aircraft.

In March the airplane was removed from flight status for several crew-escape system changes and the installation of research-related equipment for a modal control (elastic mode control) system designed to reduce the structural dynamic gust response of flexible airplanes flying in rough air, improve the "ride" qualities, and extend the fatigue life of the aircraft. The system operated successfully when flight tests were resumed in June. The remainder of the flights in 1968 were devoted principally to acquiring data for the dynamic loads flight-test program.

A new NASA–DOD Memorandum of Understanding executed in May calls for the continued use of the XB–70 aircraft until the currently planned program is completed or until available funds are depleted (approximately March 30, 1969).

X–15 Research Aircraft—In January, the NASA–USAF Board which investigated the X–15–3 accident of November 15, 1967, reported that, in its judgment, the accident was precipitated during the ballistic portion of the flight when the pilot allowed the airplane to deviate in heading and then flew the airplane to such an extreme attitude with respect to the flight path that there was a complete loss of control during the re-entry portion of the flight. The Board concluded that the pilot's improper controlling of the aircraft was the result of some combination of display misinterpretation, distraction, and possibly vertigo.

Although all of the most important NASA experiments in the X–15 flight program have been completed, it was decided to continue the program to obtain data required by the Air Force for three high-priority experiments.

A total of 13 flights were made by 8 different pilots above 50 miles during the year, primarily for the Air Force experiments. X–15 aircraft completed a total of 199 flights by the end of 1968, including 154 at Mach 4 or greater, 109 at Mach 5 or above, and 4 at Mach numbers greater than 6. No speed or altitude maximums beyond those obtained earlier (4,520 miles per hour and 354,200 feet) were reached in 1968.

Chemical Propulsion

Liquid Propulsion Systems—Propulsion research effort concentrated on demonstrating and testing improved concepts for spacecraft propulsion. A modified RL–10 engine using fluorine and hydrogen was tested under simulated altitude conditions; all test objectives were met, and all engine components performed satisfactorily. A single engine accumulated over 1,000 seconds of firing time at various operating conditions, including one 300-second steady-state test at 15,800-lb.-thrust. The feasibility of applying fluorine-hydrogen to flight propulsion systems has been thoroughly demonstrated and this technology is now ready for applications to high energy missions to the far planets or to the Sun.

Test work continued on advanced high-performance engine technology for future launch vehicles. A 100-inch-diameter plug-nozzle thrust chamber, which burns liquid oxygen and hydrogen, was tested at sea level, and the annular combustion chamber will be tested at simulated high-altitude conditions to determine the flight performance characteristics of this design. A unique feature of the design—the aerodynamic plug centerbody formed by feeding exhaust gas into the base of the engine—makes it possible to design a much shorter upper stage; it is being considered in studies of advanced launch vehicles.

The OF_2-diborane propellant combination may be useful for small near-planet probes and soft-landing spacecraft because of its storability in space and high-density impulse. Thrust chamber tests at an altitude test facility with FLOX-diborane determined the vacuum performance of this space-storable propellant combination in a realistic rocket chamber. Specific impulse values of 400 seconds were measured at combustion chamber pressures of 100 p.s.i.a. (FLOX was used to simulate the rather more expensive oxygen-difluoride (OF_2) oxidizer.)

Work on less expensive methods of fabricating rocket equipment progressed. Liquid rocket components were fabricated by electrodeposition of nickel, thus eliminating the requirement for welding or machining intricate shapes and improving reliability. In research on destructive combustion-driven oscillations, progress was made in stabilizing small and medium-sized rocket engine combustion chambers with combinations of baffles and acoustic absorption devices. However, in studying occasional failures to achieve stability, it was found that the tuned absorbers greatly affect the acoustic resonances of the chamber to which they are attached, sometimes detuning the assembly so that the absorber is not effective. Therefore, alternative designs with improved acoustic qualities are being investigated.

Solid Motor Program—For the large solid motor project, technology improvements in propellant formulation, case materials, nozzle ablatives, and insulation were being investigated, to reduce the cost of components without sacrificing reliability.

During the last 260-inch motor test, pieces of propellant were ejected through the nozzle shortly before the end of burning. The ejection was caused by a lack of fusion between propellant batches and the motor wall during the 19 days required to pour the 300 propellant batches into the motor. In a study of the problem, it was found that the propellant does not distribute itself as uniformly as had been predicted. Some propellant batches proved to be several days old before they reached the motor case wall, at which time they will not bond properly. Less-viscous propellants and improved processes for pouring the propellant into the motor case were being investigated.

A motor-case steel which costs only one-third as much as the alloy used in previous chambers was successfully tested in a subscale three-foot-diameter model. It proved to be much less vulnerable to flaws formed during the welding process, surviving intentionally produced flaws several inches long and 80% of the way through the wall thickness without affecting structural performance.

Nozzles made with new ablative materials and processes were successfully test-fired on several occasions. Although the nozzles tested had an 8-inch throat diameter, it is estimated that the new materials could reduce the finished nozzle ablative cost by from 30 to 80%. Such a reduction would be significant, since ablative liners cost about a million dollars in a typical full-size 260-inch solid motor. The most successful materials will be tested on larger-size nozzles as soon as practicable.

Other research in this area was concerned with the insulation system used in motors, which is applied "wallpaper" fashion in multiple thicknesses of 0.1 inch, even where 3 to 5 inches of material is required. In an effort to replace this costly and time-consuming method, a contractor was hired to investigate the application of slurry materials which can be "poured" into place and smoothed with a trowel. Such a process, where applicable, could reduce costs (currently $10 per pound) by 90%.

Solid Propulsion Technology—Activities in this area included the finding that the microwave non-destructive testing technique, successfully used in detecting defects in large samples of solid propellant, is applicable to many other nonconductive materials; the demonstration of the feasibility of several types of start-stop-restart solid-propellant motors; the development of an analytical model to predict the entire ignition transient for a particular class of motors and the demonstration of its general validity; and further evaluation of a lithium/fluorine/hydrogen tripropellant hybrid system. The effect of introducing hydrogen as a third propellant is to reduce the combustion temperature and increase the specific impulse. This propellant combination has a theoretical specific impulse of over 500 seconds among the highest obtainable from chemical reaction propulsion systems.

Biotechnology and Human Research

Vestibular Research—Sixteen anti-motion sickness drugs were tested singly and in combination in 500 tests on 50 volunteer subjects. A combination of amphetamine and scopolamine was found to be far more effective than the popular anti-motion sickness drugs and should have widespread application in commercial and private transportation.

Stress Endocrinology—A new technique for the maintenance of body fluid and electrolyte balance was developed in connection with studies of the stresses of aerospace flight and their effects on fluid and electrolyte balance. Changes in the amount and composition of urine, which are clues to fluid and salt loss through the kidney, are fed into a computer which calculates the corrective amounts of fluid and electrolyte needed. This information is then used to control replacement into the circulation through a motor-driven syringe. Since maintenance of proper fluid and electrolyte balance in burn victims is necessary to prevent shock, this method of automating its control should prove useful in their treatment.

Bioinstrumentation—Bioinstruments developed by NASA centers have found widespread applications in Government agencies and elsewhere. The Federal Aviation Agency used spray-on electrode kits, recorders, and data-analysis equipment from Flight Research Center for monitoring the effects of job stresses on air traffic controllers. A private ambulance company employs the spray-on electrodes and related equipment to transmit electrocardiograms from ambulance to hospital where they are analyzed before the patient arrives. In addition, information on the spray-on electrode technique was furnished to more than 200 domestic and foreign hospitals and laboratories.

The Electronics Research Center tested a newly developed oculometer—an instrument which measures eye pupil size, blink rate, and direction of gaze without attachment to the subject. Its accuracy in measuring eye pointing direction is better than 0.5 degrees. The device should be useful in determining optimum layouts for cockpit instruments, in measuring mental alertness, in studying how children learn to read, and in gun and camera aiming systems, and man/computer communications, as well as in other areas.

Aircraft Noise and Sonic Boom—NASA is conducting laboratory studies and field surveys to obtain a better understanding of noise parameters as they affect people psychologically and physiologically. In 1967, acoustical and sociometric surveys of airport noise carried out in Chicago, Dallas, Denver, and Los Angeles involved interviews with over 3,500 people while related noise measurements were being taken. Three additional cities will be surveyed. The potential noise characteristics of future V/STOL aircraft were being evaluated by means of noise synthesis and simulation techniques developed for predicting the noise signatures of aircraft while still in the design stage.

The synthesized noise is to be tested on subjects, and its effects compared to those of existing aircraft. In a study of reactions to sonic boom, subjects were exposed to simulated outdoor sonic booms of different waveforms and intensity and judged their relative loudness and annoyance by using a paired comparison technique. It was found that judgments were unaffected by changes in sonic-boom duration and that slower boom rise-times resulted in decreases in subjective loudness and thus in annoyance.

Life Support Systems—In a space cabin simulator life support system test completed in April, four men lived and worked for 60 days in a closed chamber. During 51 days of the test their oxygen requirements were supplied from oxygen reclaimed from their expired carbon dioxide. When the oxygen recovery system malfunctioned, the crew restored it to full operation, and the run was completed as planned. During the period of "down time" oxygen was furnished from a stored supply. For 57½ days two men drank only water regenerated from urine and cabin condensate, consuming over 51 gallons of this water. The other two men drank 55 gallons of distilled tap water. All of the water met the quality standards established by the National Academy of Sciences, its potability was acceptable, and no ill effects were noted in any of the subjects.

Spacecraft Atmosphere Control—For physiological reasons, extended manned space flights will use a two-gas atmosphere (oxygen plus nitrogen or another inert gas). A mass spectrometer system for sensing and controlling a two-gas atmosphere was designed, fabricated, and tested. The reliability of the unit, which weighs only 6½ pounds and uses less than 3½ watts of power, was tested and proven in the 60-day, four-man, space cabin simulator test. The system continuously monitored the partial pressures of oxygen, nitrogen, carbon dioxide, and water vapor and controlled the oxygen and nitrogen concentrations with the desired accuracy. Its response rate was fast enough to keep within the desired range, and there was no performance degradation over the test period.

Protective Systems—Significant improvements in the Ames Research Center hard spacesuit helped achieve several design goals: a weight of 55 pounds; improved mobility in the waist, torso, and pelvic sections; refined closure development; improved boot configuration and ankle joint articulations; shoulder width reduction to 24 inches; and operational pressures up to 10 pounds per square inch.

Locomotion and Restraint Aid—The Ames Research Center developed a locomotion and restraint aid (LARA) for possible use in large spacecraft. A torso harness and a track are connected through springs to hold an astronaut's feet against the spacecraft structure and thus provide normal traction and center-of-gravity control. Tests in a neutral buoyancy tank showed that the LARA eliminates the need for cumbersome tethers, foot stirrups, and other work aids and enables the astronaut to walk, sit, stand, and work in a zero-gravity environment.

Space Tools—Tests have shown that most conventional hand tools are unsatisfactory in a weightless environment since they require the user to exert a large torque, and any attempt to do this in space is likely to result in turning the man rather than the tool unless he is firmly anchored. Special tools and fasteners developed by NASA centers to overcome this problem include a quick-operating fastening device which requires only a small turning force (Ames), and a tool using an inertial method for tightening or loosening nuts and bolts (Marshall). To tighten a nut, a lightly restrained operator imparts a rotary motion to a weighted crossbar on the tool shaft; to loosen it, he sharply raps the end of the crossbar.

Space Vehicle Systems

Aerothermodynamics—The NASA HL–10 lifting-body research vehicle completed 12 successful glide flights following minor modifications to the vehicle to correct roll control deficiencies uncovered in its initial flight in December 1966. The program moved into a second phase when a rocket engine was used for the first time in November to propel the vehicle to a higher altitude and increased Mach number. The rocket engine was ignited and lifted the craft from 35,000 feet to over 43,000 feet. During 184 seconds of engine burn the vehicle reached a top speed of 610 m.p.h.

Progress was made in research on a flexible wing designed for land recovery of manned spacecraft which can be stowed and deployed like a conventional parachute. Drop tests of a 4,000-square-foot wing with payloads of 5,000 pounds were successfully conducted under conditions simulating terminal descent of a large manned spacecraft such as APOLLO. Advances were also made in research on parachutes capable of decelerating and landing unmanned probes in the Martian atmosphere. Effort was concentrated on extending parachute technology to higher Mach numbers and on investigating attached inflatable devices offering higher drag effciency and consequent greater landed payload weights.

Structures—Laboratory tests of small models of a very large orbital radio telescope antenna (about 1,500 meters in diameter) indicated that such a large flimsy structure should be practicable. Studies were also under way on deployment and control techniques and on experimental methods for demonstrating system feasibility.

Environmental Factors—On August 29, the three PEGASUS satellites were switched off after each had operated in orbit for more than three years. During their operation, they recorded a total of 2,265 verified meteoroid penetrations, yielding the most significant data available at this time on the meteoroid hazard to spacecraft. In addition, the PEGASUS spacecraft yielded useful data on radiation fields in space, spacecraft thermal control techniques, and rotational dynamics of satellites.

Experiments to determine the meteoroid penetration resistance of simple double-sheet structures indicated that the effectiveness of the spacing between the sheets, in increasing penetration resistance, increases with increasing velocity over the range of velocities possible in the laboratory. This effect is attributed to the relative increase in projectile and front-sheet melting and vaporization that occurs as the impact velocity increases. However, the actual effectiveness of double-wall structures in preventing meteoroid penetration must be determined in the actual environment. To do this, improved pressure cell sensors were developed which will make it possible to obtain anchor-point data on such effectiveness by means of quite modest flight experiments.

A new anode design, developed for solar simulator lamps, reduced lamp failure due to inadequate anode cooling. The new liquid-cooled anode has a carefully contoured coolant passage through its tip so that the coolant velocity is higher in the hottest region. The new lamp configuration was also tentatively adopted by DOD for use in 30-Kw lamps to be carried aboard helicopters for producing night illumination.

Electronics and Control

Fluidic Yaw Control Subsystem—The Langley Research Center evaluated and laboratory tested a fluidic yaw control subsystem, based on a design researched and developed at the Center. Preliminary data indicated that the desired performance can be achieved and plans were made to continue testing to obtain more data on reliability and to develop a closed-loop system using a newly developed fluidic gyroscope. The objective of this research is to develop a low-cost, reliable, automatic control system for light general aviation aircraft.

Brushless DC Motor—An early model of the DC brushless motor has been ground tested for over three years, recording over six billion shaft rotations; similar models, driving lubrication type experiments, have been space flight-tested. Test data indicated that the motors will provide high reliability and improved performance as drive motors for gyro gimbals, solar array panels, and other applications.

Scanning Electron Mirror Microscope—The Electronics Research Center developed and tested the prototype of a new instrument, the scanning electron mirror microscope (SEMM) for non-destructive study and examination of semiconductor devices. The mirror effect is achieved by establishing a voltage gradient between the electron beam and the test specimen which reflects the impinging electrons, thereby keeping them away from the surface of the device under test and preventing damage. The test results were satisfactory, and an operational model is being developed.

Semiconductor Memory Device—A variable-threshold transistor was developed which can be used as a non-volatile, high-density information storage element and requires no power to maintain the state of the system. The device is a modification of the field effect transistor. The new device can be interrogated repeatedly by small signals and restored to its original state by the application of a voltage pulse of equal magnitude but opposite polarity. It is compatible with large-scale integration technology and can substantially reduce the complexity of logic circuits in computer applications.

Laser Research—An argon laser was used by Goddard Space Flight Center as a high-power signal to measure some of the effects of the atmosphere on narrow light beams projected out into space, information which is essential for work on laser communication. The laser signals were received by the GEOS II satellite and telemetered back to Earth for analysis. This experiment was the first successful laser communication with a satellite.

Two ground stations using laser systems made contact with the SURVEYOR VII vehicle, on the surface of the Moon. The SURVEYOR TV camera photographed the Earth, and the pictures telemetered clearly indicated the locations of the two laser ground stations. This experiment, which demonstrated that a relatively low-power but very narrow laser beam can be precisely pointed to an object on the lunar surface, is a significant advance in research leading to the establishment of deep space laser communication.

The first continuous-wave tunable laser was developed and operated under a NASA grant. It produces red light and operates on the parametric principle, producing an output which has the single color characteristic of normal lasers but can be tuned over a wide band. The tunable characteristic will be useful in laser communication systems and in laser analysis of the constituents of materials.

RAM C–II—The RAM C–II re-entry communication flight experiment, conducted on August 22, sought diagnostic data on attenuation of radio signals ("blackout") at re-entry velocities in the 25,000 feet per second regime. The test provided values of electron density in the flow field which will be compared with and used to improve the theoretical models. This work will make it possible to predict radio blackout more accurately, and to develop techniques for alleviating the blackout problems experienced on returning spacecraft and planetary landers.

Combustible Gas Detector—Ames Research Center developed a system which will readily detect minute quantities of combustible hydrocarbon gases. Using a small helium-neon laser, operating in the infrared at 3.39 micrometers, and a solid-state detector, the system measures the absorption of the laser light at the vibration frequency of the coupled hydrogen and carbon atoms. Its sensitivity is such that it can be used to measure the absorption coefficients of gases such as methane, gasoline, alcohol, and acetone. The system has the advantage of remote detection, since the laser and the detector can be isolated from the combustible gases and can be used when large volumes are to be monitored. It is being evaluated for detecting fire and explosive hazards as well as seepage from natural gas lines. The principle may also be used in medical applications and industrial process control.

Solar Radiation Measurement—The Jet Propulsion Laboratory (JPL) developed a highly accurate wideband radiometer for measuring real and simulated solar radiation. Because of its confirmed accuracy, the instrument is applicable as an absolute standard with less than 0.5 percent error throughout the visible and IR range of the spectrum. The device was used to calibrate other radiometric instruments for solar simulator experiments, and it was flown on high-altitude aircraft at 40,000 feet to determine true solar radiation outside the major portion of Earth's absorbing atmosphere. The ability of this device to provide accurate data on solar energy should have application in research on the heat balance of spacecraft.

X-ray Detection—In research on solar phenomena and solar flare prediction, it is necessary to measure low-energy X-rays produced by the Sun. However, detectors for "soft" rays, such as proportional counters, are limited to wavelengths shorter than 2 nanometers (10^{-9}m) by the opacity of the material used as entrance windows, which must be extremely thin but able to withstand the difference beween the gas pressure in the counter and the ambient space environment. The Electronics Research Center developed a simple, low-cost method for making such windows which involves stretching inexpensive polypropylene sheets approximately 26 micrometers thick to a resultant thickness of only 1 micrometer. X-ray counters made with such window material withstood a pressure differential of nearly 1 atmosphere, permitted transmittance of 70 percent of X-rays up to wavelengths of 11 nm, and made it possible to extend the detector measurement range to cover the soft X-ray region (.1–10 nm.) of the spectrum.

Cockpit Displays—In a NASA-sponsored research project, it was found that a hologram and moving light source could be used to replace certain complex electronic navigational displays in aircraft and spacecraft. Other displays being developed use a cathode ray tube to portray a set of electronically generated converging straight lines which change position to simulate perspective in response to vehicle orientation. The researchers were able to achieve a similar effect from a single hologram transparency made of a point source of light recorded in two different positions. The hologram was made so that the reconstructed image consisted of two rows of points which appeared to recede behind the transparency in true three-dimensional perspective. By moving the reconstructing light source in coordination with vehicle motion, an illusion of change in perspective can be created to show required navigational corrections.

Data Compression—Studies at Goddard Space Flight Center showed that telemetry channel capacity can be conserved by applying a mathematical technique, "bit plane encoding," to on-board measurements of energetic particles by scientific spacecraft, thus "compressing" the data by a factor of 50 or more before transmission. When this technique is used, data samples, in the form of binary numbers, are arranged in a rectangular matrix, and the statistical properties of the matrix extracted by an on-board computer. Data compression and resultant saving in channel capacity is achieved by transmitting only the computed values which can be interpreted on the ground to give the required information.

At JPL, investigators found that it was feasible to increase the amount of video information which can be transmitted from deep space by using a mathematical process (the Fourier transform) to compress television pictures a hundred-fold or more for transmission from planetary spacecraft to Earth. A digital computer breaks the picture down into its elementary frequency and phase components and selects for transmission only those which contribute most to picture quality, thus saving channel capacity. By reversing the process at the receiver, the picture can be reconstructed.

Space Power and Electric Propulsion

The Agency's space power and electric propulsion programs continued to receive research and development emphasis during 1968.

Electric Engine Systems—The SERT II (Space Electric Rocket Test) spacecraft, aimed at verifying long-term ion thruster performance in space, continued to progress toward a 1969 launch.

In addition, during the past year, experimenters made the first attempt to use electric propulsion operationally in a NASA program. The ATS–IV satellite carried an operational resistojet system for East-West station-keeping along with an ion engine experiment. While the spacecraft failed to achieve synchronous orbit, it was possible to test both the operational and experimental systems. Telemetered results indicated that design performance was achieved.

At the end of the year approximately 5,000 hours of a planned 8,000-hour, high-temperature resistojet endurance test had been completed. Such engines could be used in the manned space station as position control systems.

Work also continued on the systems technology for solar-powered electric primary propulsion. Such systems offer potential cost and capability advantages for automated space missions and continued to appear feasible.

Nuclear Electric Power Generation—The major components of the 35 KWe SNAP–8 power conversion system were subjected to further testing. By year's end, all three system pumps had exceeded 10,000 hours of demonstrated life. Development of the boiler and turbine, which had lagged in previous years because of technical problems, was progressing satisfactorily. Basic system technology testing of the "breadboarded" power conversion system, using a non-nuclear heat source, led to the demonstration, in principle, of the automated bootstrapped start-up typical space operation.

The SNAP–19 isotope generator was launched on the NIMBUS B spacecraft on May 18, 1968. The mission was aborted because of a booster guidance malfunction. The SNAP units, however, were subsequently recovered and, to a considerable degree, demonstrated the safety of the device. Another SNAP–19 isotope generator is to be flown on a duplicate NIMBUS B spacecraft early in 1969.

The SNAP–27 generator reached the final stage of development. It will be ready for use on APOLLO as a source of power for the APOLLO Lunar Surface Experiment Package (ALSEP). Steps were being taken to adapt and evaluate SNAP–19 and SNAP–27 technologies for deep-space planetary science missions. The advanced nuclear electric power program continued to stress three energy conversion concepts for long-lived power in the kilowatt range and higher.

In the potassium Rankine turbogenerator program, continuing progress was made in the development of basic and component technologies. As a specific example, new, higher-strength, liquid metal corrosion-resistant refractory metal alloys were reported.

The effort in the Brayton cycle turbogenerator program continued to emphasize development of the high-performance components and subsystems in the 2–10 KWe power range. The single-shaft 5.5 KWe compact, rotating unit began undergoing preliminary tests. This unit consists of a turbine, alternator, and compressor mounted on the same shaft and rotating on gas bearings. Subsystem tests on the control, start-up and gas management system were being initiated, and a complete power package was being assembled for a system test early in 1969.

In the thermionic conversion area, a number of significant events occurred. Four uranium fuels test programs began testing at the NASA Plum Brook Test Reactor. Important experimental data were obtained on the voltage breakdown characteristics of certain materials, fuels, and mechanisms. And a joint NASA–AEC–Contractor team established reference reactor designs (at the 300-KW power level) for the three principal fast neutron spectrum thermionic reactor concepts.

Solar Power Generation—A significant advance in the generation of electric power in space was realized with the recent completion of a four-year effort to achieve technology readiness of a large-area, lightweight, photovoltaic solar cell array. Up to 50 KW of electric power can now be generated at a weight cost of 50 lb/KW on board spacecraft that are subjected only to low-level acceleration after solar cell array deployment. Such space vehicles would include most unmanned planetary flyby spacecraft and many synchronous-altitude applications satellites.

This new technological capability represents a roughly 50-fold advance in power level over the highest used thus far in the nation's space efforts. For many important uses such a capability would permit the power system weight to be reduced by a factor of 2 to 3, while still generating the required amount of electric power.

Chemical Power Generation—A simulated planetary landing has shown that a battery can survive both sterilization temperatures and forces many times that of normal gravity. A 12-cell, silver-zinc battery, sterilized at 257° F for 24 hours, was dropped into the California desert aboard an experimental Mars lander. Moments after impact the battery began furnishing the power to extend a wind gauge and to operate a radio transmitter and a timer.

The combination of reinforced electrodes, heat-resistant separator, and high-strength plastic case proved that batteries can be built to withstand unusual heat and shock. The present product is marginal, however, and needs improvement before it can be used with confidence for such a difficult mission.

In another area of effort, an experimental power control unit successfully withstood a typical sterilization cycle (125° C for 72 hours) and underwent drop testing equivalent to 2,500 g's. Subsequent laboratory tests disclosed no degradation in power control unit performance.

Nuclear Rocket Program

The nuclear rocket program is a joint endeaver of the National Aeronautics and Space Administration and Atomic Energy Commission. The program's objective is to develop a 75,000-pound-thrust engine for space mission application. This engine, identified as NERVA (Nuclear Engine for Rocket Vehicle Application), will have a specific impulse of about 825 seconds, the capability for multiple restarts in space, and a very high reliability. It has been determined that an engine of this size could perform a large number of the advanced missions currently being considered in NASA planning. Engine development is being accomplished using a base of technology which took 13 years of extensive analytical and experimental research to acquire. This work, still in progress, will end with the testing of the XE ground-experimental engine.

Apart from the NERVA effort, the nuclear rocket program includes supporting and advanced technology activities to advance non-reactor component technology and stage technology. The objective in each of these areas is to advance the technology pertinent to nuclear rocketry beyond the initial performance objectives established for NERVA.

The past year was an active one in the nuclear rocket program. A major milestone was achieved with the completion of cold-flow tests on the first ground-experimental engine (XECF) in Engine Test Stand No. 1. At Test Cell "C," hot tests were completed on the most powerful reactor ever tested in the program—the PHOEBUS–2A reactor. Significant advances were made in fuel-element technology as demonstrated in laboratory tests. The first PEWEE reactor, a reduced-size reactor designed to serve as a test bed for verifying the results of fuel-element tests conducted in the laboratory, was moved to Test Cell "C" and power-tested. The first "hot" ground-experimental engine (XE) was installed in Engine Test Stand No. 1 for checkpoint prior to power-testing. All of these events and activities were directed toward establishing a firm base of technology for the development of the NERVA engine.

Engine Test Stand No. 1—Engine Test Stand No. 1 is designed to permit the testing of nuclear rocket engines in a nozzle-down altitude and in tandem (directly underneath) with the propellant tank placed as it would be arranged in a flight stage. The hydrogen gas from the engine nozzle is carried away by means of an exhaust duct. A shielded engine test compartment surrounds the engine and provides, in conjunction with the exhaust duct, a means for reducing the pressure around the engine to simulate certain aspects of operation in space. Steam ejectors pumping into the duct create the space environment. The front of the duct is closed to prevent the back flow of hydrogen into the duct vault area.

A heavy schedule of activity was carried out during the year at Engine Test Stand No. 1 in preparation for hot tests of the XE ground-experimental engine.

In April 1968, a series of experiments was run in the stand using the cold-flow ground-experimental engine (XECF) to investigate the initial start characteristics of the engine and to provide a training period for the test crew. These experiments revealed several minor problems, such as oscillations in the steam-ejector inlet line to the duct, and excessive vibrations of the front, duct-vault closure wall. The engine system and test stand operated as planned, and the test results provided the basis for proceeding with final preparations for the conduct of "hot" engine experiments. Later, the XECF was removed and re-installed with remote-handling equipment, demonstrating the capability to remotely remove and reinstall the engine in the stand.

Following the XECF test program, a series of experiments was conducted, with the aid of an engine simulator, to checkout the operation of the test stand emergency-cool-down system. This system provides an alternate means for cooling down the engine reactor in the event the flow of propellant is cutoff through the engine propellant feed system. Though some initial problems were encountered during the experiments with some of the lines and valves, all test objectives were met and good data were obtained.

After the checkout of the emergency cool-down system, work continued at ETS–1 in preparation for the XE "hot" tests. Remaining to be accomplished were: the completion of modifications to permit the remote removal of the exhaust duct following the XE test program, reinforcement of the front duct closure wall, installation of an improved steam-ejector inlet line, and final checkout and audit of the engine and test stand control systems.

Non-Nuclear Component Technology—One of the major events reported last year was the introduction of the PEWEE reactor into the supporting and advanced technology portion of the nuclear rocket program. The reactor came into being as a result of studies conducted at Los Alamos to arrive at a more economical approach to test promising advanced fuel materials and design concepts. PEWEE is now a reality, and the first test article, the PEWEE-1, was moved to Test Cell "C" for checkout and power tests.

While the PEWEE reactor work was being accomplished, studies were initiated at Test Cell "C" to define the facility modifications that would be required to test a PEWEE reactor. These studies indicated that it would be desirable to go to a more efficient feed system design to cut down on liquid hydrogen losses.

Examination of the existing Mk 25 turbopump design revealed that by reducing the blade height of the pump and modifying a few other components, e.g., the bearings and balance piston, the same basic hardware could be used to provide the 50 pounds-per-second of liquid hydrogen required for PEWEE reactor testing. Using the Mk 25 turbopump without these modifications would mean that more than 40 percent of the pump flow would have to be bypassed and burned. The cost savings that would be realized more than justified the changes. As a result of these analyses, two sets of turbopump hardware were modified this year to meet PEWEE test needs.

In the area of controls, the Lewis Research Center reported on the developmet of integrated fluidic control circuits, an extension of technology of wide-ranging usefulness. Integrated electronic circuits have been in use for some time now and have opened a whole new field of microelectronics and high-density packaging. Through the use of integrated circuits, equipment of low size, weight and power consumption can be manufactured to the most rigid standards and specifications.

In a nuclear-powered stage, however, the radiation environment makes it almost impossible to use electrical and electronic equipment in many areas. Fluidic equipment on the other hand can be made relatively insensitive to such environments. The extension of fluidic technology provided by Lewis, therefore, is a much welcomed advance.

Nuclear Stage Technology—Of major interest in the development of nuclear-powered stages is the effect of nuclear radiation on materials, including the liquid hydrogen propellant. Good data are now available on the effects of radiation on metallic and organic materials. Very little is known, however, about the effects of radiation heating on liquid hydrogen, and this will be of fundamental importance in determining propellant boil off losses, tank pressure level and the fluid properties of the hydrogen entering the engine pump. An experimental 5,000-gallon liquid hydrogen tank and supporting equipment is being designed and fabricated for the purpose of verification of analytical predictions of nuclear heating of liquid hydrogen.

Continued supporting research is being conducted in the area of long-term cryogenic storage. Work also is underway to develop a means for the reliquification of approximately 3 pounds-per-hour of hydrogen vapor. This quantity is representative of the amounts boiled off from a well-insulated stage during long-term flights in space.

Tracking and Data Acquisition

NASA's Tracking and Data Acquisition program continued to support the missions of this agency and other agencies and certain foreign governments. Such missions included APOLLO 7, APOLLO 8, SURVEYOR VII, PIONEER IX, RADIO ASTRONOMY EXPLORER, and the ORBITING ASTRONOMICAL OBSERVATORY—OAO-A2. Even while providing this operational support, the network facilities and equipment were modified and augmented to meet the requirements of approved future missions.

Manned Space Flight Network—All of the Manned Space Flight Network facilities required to support the APOLLO lunar landing became operational during the year. The Network land facilities, specifically configured for APOLLO support, consist of eleven 30-foot antenna stations and three stations equipped with 85-foot antennas. In addition, four instrumentation ships and eight instrumentation aircraft provide coverage over the broad ocean areas.

The Network started a busy year of flight activity with its support of the APOLLO 5 mission (January 22). The new network facilities provided excellent support, simultaneously, to both the LM spacecraft and the S-IVB stage of the SATURN IB launch vehicle.

The Network also performed flawlessly during its support of APOLLO 6, launched April 4. For this mission, seven of the eight instrumentation aircraft were deployed. As preplanned, the two aircraft in the Pacific Ocean area successfully acquired the spacecraft during terminal re-entry and tracked it to splashdown.

Next, the Network provided excellent support to the first manned APOLLO flight, APOLLO 7, launched October 11. First-time requirements, such as real-time television reception from the astronauts in orbit, were handled in an almost routine manner. To meet the television requirement, NASA installed specialized equipment (scan converters) at two of the network stations: Corpus Christi, Tex., and Merritt Island (Cape Kennedy), Fla. For similar coverage of APOLLO lunar missions, the Agency installed these units at the Goldstone, Calif., and Madrid, Spain, stations.

The Network's successful support of the four APOLLO missions in 1968 resulted in large measure from the experience gained during numerous mission simulations conducted between flight missions. These realistic simulations, assuring constant operational readiness of both facilities and personnel, were enhanced by the use of a Test and Training Satellite (TETR). In addition to the mission simulations involving real-time operations with the Mission Control Center at Houston, the TETR spacecraft provided a tracking target for checkout of individual stations. The first such satellite, TETR–I, was successfully launched in December 1967; it re-entered Earth's atmosphere on April 26, 1968. A second spacecraft, TETR–II, was launched piggyback aboard the vehicle which placed PIONEER IX in its trajectory around the Sun. TETR–II participation in the Network checkout contributed to the successful support of the APOLLO 8 mission.

The APOLLO 8 flight demonstrated the network's capabilities for support of a manned lunar landing. Voice communications were excellent; tracking and trajectory determination accuracies were well within requirements; telemetry provided all data required for control center assessment of launch vehicle, spacecraft, and astronaut functioning; and the network received and relayed the first manned flight television sequences from near the Moon with better quality than those of APOLLO 7.

Deep Space Network—During the year, the Deep Space Network supported the final flight of NASA's unmanned lunar programs. While it will furnish support to the lunar phases of APOLLO, in the future it will support planetary and interplanetary flight programs.

The final unmanned lunar flight, SURVEYOR VII, was launched on January 7, and received continuous coverage by the Deep Space Network until it successfully soft-landed on the Moon on January 9. The network's last contact with the spacecraft occurred on February 20. During the period of coverage, the tracking stations received over 21,000 television pictures taken from the lunar surface.

The network continued to handle a substantial workload in 1968, with PIONEER IX (launched successfully on November 8) added to the on-going PIONEER VI, VII, and VIII missions. The PIONEER spacecraft, originally planned for a useful lifetime of 6 months, have exceeded all design expectations, and their lifetimes are now estimated at 5 years.

While it was providing this mission support, the network was also being modified and augmented to meet the dual MARINER '69 mission requirements. New multitelemetry equipment was being installed at the network stations. Although specifically constructed for MARINER '69, this equipment was designed with sufficient flexibility to accommodate, with only a minimum of changes, other spacecraft which may evolve after 1970.

In June, two Deep Space Network Stations at Goldstone, Calif., successfully tracked the Asteroid Icarus as it passed within 4 million miles of Earth (June 14). A standard-size 85-foot-diameter antenna, with a powerful 450-kilowatt transmitter, transmitted radio waves to the Asteroid, and the giant 210-foot antenna received the radio wave echoes some 42 seconds later. Studies of the signals received have improved our knowledge of the Asteroid's physical characteristics and its rotation rate. Preliminary analysis of the data indicated that Icarus has a radius of about one-fourth mile and rotates once every 2½ hours.

Satellite Network—The Satellite Network continued to support about 40 satellites. This network serves both NASA's scientific and applications satellites and a wide variety of space projects conducted by other Government agencies and by private industry (the Communications Satellite Corporation). In addition, most of the NASA tracking and data acquisition support to international programs is provided through its facilities.

Among the major flight projects successfully launched during 1968 and supported by the network were OGO–V, EXPLORER 38, and OAO–A2. During the EXPLORER 38 (RADIO ASTRONOMY EXPLORER) mission, the network contributed significantly to a major technological achievement by NASA. The satellite's antennas were extended to their maximum length of 750 feet each, resulting in a tip-to-tip measurement of 1,500 feet—about five times longer than any object previously placed in space. Extension of the antennas was controlled by a series of radio signals orginated at the control center, Greenbelt, Md., and transmitted to the satellite via the network tracking stations.

In addition to meeting the planned support requirements of a flight mission, such as RAE, the Network is often called upon to provide emergency or extraordinary support. An example occurred during the ATS–4 mission. Because the launch vehicle malfunctioned, the spacecraft was placed into a highly elliptical orbit rather than a planned synchronous orbit. A series of delicate spacecraft maneuvers—directed by commands transmitted via the Network—was necessary to reduce the spin rate of the spacecraft. The commands were successful and the spin rate decreased, thereby permitting some spacecraft experiments to be conducted and data acquired. Without the command capability of the network, these valuable data would have been unobtainable.

The network was also supporting OAO–A2, launched December 7. This complex scientific satellite required unprecedented support for real-time command and control coverage. The network fully met all support requirements and continues to receive valuable astronomical data.

University Programs

These programs, which comprise all NASA-sponsored research projects in educational institutions, include two main parts: (1) Project-oriented grants and research contracts; (2) sustaining university support for special training, research, and facilities. The Office of University Affairs maintains overall policy level supervision. The program, which is designed to enable the universities to participate fully in the aerospace effort, emphasizes high-quality research which benefits NASA and at the same time strengthens the colleges and universities.

In 1968, project-oriented research was funded at the $101-million level. Of some 1,400 active projects with universities, 30 percent were started in this year. The step funding technique was used to achieve more predictable long-term support patterns and to even out funding fluctuations related to variations in NASA's annual budgets. As a result, research funds were used more efficiently and output was increased.

During the year, the content and nature of the Sustaining University Program were modified to meet the changing conditions of the space program and a reduced budget. Support of the program (set at $45.1 million in 1965) was reduced to $10 million in 1968, necessitating a cut in the predoctoral training program from 1,300 new starts in 1966 to only 45 in 1968. No new funds were earmarked for the construction of facilities on university campuses in 1968, and the research program ($13 million in 1966) was reduced to approximately $6 million in 1968. As a consequence, practically all participating universities received reduced support, a few were dropped from the program, and additional schools will have to be dropped in the coming year.

International Affairs

The number of countries participating in cooperative, mutually funded projects with NASA increased to 21 in 1968, as agreements were completed with Mexico and Switzerland. New agreements were reached with Brazil, Canada, France, Germany, India, Norway, Spain, and Sweden.

The Agency further diversified its international cooperative projects, signing agreements with the Brazilian National Commission for Space Research (CNAE) and the Mexican National Commission of Outer Space (CNEE). These accords provide for cooperation in developing, testing, and using Earth resources sensors in aircraft, with emphasis on applying such techniques to the specific economic problems of

Brazil and Mexico. An agreement was also made with Mexico for the use of APT equipment loaned by NASA to supply cloud pictures to Mexican government agencies and to coordinate APT data with other meteorological information from conventional sources.

Programs such as these are responsive to the frequently expressed desires of the President and the Congress that ways be explored to apply space research and technology to the problems of developing countries.

In December, NASA and the German Ministry for Scientific Research agreed to a cooperative project to release a barium-ion cloud at an altitude of about 20,000 miles. As the cloud dissipates along the Earth's magnetic lines of force, it will be photographed to permit the measurement of magnetic and electric fields, to simulate the action of the solar wind on an ionized comet trail, and to provide basic new data on behavior of an ion cloud in a collisionless plasma.

Meanwhile, earlier projects came to fruition. During the year, NASA launched three satellites built and funded by the European Space Research Organization (ESRO). ESRO–II, designed for the integrated study of cosmic rays and solar radiation, was launched in May. ESRO–I, launched in October, continued to study high-latitude energetic particles and their effects on the ionosphere. On December 5, NASA also launched the ESRO Highly Eccentric Orbit Satellite (HEOS–I), an interplanetary physics research spacecraft, in an elliptical orbit carrying it more than 120,000 miles from Earth. HEOS–I was the first foreign satellite NASA has launched on a reimbursable basis.

Foreign experiments flown on NASA spacecraft increased to 11 with the launching of ORBITING GEOPHYSICAL OBSERVATORY V, which carried one French, two British, and one Dutch experiment.

Sounding rocket experiments were launched in cooperation with Argentina, Brazil, Canada, Germany, India, Norway, Spain, and Sweden. New sounding rocket cooperative agreements were made with all of these countries except Argentina.

Cooperation in aeronautics involved Canada, France, Germany, and the United Kingdom on four separate projects involving V/STOL aircraft. Through this shared-cost work, NASA benefitted from highly advanced foreign developments in this field.

Foreign investigators selected to analyze the lunar surface material to be brought back by the Apollo astronauts increased from 29 to 35. Two new countries represented in this program are Australia and Belgium. Forty-four experiments on the lunar surface samples proposed by these investigators have been approved.

The Inter-American Experimental Meteorological Network (EXAMETNET), a joint venture by NASA with Argentina and Brazil, continued active. Small meteorological rocket launchings at Wallops Island were coordinated with launchings in Argentina and Brazil.

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 49 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 with special reference to the needs of developing countries.

On May 3, an agreement was concluded with the United Kingdom to establish and operate a tracking station on Grand Bahama Island to support project APOLLO. The existing agreement with the United Kingdom for the operation of the tracking station in Bermuda was broadened on January 17 to include support of non-experimental space projects of a peaceful and scientific character.

Brazil, Ethiopia, Mauritius, and Thailand agreed to the temporary stationing of geodetic satellite observation camera teams on their territory as part of the National Geodetic Satellite Program.

An agreement was concluded with Mauritius on September 3, for the building of a parking apron at Plaisance Airfield, Mauritius, to accommodate the operation of APOLLO/Range Instrumentation Aircraft (A/RIA).

Industry Affairs

NASA continued its efforts to improve its contracting practices, to improve the management of Government property, to reduce costs, to improve its labor relations, and to strengthen its reliability and quality-assurance activities.

Development of Contracting Guide—NASA, in close cooperation with the Department of Defense and other Government agencies, developed new training instructions and operating guidelines. These cover incentive contracting aspects of the procurement process from procurement planning through source selection, cost analysis, negotiation, and contract administration.

While there is a significant difference between the defense procurement mission and the space program, there are many similarities in the research and development contracting situations. The procurement regulations of NASA and DOD have much in common. In addition, both agencies use many of the same industrial contractors. Thus, NASA's actions to develop common guidelines wherever possible will assist both industry and Government contracting offices.

Government Property Management—NASA continued its efforts to improve the effectiveness of its property administration during the year. New property management procedures now included in NASA contracts were helping the contractors to develop better and tighter controls for Government property. This subject was given major emphasis by the NASA Headquarters Procurement Management Survey teams and by other specialized teams during their visits and reviews conducted at NASA installations.

Cost Reduction—During 1968, the NASA Cost Reduction Program produced savings of $320 million. During a period of increasing austerity, the progress and general acceptance of the basic concepts of planned verifiable economies reflect the positive attitude of NASA employees and contractors toward the program. The NASA in-house program produced cost reductions of $150 million, with an added contribution of $170 million from voluntary participation by 38 major contractors. At the end of its fifth year of operation this program has produced measurable accumulated savings of $1.8 billion.

Labor Relations—The number of man-days lost because of strikes increased from 4,791 in 1967 to slightly over 10,000 in 1968. This increase resulted primarily from the large number of negotiations of labor contracts in the space and construction industry which impacted directly on the Center support contractors.

While the number of man-days lost resulting from negotiations were substantial, management actions developed in advance of negotiations virtually eliminated any impact on NASA programs. When the 7,200 man-days lost as a result of negotiations are deducted from the year's total of 10,000, the remaining loss is less than the comparable figure for 1967.

Reliability and Quality Assurance Office—NASA completed a comprehensive evaluation of the Reliability and Quality Assurance activities at all of its field installations. These reviews focused on organizational and management problems and resulted in a number of improvements in the conduct of the NASA Reliability and Quality Assurance Program. The Agency was making plans to initiate a new series of evaluations of the Reliability and Quality Assurance operations which will focus on hardware effectiveness.

Technology Utilization

Through its Technology Utilization Program, NASA continued its efforts to increase the return on the national investment in aerospace research and development by encouraging additional uses of the knowledge gained.

This Agency also continued to prepare and distribute Tech Brief announcements and Special Publications at a high rate. It received more than 16,000 individual requests for Tech Brief backup material, and more than 9,500 requests for general information regarding products and services of the Technology Utilization Program.

During the year, the Lawrence Radiation Laboratories (LRL) of the Atomic Energy Commission began reporting through the NASA announcement system innovations derived from its research endeavours. LRL thus joined Argonne National Laboratories and Sandia Corporation as AEC contractor installations participating in the NASA–AEC Tech Brief announcement program.

As evidence that the NASA-sponsored experimental Regional Dissemination Centers (RDC's) form a unique bridge among the governmental, academic, and industrial communities, Indiana University and the University of Pittsburgh, hosts of two of the older RDC's, decided to continue operations after NASA financial support ends. Such support is expected to end in early 1969.

Two other Regional Dissemination Centers—at Midwest Research Institute in Kansas City, Mo., and at Wayne State University in Detroit, Mich.—completed the NASA-sponsored phase of their experiments during 1968. Each was also making plans to continue aerospace technology dissemination and transfer activities.

Oklahoma State University, under contract to NASA, was preparing educational monographs based on NASA R&D reports. Such reports are to be disseminated on a trial basis to professors of upper class and graduate engineering courses. Two hundred and forty-eight professors at 106 universities requested these monographs for review and classroom use. The decision to have such monographs developed was based on evaluation reports received from professors who have used similar devices in their classrooms and overwhelmingly favor them.

Late in 1967 NASA contracted with the Denver Research Institute (DRI) to conduct studies that might improve the effeciveness of NASA's technology transfer programs by providing data on the uses made of the technology. Continued analytical efforts by DRI should contribute to a further understanding of the factors affecting technology transfer.

NASA continued to work with the Office of State Technical Services (OSTS), U.S. Department of Commerce. One RDC director was designated as responsible for the State Technical Services Program in New Mexico. OSTS asked another director to help develop such a program for Indiana.

Three Biomedical Application Teams worked with 18 medical schools and medical research institutes to help identify and solve technical problems inhibiting the progress of medical research. More than 60 technology transfers were effected by matching identified problems with information from NASA.

The Biomedical Application Team approach was also being applied to problems in the public sector. One team, under contract to NASA, was working with the Law Enforcement Assistance Administration to help solve problems in police communications in medium-sized cities. Another was working with the Bureau of Reclamation, helping to solve problems related to weather modification.

NASA sponsored several conferences on technology utilization in cooperation with the Small Business Administration and the Atomic Energy Commission. The Office of State Technical Serivces of the Department of Commerce, the Science Information Exchange of the Smithsonian Institution, and the Library of Congress National Referral Center for Science and Technology participated in the conferences. Audiences were composed primarily of senior officials from medium and small-sized nonaerospace industrial organizations.

The NASA-sponsored Computer Software and Management Information Center (COSMIC) at the University of Georgia continues to gain acceptance from the industrial, education, and business communities as an outlet for NASA-developed computer programs. Approximately 400 computer programs are listed in the COSMIC catalogue. Many more are being evaluated by the university. The Department of Defense and NASA reached an interagency agreement, under which DOD research and development installations will furnish computer program listings, card decks, run instructions, and associated software to COSMIC for evaluation as to their commercial utility and possible inclusion in the COSMIC inventory.

Relationships With Other Government Agencies

Early in the year, NASA's Office of Defense Affairs was redesignated the Office of DOD and Interagency Affairs. In the process, this office's assigned functions were broadened.

One of the coordinating mechanisms between NASA and the Department of Defense is the Aeronautics and Astronautics Coordinating Board (AACB) and its panels covering aeronautics, launch vehicles, manned space flight, supporting space research and technology, space-flight ground environment and unmanned spacecraft.

During the year, the AACB reviewed the proposed facilities construction programs for fiscal year 1969. It also reviewed the large ground test facilities needed to carry out foreseeable aeronautical programs in the next 10–15 years. In addition, it initiated launch vehicle studies to determine the future needs, and established a policy concerning the criteria that would apply to biological in-flight experiments being considered for the manned space flight program.

In other areas of effort the AACB studied the DOD and NASA funding patterns with respect to universities; reviewed the instrumentation aircraft and ship requirements in support of the APOLLO Program and DOD programs; and initiated a review of certain DOD and NASA activities where cost reductions could be achieved.

During the year, the number of military detailees assigned to NASA was reduced to about 300. Approximately 10 NASA employees were assigned to DOD organizations.

Policy coordination and high-level exchange of plans and proposals took place through the National Aeronautics and Space Council, of which the Administrator of NASA is a member.

NASA developed informal relationships with the Department of Health, Education, and Welfare (HEW) to consider areas of mutual interest involving the role communications satellite technology might play in advancing educational and cultural objectives (instructional TV in schools, public TV, and medical education for practicing physicians).

NASA continued to work with the Department of Transportation on matters involving aeronautical research. In addition, the two agencies continued to explore matters concerning development of navigation satellites and related space technology that might apply to certain transportation problems.

NASA advised the Federal Communications Commission (FCC) on some of the technical aspects of communications satellite systems, including launch vehicle capability and costs. It also participated actively in the work of the President's Task Force on Communications Policy, with particular emphasis on the issues involving the use of the elecromagnetic spectrum, a domestic satellite system, and the deveolpment of communications technology.

NASA Safety Program

NASA took additional action to develop a more effective system of identifying hazards and providing controls appropriate to the complexity of its programs and the sophistication of its technologies. Since the APOLLO accident, the agency has substantially strengthened its safety organization, developed new safety concepts and data, and established better means of disseminating guidance.

NASA's Safety Program is based on identifying hazards, eliminating or controlling them as much as possible, and defining the remaining risk. Risk evaluation is to be an intrinsic part of basic decision-making. The same management elements charged with program success are responsible for achieving adequate safety. Safety staff personnel are to establish guidelines, provide consultation, and check performance to assure adequacy of safety efforts. In addition, the agency increased its control of contract safety matters and took measures to make certain that the hazardous aspects of contractor activities are identified.

The Aerospace Safety Advisory Panel.—This panel, advisory to the Administrator, initially concentrated its efforts on APOLLO technical management and system safety activities. Reviews were held at the Manned Space Flight Centers and at the APOLLO principal contractors' plants. A permanent Executive Secretary staff supports this activity. Actions taken to strengthen the functional management of safety during the year included, among others, having a new NASA Director of Safety and appointing a Headquarters Installation Safety Officer.

APOLLO Safety.—Efforts resulting directly from the APOLLO 204 accident continued into 1968. They included follow-up on Command Module design changes, procedural changes, and the incorporation of additional safety features at the launch complex. Additionally, substantial efforts were put forth in all manned space flight activities in emphasizing safety across-the-board with special attention to system safety. Scheduled safety evaluations are now routine.

One of the agency's safety motivational efforts is the Manned Space Flight Awareness Program, which rewards exceptional individual contributions to safety. Additionally, a Zero-Defects-on-Delivery Program successfully persuaded 20 air-freight carriers to provide special care to NASA space-hardware shipments. Study contracts were awarded in the area of space rescue aspects of the Advanced APOLLO Applications Program.

Protection of Property.—Fire prevention and protection received a great deal of attention, with emphasis on the risk assessment and adequacy of staff skills. Particular attention was given to collections of both valuable and one-of-a-kind property items. Considerable work was done to assure protection of the component parts and to protect locations of the tracking and data-acquisition networks supporting APOLLO.

Identification of Hazards.—NASA established an agency-wide Hazards Identification Committee. This committee was active in the areas of identifying and classifying known hazards of NASA operations. This group will be instrumental in instituting an appropriate system to make certain that pertinent data is adequately collected, classified, and disseminated.

Safety Standards.—Agency-wide safety standards do not exist, although generally accepted standards are used by the field installations. A NASA Safety Standards Committee, with agency-wide representation, was established to advise on external and internal standards suitable for agency adoption. Among the many standards under consideration are those on lasers, electromagnetic radiation, and pesticides.

Aerospace Safety Research Data Institute (ASRDI).—This institute was initiated as an effort of the Lewis Research Center and as an intrinsic part of the NASA Safety Program. The ASRDI will provide a bank of interpreted safety technical data and will support the conduct of safety research where gaps in safety technical data are identified.

Facilities Management

NASA significantly strengthened its facilities management program by integrating various Headquarters facilities elements into a single Office of Facilities. The new office provides direct support to the Program Directors in developing and maintaining NASA's in-house and contractor-held industrial plant capability. It is also responsible for the full range of management activities necessary for the planning, acquisition, development, use, and disposal of facilities.

Major new facilities that became operational during the year include a Flight Simulator for Advanced Aircraft at the Ames Research Center, Moffett Field, Calif.; a Propulsion Component Evaluation Facility at the Lewis Research Center, Cleveland, Ohio; a Space Power Facility and a Spacecraft Propulsion Research Facility at Lewis Research Center's Plum Brook Station, Sandusky, Ohio; a Flight Crew Training Facility, an Atmospheric Re-entry Material and Structures Evaluation Facility, and a Lunar Receiving Laboratory at the Manned Spacecraft Center, Houston, Tex.; and an AEROBEE 350 Launch Complex at the White Sands Test Facility, Las Cruces, N. Mex.

DEPARTMENT OF DEFENSE

CHAPTER IV

Introduction

Three major actions and events highlighted Department of Defense space and aeronautical activity during 1968: (1) Enlargement of the Phase I Defense Satellite Communications System to a constellation of 22 operating satellites and 39 surface terminals; (2) Growth of the TRANSIT navigational satellite system to a four-satellite, fully operational system; and (3) First flights of the C–5A, the world's largest military cargo aircraft.

Space Development Activities

Manned Orbiting Laboratory—Development of the Manned Orbiting Laboratory (MOL) continued to progress during the year with the program approaching its peak of activity.

The flow of structural test assemblies of major system components between associate contractors began, and procurement of various subsystem components continued. Demonstration firings of the first-stage engine of the TITAN IIIM booster engine were concluded successfully, and preparations were made for static test firings of the booster's second-stage liquid-fuel engine and the seven-segment solid rocket motors. Construction of the MOL launch complex at Vandenberg Air Force Base, California, neared completion and preparations were made for the installation of associated ground equipment.

Fourteen Aerospace Research Pilots continued training for the 30-day MOL missions, during which they will conduct defense-oriented experiments involving very complex equipment. The flight program will advance both manned and unmanned space technology and ascertain the full extent of man's utility in space for defense purposes.

The close working relationship between NASA and DOD continued to provide an exchange of technology, hardware and experience valuable to both the APOLLO and the MOL programs.

Titan III Space Booster—The TITAN III Program continued in the flight test phase, with two TITAN IIIC launches occurring during the year. The first launch, in June, successfully carried eight initial Defense Communications Satellites into orbit; the second, in September, placed three Office of Aerospace Research satellites and one experimental communication satellite into various orbits.

The R&D flight test program has been extremely successful. A total of 58 useful payloads have been carried on nine of the TITAN IIIC developmental launch vehicles to date.

The R&D goals of the TITAN IIIC development program have been essentially accomplished, although two R&D vehicles remain to be flown. TITAN III configurations are being produced both with and without the large solid motors attached, thus making it possible to handle a wide variety of military payloads. The TITAN III configurations have demonstrated high reliability, and there is a great degree of commonality between versions.

DOD Satellite Communications—The DOD program for satellite communications consists of the Long Distance Point-to-Point System and the Tactical Satellite Communications Program.

Long Distance Point-to-Point System—This system meets the Government's unique needs for satellite communications. It consists of the SYNCOM, Defense Satellite Communications System (DSCS), and International Cooperative Efforts.

SYNCOM—The SYNCOM satellites, developed and orbited by NASA originally for R&D purposes, have provided DOD Earth terminals with an interim means for passing operational traffic in the Pacific area. During 1968, as the greater capabilities of the DSCS became increasingly available, use of the SYNCOM satellites by DOD decreased. SYNCOM II is no longer scheduled for use because of technical difficulties; however, SYNCOM III is in regular use. Shipborne terminals have been activated aboard the USS ANAPOLIS and USS ARLINGTON and use SYNCOM III to operate with a ground terminal at Guam to provide an operational system for the Navy.

Defense Satellite Communications System (DSCS)—The Initial Defense Communications Satellite Project (IDCSP) was declared operational in 1967, and since that time has been designated Phase I of the Defense Satellite Communications System. The Phase I space subsystem deployment was completed in June 1968, when eight additional satellites were successfully orbited by a TITAN IIIC launch vehicle. Of the total of 26 Phase I satellites placed in orbit, 22 are currently being scheduled for operational use. The initial ground terminal procurement of 29 terminals has also been completed, with terminals deployed to New Jersey, Maryland, Colorado, California and Alaska, as well as Hawaii, Guam and other overseas bases. Additionally, three terminals have been leased from industry and deployed overseas. Seven shipborne terminals are being modernized for installation on Fleet flagships and the USS WRIGHT.

This Phase I system has proved a most useful addition to command and control communications capability. It has permitted the re-routing and continuation of vital communications during two separate cable breaks in the Western Pacific, and it has provided a new capability not previously possible—the rapid transmission of high-quality photographs directly from Vietnam to the United States.

In June 1968, it was decided to proceed with Phase II of the DSCS. Under current Phase II concepts, several new satellites will be placed in synchronous equatorial orbit by early 1971. They are to be equipped with "Earth coverage" antennas which direct most of their radiated power towards the Earth so as to uniformly cover that portion of the globe visible to the satellite. In addition, there will be steerable narrow-beam antennas capable of concentrating a portion of the satellite's power on an area of the Earth's surface one to two thousand miles in diameter.

Each new satellite will be able to provide hundreds of voice channels over the portion of the Earth visible to it and additional hundreds of channels within the narrow beam areas. The Phase II Earth subsystem will utilize to the maximum the terminals acquired during Phase I by modifying them to Phase II specifications. Additional terminals will be procured and certain new types of terminals will be developed to meet special requirements. With the new satellites and increased number of Earth terminals, the Phase II system will greatly increase the number of satellite channels available for unique Government needs. It will provide greater communication capabilities into and within theaters of operations much more quickly and effectively than do conventional communications techniques.

International Cooperative Efforts—Under the provision of an earlier Memorandum of Understanding, the Department is procuring two synchronous "SKYNET" satellites for the United Kingdom as an augmentation of the United States Phase I system. The first SKYNET satellite is scheduled for launch in mid-1969. Tests using Phase I satellites were conducted in which simultaneous operation of two United States and two United Kingdom Earth terminals demonstrated the feasibility of simultaneous but independent use of one satellite. In addition, there were exploratory talks with the United Kingdom of possible operational use of the Phase II system by that nation.

Cooperative effort with NATO for the establishment of NATO's preliminary satellite communications system continued during 1968. Use of Phase I satellites was provided to NATO for tests between two Earth terminals purchased from a U.S. firm by NATO. Also during 1968, procurement actions by NATO resulted in the Department contracting with a U.S. commercial source for a SKYNET-type satellite for NATO use beginning in late 1969.

Support of Canadian R&D satellite communications tests continued with the preparation of plans for additional tests in early 1969.

Tactical Satellite Communications Program (TACSATCOM)—This is a joint Service Program which has made substantial progress during the past year. Building on the earlier work of the Massachusetts Institute of Technology Lincoln Laboratory experimental satellite series, the Services in 1968 continued testing of the fifth satellite (LES–5), launched in July 1967 into a near-synchronous equatorial orbit with a slow eastward drift. New communications techniques have been tested, using experimental terminals installed in airplanes, ships and trucks; and joint tests were conducted with selected NATO countries. Aircraft, ships and ground terminals have acquired valuable data through the exchange of error-free teletype messages, without interruption, over transoceanic and transcontinental distances. A larger and more advanced satellite (LES–6) was successfully orbited on September 26, 1968. This satellite is now in stationary synchronous orbit, and the Services have initiated an extensive test program to explore further the uses and techniques for tactical communications.

A larger, more complex satellite (TACSAT I) is now scheduled for launch in early 1969. This satellite will be tested, in conjunction with a limited number of communications terminals installed in tactical vehicles, operational aircraft and combat ships, to provide the basis for the development of a truly operational tactical satellite communication system within the next few years.

The Air Force has had the responsibility for developing and launching the experimental satellites for the TACSATCOM Program and has developed appropriate aircraft terminals. Extensive testing of these terminals has proceeded, in coordination with the other Services.

The Army has built and is testing several types of ground terminals—jeep, shelter and van installations—under varied environmental conditions and in simulated tactical situations to demonstrate the operational feasibility of using spacecraft repeaters for tactical communications needs. An advanced portion of the Army program involves two families of terminal configurations, similar except for frequency bands. These terminals are being developed on a concept of modular construction and commonality of basic equipments to guarantee interoperability betwen terminal types. The terminals have been developed in man-pack, team-pack, jeep-mounted, shelter installations, airborne and seaborne configurations. Tests will be initiated in early 1969, with the launch of the TACSATCOM I satellite.

Using similar techniques, the Navy is extensively testing terminals aboard ship, on naval aircraft, with other Services and in supporting laboratories to demonstrate the feasibility of using satellites for reliable naval tactical communications and to develop operational procedures and doctrine. All practical operational applications are being explored with a view toward enhancing open-sea communications reliability.

The military Services are conducting a cooperative TACSATCOM testing program involving nine NATO participants—Belgium, Canada, Federal Republic of Germany, Italy, The Netherlands, Norway, SHAPE Technical Centre, United Kingdom and United States. The NATO countries joined with the United States in the test program, using terminals built in their own countries or purchased in the United States.

Spaceborne Nuclear Detection (VELA)—The purpose of the VELA Satellite Program is to develop a satellite capability to detect nuclear explosions from the Earth's surface to deep space. It is a joint research and development program of the Department of Defense and the Atomic Energy Commission.

Launches of two satellites each have occurred in 1963, 1964, 1965, and 1967; another launch is scheduled for 1969. The AEC-furnished payload for detecting nuclear radiation, electromagnetic pulse signals, optical radiation from the fireball, and natural space background will incorporate improvements to previous designs.

The on-orbit spacecraft have continued to perform well. In addition to the function of monitoring for nuclear test ban treaty violations, the spacecraft are supplying a wealth of natural radiation background data which are used by NASA, the Environmental Science Services Administration (ESSA), and DOD.

Geodetic Satellites—Effort in the DOD geodetic satellite program during 1968 included observations of GEOS–B, PAGEOS, NAVY NAVIGATION SATELLITES, SECOR, and other satellites. The GEOS–B, which carries a SECOR transponder, an optical beacon, a Doppler transmitter, and a range/range rate transponder in addition to laser reflectors and a C-Band beacons, was launched by NASA in January 1968. The geodetic satellites will continue to provide more precise information about the Earth's size, shape, mass, and gravitational field, in addition to determining geodetic positions for features on the Earth's surface.

The Army Corps of Engineers continued the SECOR Geodetic Satellite Program, providing a global control net around the equatorial area and geodetic positions for range tracking instrumentation. Observations made in 1968 resulted in the extension of the SECOR network to the Indian Ocean area. It is expected that the network will be completed when the last link, at Hawaii, is closed during 1969. A second major program managed by the Army, and accomplished by the Army and the Coast and Geodetic Survey, is the PAGEOS Primary Geometric Network. This program will establish a world-wide geometric net and constitutes the primary contribution to the National Geodetic Satellite Program. Observations have been accomplished from 33 of the 45 stations, and are scheduled to be completed by the end of Fiscal Year 1970.

The Navy Doppler Network (TRANET) observed several satellites during 1968, including the NAVY NAVIGATION (TRANSIT) SATELLITES, GEOS–A, and GEOS–B. Thirteeen permanent stations and five mobile vans were in operation. These data are used to improve the model of the Earth's gravity field and provide center-of-mass positions for specific locations as required. The program has now resulted in the determination of harmonic coefficients of the gravity model through the 12th degree and order, and selected higher terms. (Prior to the use of satellites, the gravity model was known only through the second degree and order.) In addition, the positions of 19 new sites were determined this past year.

The Air Force PC–1000 camera systems continue to operate in South America to provide a satellite densification network in support of mapping and charting efforts in that area.

Navigation Satellite System (TRANSIT)—The TRANSIT System, operated by the United States Navy, achieved the operational four-satellite constellation in March, when a new commercially built satellite joined the three laboratory-built satellites launched in 1967. The TRANSIT System was officially declared fully operational to the Fleet in October.

Following the Vice President's announcement of the release of the TRANSIT System for commercial use in 1967, two companies have developed shipboard receivers for sale to interested U.S. parties.

Space Ground Support

DOD National Ranges—The principal Department of Defense National Ranges which provide ground (and airborne) support for space activities are: (1) Air Force Eastern Test Range (ETR), (2) Air Force Western Test Range (WTR), (3) Air Force Satellite Control Facility (SCF), (4) Navy Pacific Missile Range (PMR), and (5) Army White Sands Missile Range (WSMR). All provide range support to all Government users whose programs are uniquely suitable for implementation at a particular range or ranges. All are currently in the process of conversion of telemetry systems to operation in the Ultra High Frequency (UHF) band. At PMR and WSMR, space activity amounts to approximately 4% of the total range effort. Activity at the major space support ranges follows:

Eastern Test Range—During the past year the Eastern Test Range has been emphasizing development and improvement of its mobile data-gathering fleet. These are aircraft and ships which can be strategically located throughout the world to gather data for various ballistic and space programs when land-based instrumentation is not adequate or available.

Eight APOLLO Range Instrumented Aircraft became operational in 1968 and successfully supported various DOD programs and the manned APOLLO program. Four additional telemetry aircraft will become operational in 1969. A modification program to improve the support capability of the Advanced Range Instrumentation Ships has also been initiated.

Western Test Range—Five instrumented ships developed for the support of the APOLLO program became operational in the spring of 1968. These ships are operated by the Air Force in support of NASA.

A precision tracking radar, an FPQ–6, became operational at the Western Test Range's Pillar Pt., Calif., tracking site in June 1968. This radar will improve the capability for accurate flight trajectory measurements of ballistic missiles launched from Vandenberg Air Force Base, Calif.

Bikini Atoll, which was under the control of the Western Test Range, was recently returned to the Trust Territories of the Pacific. The AEC has declared that this location is now habitable.

Satellite Control Facility—Major effort has been continued toward overall upgrading of Satellite Control Facility capabilities established in previous years. Construction began on a new addition to the Satellite Test Center at Sunnyvale, Calif. This will provide 14 new Mission Control complexes and house the Advanced Data System (ADS) and the Expanded Communications Electronics System (EXCELS). The Space Ground Link Subsystem (SGLS) was installed at three tracking stations and successfully supported the first satellite flown with this new equipment in October 1968. Installation of SGLS is continuing at the remainder of the tracking stations. The new Guam station is nearing completion and will become operational in early 1969. This modernization will provide a flexible, responsive satellite control network for existing and future DOD space programs.

Space Detection and Tracking—Air Force SPACETRACK and Navy SPASUR form the North American Air Defense Command's Space Detection and Tracking System (SPADATS). A new AN/FPS-85 phased array radar became operational in 1968. Located at Eglin Air Force Base, Fla., it will significantly improve the SPADATS capability to detect, track, identify and catalog all man-made objects in space.

Aeronautics Development Activity

C-5A Heavy Logistics Transport Aircraft—The C-5A, the world's largest military cargo aircraft, made its first flight and commenced Category I testing on schedule, in June 1968. Since that time three aircraft have flown 31 flights, for a total flying time of approximately 88 hours. Delivery dates on the next three aircraft have slipped slightly, but deliveries are expected to be back on schedule in May 1969. The C-5 engine (TF-39) has completed the 150-hour endurance test of the Formal Qualification Test (FQT). It is estimated that the FQT will be completed in May 1969.

F-111 Aircraft—The F-111A program has been in the process of transition from development to in-fleet status during the past year. Nearly 90 aircraft have been delivered to the Tactical Air Command. The Contractor's Category I test effort at Ft. Worth, Tex., Eglin AFB, Fla., and Edwards AFB, Calif., is continuing in those areas which normally proceed throughout production delivery. The Air Force Category II program at Edwards AFB also continues. The bulk of the continuing work is in the areas of weapons clearances, static and fatigue testing and full-flight envelope clearance.

The F-111D model which incorporates the advanced avionics package is, of course, still in the development stage, with first deliveries not scheduled until the latter part of 1969. The emphasis is almost completely on the avionics system, since development and testing of the aircraft itself has been largely accomplished in the F-111A program.

The success of the accelerated service test program which was initiated in June 1967 at Nellis AFB, Nev., resulted in a decision to deploy six F-111A's to SEA for a 6-month operational evaluation. This deployment took place on March 15, 1968, with the first stop at Guam, 5,770 nautical miles from Nellis. The unit landed at Takhli on March 17 and flew its initial combat mission 8 days later. The combat missions flown demonstrated a high capability for penetration and promise bombing accuracies during night and inclement weather unequalled by our other tactical systems.

Although the F-111 losses in 1968 were highly publicized and were the cause of concerted investigative efforts by the Air Force, it should be noted that the safety record of the F-111 exceeds other century-series aircraft at an equivalent point in time and is equalled only by the F-4.

The fatigue test program has revealed the need for a modification to the wing carry-through structure. This modification will be installed in retrofit for aircraft already assembled in production or in-fleet.

Delivery of the first F-111C aircraft to the Australians took place in September 1968. Delivery of the remaining aircraft will be made after modification of the wing carry-through structure.

On August 31, 1968, the first strategic bomber version of the F-111 was delivered to the Air Force. Designated the FB-111A, the aircraft was accepted and flown to Edwards AFB, where scheduled flight test will be completed. Later, bombers will be delivered to Carswell AFB, Tex., for build-up of the Combat Crew Training Wing.

Tactical Air Command is in the process of equipping the tactical wing at Nellis AFB. Crews are also flying the F–111A in the Combat Crew Training Wing at the same location.

Advanced Tactical Fighter—The Navy released a Request for Proposal (RFP) to industry in June 1968 which describes a two-place, twin-engine, advanced fighter aircraft, the F–14A. The F–14A will be a new airframe utilizing the TF30–P12 engine and AWG–9/ PHOENIX missile control system which will be modified to be compatible with SPARROW, SIDEWINDER, and guns as well as PHOENIX. In addition to its Fleet Air Defense capability, the F–14A will have capabilities generally superior to those of the F–4 in other fighter roles in the early 1970's. Advanced-technology engines and avionics are under development for installation in the F–14A airframe to produce a modification with significant improvement in performance, to counter the threat of the late 1970's and early 1980's.

The Air Force has initiated Contract Definition for an advanced air-superiority weapon system to be operational in the mid-1970's. This aircraft, the F–15, is designed to provide the necessary maneuverability and performance for air-to-air combat to maintain air superiority. It will replace the F–4 in the air-superiority role and assist in balancing the overall tactical force capabilities in the 1975–1980 period. Although emphasis has been placed on optimizing the F–15 for air superiority, it will also have a substantial visual air-to-ground capability for augmenting and fulfilling tactical requirements when air supremacy has been achieved.

A–7 Development—The Navy A–7A has proven its versatility, flexibility and increased ordnance-carrying capability in combat, numerous squadrons having seen action. The A–7D/E Air Force/Navy joint development program is progressing on schedule. Incorporation of the TF–41 engine in all the Air Force A–7D aircraft and the Navy A–7E (following production number 67) is expected to improve performance significantly.

Carrier-Based ASW Aircraft—The VS(X) is to be a new carrier-based Anti-Submarine Warfare (ASW) aircraft to replace the present S–2E Tracker. The VS(X) will have vastly improved speed and range as compared with present carrier-based ASW aircraft. It will have a four-man crew capable of monitoring additional sonobuoys, and will carry a larger weapon load. Its sensors will include a new radar, sonobuoys, magnetic detection devices, and cameras. The highly integrated avionics system will be designed around a central digital computer of advanced design, enabling the crew to process and interpret the large amount of information received from the sensors.

VS(X) development is proceeding on schedule. In April 1968 a contract was awarded to develop the TF–34, a high by-pass turbofan engine designed specifically for the VS(X). Five major aircraft manufacturers submitted proposals in April 1968 to conduct Contract Definition for the aircraft. Two companies were selected in August for this Contract Definition; they submitted firm development and production proposals in December.

Helicopter Development

AH–56A (CHEYENNE)—The AH–56A is the first helicopter developed as an integrated aerial weapons system. Ten prototype aircraft have been fabricated and delivered to the Army. It is designed to be the fastest, most lethal and least vulnerable helicopter in the 1970–80 timeframe. Since the first flight occurred September 21, 1967, the contractor has conducted an intensive ground and flight test program. Test results to date indicate that performance specifications will be met. On January 8, 1968, the Army exercised a production option to procure 375 CHEYENNE's over a four-year period.

AH–IG (HUEYCOBRA)—The Army developed and procured the AH–IG in 1966 in response to an urgent requirement of the Vietnam field commander for an improved armed helicopter. The AH–IG carries machine guns, rockets and a grenade launcher. Deployment of the aircraft to Vietnam began in August 1967. The AH–IG serves as the Army's interim armed helicopter pending the production and deployment of the AH–56A.

V/STOL Development

CX–84—The Canadian Government is procuring three CX–84, formerly designated CL–84, test aircraft for military operational suitability testing beginning in calendar year 1969. U.S. DOD personnel will assist in and monitor these tests by providing advice, limited equipment, and one part-time engineer.

X–22—The X–22 ducted-propeller research aircraft is being used, under Navy management, as a variable-stability research aircraft. A Military Performance Evaluation (MPE) utilizing the variable-stability system is scheduled for March 1969.

Light Intratheater Transport—The Light Intratheater Transport (LIT) is being programmed for the mid-1970's to replace the C–7's/C–123's and augment the C–130E's. The new transport will be able to operate in the forward area to support Army combat units and will have adequate payload capacity to distribute cargo that has been offloaded from C–5 and C–141 aircraft.

The program is in the final steps of the concept formulation phase, which is evaluating V/STOL (vertical/short takeoff or landing) and STOL (short takeoff or landing) concepts. Results of these evaluations will provide the basis for design selection.

AC–130 Gunship II—The side-firing AC–130 Gunships were developed for night and limited all-weather operation to support interdiction and close air-support missions in a semi-permissive environment. They are configured with four 20mm Gatling guns and four 7.62mm miniguns, night-attack sensors for improved target detection and accurate gun laying. Modification of these aircraft is currently in progress.

Advanced Manned Strategic Aircraft—During 1968 the Air Force continued studies and advanced development of critical components in order to amplify and verify the design and characteristics of an advanced strategic bomber with sufficient range and flexibility to enable it to meet both nuclear and conventional weapons delivery requirements.

The Air Force has an approved program that will involve a competitive design phase for systems, avionics and propulsion contractors. This effort will be directed toward reducing development lead time; over a two-year period it will define the details of the system to provide more accurate configuration and cost estimates. No commitment to build a vehicle will be made until the two-year effort and the projected threat are evaluated.

National Clear Air Turbulence Program—The Department of Defense has been assigned responsibility for that portion of the National Clear Air Turbulence Program concerned with observations, measurements, special reconnaissance, and development of devices to detect turbulence ahead of an aircraft in flight. This, in turn, was assigned to the Department of the Air Force.

A detailed management and development plan has been prepared by the Department of the Air Force to initiate the DOD portion of the plan in Fiscal Year 1970. The Air Force is also actively coordinating its activity with that of the Department of Commerce.

Tropic Moon III—Tropic Moon III is a program to modify 16 B–57 aircraft to a self-contained night-attack configuration. These aircraft will contain an array of electronic sensors fully integrated with the weapon delivery system to provide for improved target detection and accurate weapon delivery in darkness. Because of their relatively high speed potential and munitions-dispensing versatility, the aircraft will primarily be employed against interdiction targets in medium-to-high threat areas.

Shed Light—Shed Light is a grouping of U.S. Air Force programs which will provide increased night operational capability to our tactical forces as rapidly as possible. It involves approximately 60 primary and supporting development projects. These are interrelated to provide an effective mix of weapon systems to strike a variety of targets in various threat environments. Both self-contained and hunter/killer system concepts have been explored.

Significant progress has been made over the past 30 months in developing night-attack sensors and in integrating them with existing aircraft. Several equipments have been employed and evaluated in combat or are in the process of being developed with testing to be conducted in Southeast Asia. These include Low-Light Television equipment mounted on B–57 and A–1E aircraft; Side-Looking Infrared and Forward-Looking Radar with Moving Target Indicator installed on AC–130 Gunships; night observation devices on AC–130 and Forward Air Control (FAC) aircraft; and battlefield illumination and airborne real-time reconnaissance systems in RC–130 aircraft.

More sophisticated and advanced sensor packages for several different types of aircraft will be placed in operation in the near future. These will include improved electronic sensors and sensor integration with improved information displays, data processing and transmission systems, navigation and weapon delivery systems.

Unconventional Airborne Platforms—The Advanced Research Projects Agency (ARPA) has given special attention to relatively invulnerable targets appearing with more regularity in Vietnam. Included among these are heavy artillery, trucks, mortars, and rockets.

An examination of the characteristics of unconventional platforms, such as balloons, airships, and extremely small aircraft, indicates that these may offer unique capabilities in locating and destroying hard targets.

In the SILENT JOE II program, ARPA is evaluating the potential utility of airships as platforms for conduct of special operations in support of killing hard targets and defense of military installations. During the current, preliminary, phase of the program, an airship is being tested and various airship designs are being studied together with various payloads. A low-risk development program is being initiated to develop airship and payload systems for special missions in Southeast Asia.

Supporting Research and Technology

Over-the-Horizon (OTH) Radar—Radars developed during and after World War II to detect and track aircraft have had limited ranges. This limitation was due to the geometry of the detection environment (line-of-sight) and the operating frequency selected. The Department of Defense has now developed OTH radars, utilizing ionospheric refraction of radar energy, which have demonstrated a capability to detect aircraft (and missiles) below the line-of-sight horizon. The OTH techniques have demonstrated radar detection ranges of several thousand miles. Laboratory and field evaluations are continuing, to determine the desirability and feasability of applying this technique to improve the capability to detect and track aircraft as well as to enhance missile early-warning capabilities.

Spacecraft Technology and Advanced Re-entry Tests (START)—The Air Force's current efforts in developing technology for maneuverable re-entry spacecraft are concentrated in two major areas. These are the PILOT (X–24A) program and advanced spacecraft studies. The X–24A testing will be limited due to the reduced likelihood that this technology will be applied directly to future military systems. The advanced studies will seek to channel exploratory development effort toward future military needs. Advanced spacecraft configurations will be considered in conjunction with both available and advanced launch vehicle concepts.

Advanced Space Power Technology—The Air Force program has continued to identify various advanced concepts for improving the power-to-weight ratio of electrical power systems essential for space missions in the 1970's and beyond.

In 1968, advanced development of a Large Retractable Solar Cell Array was initiated to demonstrate the capability and reliability of lightweight, flexible solar cell arrays. Current plans provide for a flight demonstration of this array in Fiscal Year 1971. Successful demonstration of this technology will enable a 50% reduction in weight and an 80% reduction in volume over current solar cell array configurations in the 500-watt to 20-kilowatt power range.

Radiation-Cooled Fuel Cell High Load Test—The Air Force has completed in-house the high load testing of a radiation-cooled fuel cell module developed under a contract with industry. The fuel cell was subjected to a high-power load profile (90-minute cycle) to determine its overload capabilities under conditions representative of several potential user requirements. The module was operated in a thermal-vacuum bell jar chamber through an environmental temperature range from 20° F to 100° F. Power produced by the fuel cell ranged from approximately 56 to 385 watts (130 watts average). The average power represented a 30% increase, or overload, over contract design and performance requirements of 100 watts.

Cobalt–60 Thermionic Generator—The Air Force has recently established the feasibility of using Cobalt–60 isotope as a high-temperature thermal energy source of thermionic energy conversion for space and ground power. This achievement is expected to be a step forward in high-temperature thermal energy source technology for static-energy conversion devices (both thermionic and thermoelectric generators). Availability of such a heat source has been an objective for several years, and its absence has been a deterrent to full exploitation of thermionic generators.

Although Cobalt–60 isotope was available in large quantities at relatively low cost, it had not been considered a suitable energy source for space electrical power generators. It was generally accepted that the shielding required to reduce its very intense gamma radiation to safe working levels would be prohibitive in size and weight. However, this intense gamma radiation can be turned into an asset by using a new generator design approach in which the gamma radiation shielding weight is not critically degrading.

DOD Gravity Experiment (DODGE)—The DODGE satellite, launched in 1967, is the first satellite to use three-axis gravity-gradient stabilization at near-synchronous altitude. Many experiments have been conducted, including extending and retracting the 10 long booms, tumbling the satellite, studying boom bending due to solar heating, and determining the effects of solar pressure. Operation within the limits of $\pm 2°$ in roll and pitch and 5°–7° in yaw was demonstrated in 1968. Evidence indicates that it will be desirable to couple a single-axis gravity-gradient boom system with a small moment-of-inertia flywheel for the optimum semipassive stabilization at this great altitude.

SOLRAD—Solar Radiation Monitoring Satellite Program—The objective of the SOLRAD Program is to perform continuous monitoring of solar X-ray and ultraviolet emission to provide indices of solar activity upon which a system of ionospheric disturbance forecasting can be based.

The SOLRAD IX satellite, launched March 5, 1968, provides data which are reduced and encoded in a standard format and delivered to the AGIWARN and SOFNET networks within 15 minutes of reception. From analyses of these data, warnings of increased solar activity are sent to the Communications Commands.

Navigation by Satellite—The Naval Research Laboratory is developing a new satellite navigation concept called Timation, which can be used for providing continuous navigational fixes from low-altitude or synchronous satellites. In the Timation experiment a satellite contains a stable oscillator controlling its transmissions. On a ship the navigator compares the satellite's transmissions with his own oscillator. If both oscillators are suitably synchronized, he can determine his range from the satellite. Knowing the satellite's position, he can use celestial-navigation techniques to determine the ship's position. The concept has been proven feasible in tests conducted in 1968 with an experimental satellite. It may lead to low-cost, simple equipment for ships, aircraft, and other users.

Turbojet Engines—The Air Force has achieved technological advances in turbojet engines. This year two new engines were flown on their maiden flights with very good results, one new engine has started development, and demonstrator engines continue to be tested for use in new aerospace weapon systems.

The TF–41 and the TF–39 turbofan jet engines both had excellent test flights in the A–7D and C–5A, respectively. The Air Force also began development of demonstrator engines for the F–15 air-superiority aircraft, while advanced development work continued in support of potential VTOL systems and the advanced manned strategic aircraft (AMSA).

Advanced Turbine Engine Gas Generator (ATEGG)—This program provides a means to demonstrate new component design concepts in an engine environment. The objective is to provide new engine component technology which can be used, in future aerospace systems, with low risk and minimum development time. Four contractors are participating in the program.

These contractors are developing turbine-engine gas-generator cores which push the threshold of technology on all fronts, placing emphasis on thermal efficiency and thrust-to-weight ratio. Significant increases in technology are possible, in a minimum of time and with modest funding, through the demonstrator engine approach.

Turbo Shaft Engine Project—The Army is conducting a development program in which each of two contractors will build and test a 1,500-shaft horsepower (SHP) demonstrator engine to demonstrate advanced gas turbine engine technology. Goals are engines that will have 40% lower weight and 25% lower fuel consumption than current engines of comparable power, while also providing higher reliability and improved maintenance features. The program is now half completed, and the preliminary indication is that the objectives can be attained.

Aircraft Propulsion Subsystem Integration (APSI)—The Aircraft Propulsion Subsystem Integration Program is an Air Force project to develop air inlet, engine and exhaust nozzle design criteria which may be used to assure compatibility between airframe and propulsion systems of future gas turbine-powered aircraft. These criteria will permit the selection of that combination of airframe, inlet, engine and exhaust nozzle which will tend to minimize future propulsion system losses throughout the aerospace vehicle's flight envelope.

Industry contractors of this program have been busy over the past year developing coordinated tests and studies to solve the problem of aircraft propulsion compatibility. The work completed thus far indicates that high payoffs in performance gains are possible. The program has ramifications that extend to added performance in all aerospace vehicles, both military and civilian. Aircraft will benefit through improved inlet systems engine performance and reduced nozzle drag, particularly in the supersonic regime of flight.

VTOL Integrated Flight Control Systems (VIFCS)—The objective is to evolve handling-qualities criteria, control power requirements, displays and aerodynamic prediction techniques to support the development of future operational V/STOL aircraft. The primary research flight-test vehicle is a modified XV–4A aircraft, designated the XV–4B, which uses a jet direct-lift configuration. The two-place XV–4B aircraft has a total of six J–85–19 jet engines. Two are used as lift/cruise engines and are mounted in nacelles on either side of the fuselage. The other four are used as lift engines and are mounted vertically in the center of the fuselage.

The XV–4B completed all its conventional-mode test objectives in two flights. The first vertical take-off and landing flight will occur in the near future.

Load Alleviation and Mode Stabilization (LAMS)—The flight-test phase of the Load Alleviation and Mode Stabilization (LAMS) Program was completed in May 1968. The objective of the two-and-a-half-year Advanced Development effort was to demonstrate advanced flight control techniques which would alleviate gust loads and control structural oscillations.

A heavily instrumented B–52E aircraft was modified to use the system in flight tests. Aircraft response data in turbulent flight conditions were obtained for different aircraft control system configurations, including an unaugmented system and the LAMS system. Indications are that the LAMS reduces significantly the fatigue damage rates incurred in gust turbulence.

Airborne Warning and Control System (AWACS)—The AWACS is being developed to provide the Aerospace Defense Command with a survivable warning and control environment for air-defense interceptors, and the Tactical Air Command with command, control and communications for quick-reaction global deployment with the Composite Air Strike Force (CASF) to any limited-war area.

The AWACS will be self-contained in a subsonic, cargo, jet aircraft. The aircraft will contain a surveillance radar capable of detecting and tracking low-flying aircraft, a mixture of long- and short-range communications, data processing, and displays. It will carry a crew of about 30–40 personnel.

Advanced Composite Materials Application—A full-scale horizontal stabilizer for the F–111 has been made using a boron-plastic composite skin. It weighs 25% less than the tail with aluminum skin. A set of these tails will be flight-tested early in 1969.

Boron-plastic composites have also been applied to several secondary structures. Upper and lower wing panels and an aft main landing gear door for the F–111 aircraft have been successfully fabricated and tested. An A–6 outer wing fence, T–38 landing gear door, and an F–4 rudder have also been fabricated and tested. All components have been flight-tested, and some have over 100 hours of flight time. No damage to any of the components has occurred during the flight-test program.

Work is currently under way on wing and fuselage development and on jet engine components. The technology has also been developed for the application of boron-plastic composites to helicopter aft main rotor blades (CH–47 aircraft) and C–5A wing slats and F–X wings. An eventual weight savings of about 50% is expected.

Space Experiments Support Program—The Air Force Space Experiments Support Program (SESP) combines different Department of Defense space flight experiments on single launch vehicles and insures that launch vehicle capacity is fully utilized.

Related to this effort is an Aerospace Research Support Program, which now utilizes SESP boost capacity for research and environmental satellites. In the overall program during 1968, a total of three launches successfully orbited eight satellites containing 26 experiments.

Under the Quadripartite Military Technical Cooperation Program, we have recently invited the United Kingdom, Canada and Australia to fly experiments aboard our Space Experiments Support Program. Other cooperative efforts are already under way in the military communications satellite area.

Systems Survivability—The Air Force has continued to develop its program to assure the survivability of its weapons systems in the hostile environments of both nuclear and non-nuclear conflicts. As an adjunct of this program, it is preparing satellites to withstand not only the natural environments of space but also the harsher environments arising from nuclear weapon detonations. Efforts are continuing to assure continued operation of satellite systems during atmospheric nuclear testing, should it be resumed, or in wartime.

Cooperation With Other Government Agenies

Coordination and cooperation continues with other Government activities, particularly the National Aeronautics and Space Administration (NASA). Included are frequent informal discussions at all levels of the respective agencies, scheduled meetings of formal coordinating panels and boards and direct support to NASA.

National Aeronautics and Space Council—Policy coordinated and high-level exchanges of plans and proposals take place through this organization, of which the Secretary of Defense is a member.

Aeronautics and Astronautics Coordinating Board (AACB)—During the calendar year, four AACB meetings were held in which information was exchanged, and space and aeronautics programs were coordinated. Emphasis was placed on conducting joint studies in manned space flight, space networks and ranges, environmental monitoring, propulsion, and a number of other areas of common DOD/NASA activity. These studies are directed not just at avoiding duplication and assuring full coordination, but at possible savings through reductions and consolidations.

DOD Support of NASA—DOD support of NASA totaled more than $225 million during Fiscal Year 1968. The major items of support include operation of the National Ranges, which provide support to both manned and unmanned spacecraft launches. Two hundred ninety-one military personnel are assigned to NASA (186 Air Force, 20 Navy, 83 Army, 2 Marine Corps). Examples of the more than 400 support activities follow:

ARMY—

Construction Support—The Corps of Engineers supported NASA by providing real estate acquisition and land management services, and design and construction of facilities at the John F. Kennedy Space Center, the Mississippi Test Facility, and the Electronics Research Center.

Lunar and Planetary Activities—The Army Map Service assisted NASA by producing large-scale maps, photomaps, and landmark graphics from LUNAR ORBITER photography for use in the APOLLO program and various scientific studies. Construction of a 1:2,000-scale lunar landing site relief model, for use in astronaut training, was begun. Studies to improve the lunar geodetic control network were continued. A series of Mars maps was produced for use in planning the MARINER 69 Flyby.

Aerospace Feeding Systems—The United States Army Natick Laboratories continued to develop new and improved aerospace food products for NASA and the United States Air Force which were made available for use in simulated tests and flight qualifications. About 30 candidate flight foods have been improved and crush protection increased. Menus for APOLLO flights were planned according to the astronaut's individual selections from available flight-qualified foods.

NAVY—

APOLLO—The Navy continued to provide the recovery fleet and other support forces to assist the APOLLO program.

Medical Projects—The Naval Aerospace Medical Institute, Pensacola, Florida, provided facilities and personnel to assist NASA in the study of space-related medical phenomena. Also, technical research and inspection services were furnished in the NASA acquisition of astronaut seats for the Zero-G test facility.

AIR FORCE—

Test Range Support—Approximately 25% of the total United States Air Force support provided NASA during the first six months of this year was devoted to test-range support of spaceflight and recovery operations. A significant portion of these costs was for the APOLLO Range Ships, which will provide communications and data support for that program. Other types of test-range support include range instrumentation, data acquisition, transmission, processing and reduction, calibration and repair of precision measurement equipment, industrial support, launch-complex control and support operations, and facilities engineering on the Air Force Eastern and Western Test Ranges.

Arnold Engineering Development Center (support for the SATURN booster):

a. Altitude testing of the J–2 engine continued, with the objective of identifying the effects on the engine-start transient of anticipated thermal environmental conditions imposed on the engine components.

b. A base recirculation study was conducted to determine the instrumentation techniques and methods for measuring velocity pressure and density in base flow fields around a SATURN rocket cluster model.

c. SATURN protuberance testing was conducted using variable-height, generalized protuberance shapes on the SATURN S–IVB full-scale panel model. Static and dynamic pressures and boundary-layer parameters were measured.

Propellants—The Air Force has continued to supply support for NASA's requirements in propellants and pressurants. Under this arrangement, the Air Force Logistics Command serves as the single manager for propellants and pressurants when it is considered in the best interest of the Government.

ATOMIC ENERGY COMMISSION

CHAPTER V

Introduction

In 1968 substantial progress was made in the joint AEC/NASA nuclear rocket program. Highlights for the year included (a) the completion of two high-power tests on the PHOEBUS–2A reactor; the major test, at powers up to 4,200 megawatts, provided data on the nuclear and thermal characteristics of high power-density-reactors; a second test (with peak power at 3,700 megawatts) furnished data on the control of nuclear rocket reactors; (b) the completion of a series of tests on the XECF engine (a cold-flow test engine) to investigate the performance of a nuclear rocket engine under conditions partially simulating flight; (c) the initiation of power tests on the "hot" ground-experimental engine (XE) in ETS–1, and (d) the successful testing of the PEWEE–1 test-bed reactor at Test Cell "C". Significant progress also was made in the extension of fuel-element technology. The activities cited are directed specifically toward establishing a base of technology for the development of a 75,000-pound-thrust NERVA engine.

During the year, the AEC continued to produce technology required for development of a family of long-lived space reactor power systems in the 10 kilowatt to the megawatt range, and to develop and test nuclear radioisotope electric power units for space use. Highlight events included: (a) testing of the flight-configured ground-prototype version of the zirconium hydride nuclear reactor, the S8DR, which will be capable of serving as a heat source for space power systems up to 100 electrical killowatts; (b) completion and delivery, for integrated system testing, of five SNAP–27 isotopic space electric power generators, to be used on APOLLO landings as part of the APOLLO Lunar Surface Experiment Packages (ALSEP); (c) launch failure of the NIMBUS B satellite carrying a SNAP–19 isotopic generator, followed by recovery from the ocean off California of the isotope fuel of the generator (a repeat NIMBUS is being readied for launch in the first half of 1969, and a new SNAP–19 unit has been delivered to NASA for integration into the spacecraft); (d) start of development of a 20-watt plutonium-238 fueled generator for a NAVY NAVIGATION SATELLITE.

By the year's end, substantial progress had been made in space-directed advanced technology development. The program to develop a basic advanced reactor concept, the in-core thermionic reactor, is continuing. Another advanced concept, the liquid metal-cooled space reactor, is presently being phased out.

Nuclear Rocket Propulsion

During 1968, preliminary planning in preparation for the development of the 75,000-pound thrust engine was completed, and a development schedule was defined which indicated preliminary flight tests based on current NERVA (Nuclear Engine for Rocket Vehicle Application) and PHOEBUS reactor technology could be accomplished in seven to eight years. (Budgetary constraints in Fiscal Year 1968 forced a reassessment of the future space program, and a reexamination of the goals of the nuclear rocket program. These reviews led to the decision to reduce the NERVA thrust level from the 200,000 pounds originally proposed to 75,000 pounds. The 75,000-pound-thrust engine is not the best choice for manned planetary exploration, but it is quite suitable for a wide range of other missions for which nuclear rockets are being considered. The lower-thrust engine will use hardware of the size used in the technology program and test facilities basically available. Development costs, therefore, will be less than those of the 200,000-pound-thrust engine, particularly over the next several years.) In addition, work proceeded on the preliminary design of the NERVA reactor and critical engine hardware, i.e., the nozzle and nozzle hot-bleed port, reactor pressure vessel and turbopump. Work also was initiated on the preliminary design of modifications required to test the NERVA engine in Engine Test Stand No. 1, at full power and under simulated flight conditions.

Reactor and Engine System Technology Activities—The PHOEBUS–2A reactor tests were originally planned to demonstrate high-power reactor performance for direct application in the 200,000-pound-thrust NERVA engine. When the NERVA engine thrust was reduced to 75,000 pounds, the demonstration of high-power reactor operation became of secondary importance, and the PHOEBUS–2A became a tool for obtaining data on reactor design concepts being considered for use in the NERVA flight reactor and on a new method of reactor control based on using the liquid-hydrogen propellant flowing through the reactor core to regulate the fission process. PHOEBUS–2A test results follow:

(a) In the major experiment of the PHOEBUS–2A test program, the reactor was operated for a total test time of approximately 32 minutes, 12 minutes of which was at a power level above 4,000 MW. A peak power of 4,200 MW was achieved. Good data, applicable to the NERVA flight reactor, were obtained about the control of high power-density nuclear rocket reactors.

(b) In a subsequent test, the PHOEBUS–2A was restarted to conduct a series of experiments at low and intermediate power levels. The reactor was operated over a wide range of power levels up to about 3,700 MW and for a total test time of approximately 30 minutes. The experiments gave additional data on the nuclear and thermal characteristics of high power-density reactors. These data will be very useful in the development of the NERVA flight reactor.

Fuel Element Materials Research—Significant work also was conducted to improve the performance and duration capability of nuclear rocket reactor fuel elements.

The initial duration objective for nuclear rocket fuel elements was achieved in December 1967, with the demonstration of 60 minutes of full power (approximately 1,100 megawatts) with the NRX–A6 reactor. During 1968, laboratory tests of improved fuel elements provided test durations of more than 100 minutes. These tests were conducted under conditions far more severe than those existing during operation of the NRX–A6 reactor. Fuel element materials research has now shifted toward cyclic testing at higher power densities and temperatures.

In the laboratory programs for improving fuel elements performance, electrically heated corrosion furnaces are used for corrosion testing. The results of these performance tests must be checked periodically through full-scale reactor tests. Investigations have indicated that a smaller-sized test reactor, requiring a smaller number of fuel elements, would be more economical. As a result, the fabrication of two such reactors, the PEWEE–1 and PEWEE–2, was initiated.

During 1968, Test Cell "C" was modified to meet the requirements for PEWEE reactor testing and the PEWEE–1 reactor was moved to the cell for checkout prior to power testing in December. Test cell modifications consisted primarily of the addition of a new liquid-hydrogen turbopump and minor changes to various lines and valves to accommodate PEWEE flow requirements.

The PEWEE fuel element test reactor was designed by Los Alamos Scientific Laboratory to provide an economical means of evaluating the performance of fuel elements in the nuclear rocket program. PEWEE reactors are smaller than their NERVA and PHOEBUS counterparts and, therefore, can be built and tested in less time and at lower cost. Design of the first PEWEE reactor, PEWEE–1, began in May 1967. Eighteen months later, on December 4, 1968, power testing of PEWEE–1 was completed, in a successful program to develop and evaluate the design. Significant power operation totaled about 90 minutes, 40 minutes of which were at the design power of 514 megawatts and a hydrogen temperature of 4,600°R. The reactor was also subjected to four thermal cycles in achieving the total operating time. The test of PEWEE–1 also provided data on the performance of advanced experimental fuel elements under the highest temperature and power density conditions ever achieved in the nuclear rocket (or any other reactor) program.

XECF Ground-Experimental Engine Tests—The XECF engine tests were the first of a series of experiments planned to investigate the performance of a nuclear rocket engine under conditions partially simulating flight. The test also was the first to be conducted in Engine Test Stand No. 1, the new down-firing test stand, and to utilize the XE ground-experimental engine, an engine closely approaching that of a flight configuration. No fissionable material was included in the XECF reactor core; for this reason, no thermal energy was generated during the tests.

The XECF cold-flow test program was initiated in 1968. The two major test objectives were to verify that ETS–1 was ready for, "hot," i.e., nuclear, engine testing and to investigate engine startup in the test stand under simulated altitude conditions. Other objectives included the checking of engine/stand operating procedures and the investigation of engine malfunctions under simulated altitude conditions. The engine system and test facility operated as planned, and the test results provided the basis for proceeding with the "hot" tests of the XE engine.

As was to be anticipated, the XECF test series revealed a number of design and operational problems. Most of these have been corrected; correction of those remaining is expected to be completed in time to support the start of XE engine tests.

The final experiments of the engine system technology portion of the nuclear rocket program will be the "hot" tests of the XE engine. Assembly of the engine was completed in the fall of 1968. Full-power engine tests are scheduled for the first half of 1969.

Space Electric Power

Space Reactor Power Systems

Zirconium Hydride Reactors. Testing of the flight-configured ground-prototype uranium-zirconium hydride reactor SNAP–8 Developmental Reactor (S8DR), started in 1968. This reactor is based on technology successfully demonstrated in the SNAP–10A program in 1965 and further investigated in the SNAP–8 Experimental Reactor (S8ER). The test program includes demonstrations of restart capability and continuous operation for at least 10,000 hours at design conditions of 1,300° F outlet temperature and 600 thermal kilowatts. Reactors of this type can be mated with thermoelectric converters or mercury Rankine cycle power machinery to produce electric power in space up to about 100 electrical kilowatts.

A reference power system using the zirconium hydride reactor and the "compact" thermoelectric converter was studied during 1968 with the objective of defining subsystem and component development needs and mission integration requirements. This system offers an essentially static powerplant of high reliability for use in the mid-1970's at power levels in the range of 15–30 kilowatts. A joint AEC/NASA study was made on the possible use of this system for the orbital workshop-type missions. System studies and development of component technology for reactor systems of this type will continue in 1969.

Space Radioisotope Power Systems

SNAP–3. The isotopic power concept new being used in space systems is a radioisotopic thermoelectric generator (RTG), fueled with plutonium–238. This concept has been in active use since the first SNAP–3 power system was launched aboard a navigational satellite in 1961. On June 29, 1968, the SNAP–3 unit completed its seventh year of operation in space. It has already operated two years beyond its five-year design life, and is still in operation.

SNAP–19 Isotope Generators. On May 18, 1968, the NASA THORAD-AGENA–D vehicle, which was to carry the NIMBUS–B weather satellite and SNAP–19 isotope generators into orbit, was destroyed because of a guidance system malfunction. Search and detection operations for the two SNAP–19 plutonium–238 fueled capsules succeeded in finding the submerged satellite; the two fueled capsules have been recovered and returned to Mound Laboratory for examination and return of the fuel to inventory.

Because of the importance of the NIMBUS–B weather satellite mission, NASA has reprogrammed a NIMBUS–B–2 mission, again using the SNAP–19 isotope generators. The delivery of the SNAP–19 flight system to NASA was completed in December 1968, with a launch scheduled for the spring of 1969.

SNAP–27 Isotopic Generator. The SNAP–27, being developed by the AEC for NASA, is also fueled with Pu–238 and is designed to provide at least 50 watts of conditioned power. The SNAP–27 units will provide all the power for APOLLO Lunar Surface Experiments Packages (ALSEP) to be placed on the Moon by astronauts during APOLLO missions. These experiments are to provide information for a period of one year after the astronauts return to Earth.

SNAP–29 Isotopic Generator. The SNAP–29 generator is planned to be fueled with polonium–210, to provide hundreds of watts of electrical power for three months. Thermoelectric conversion subsystems, heat transfer units using heat pipes, and fabrication and test of the heat-source components are under development. A ground demonstration of a prototype flight system is planned for Fiscal Year 1970.

Navigation Satellite Generator. Design and development of an isotopic generator for the Navy's improved navigation satellite was started. This generator, using plutonium–238 fuel, is being designed to produce at least 20 electrical watts at a weight of less than 20 pounds.

Space-Directed Advanced Technology Development

Advanced Space Reactor Concepts—Advanced space reactors are being developed for high-performance, long-endurance space power needs envisioned for the 1980's and beyond. Electrical outputs in the power range of hundreds-to-thousands of kilowatts are being considered.

During 1968, the AEC conducted technology development of two basic advanced reactor concepts, the in-core thermionic reactor and the liquid metal-cooled reactor. In 1968 the in-core thermionic program continued to emphasize the development of fueled thermionic converters capable of long-endurance operation at emitter temperatures above 3,000° F. Several prototype converters were operated in-pile for over 1,000 hours.

Continuation of the liquid metal-cooled space reactor program beyond 1968 was not authorized by Congress and the project is now essentially phased out. Further plans for this concept have not yet been defined.

Space Power Conversion Technology—*SiGe.* High-temperature (1,800° F) silicon-germanium (SiGe) thermoelectric modules were fabricated. These are typical of the conversion devices being considered for advanced space radioisotope power concepts. Long-term life tests (over 35,000 hours) of silicon-germanium modules under both air and vacuum conditions are indicating extremely stable performance. An electrically heated generator, representative of the state of the art, in performance tests at 990° C produced 27 watts of power at a measured efficiency of 5.8%. Optimized materials now under development should improve that performance significantly.

High-Temperature Radioisotope Capsule. A capsule that can contain Pu–238 fuel forms at 2,000° F for more than five years is being developed. It utilizes a refractory metal structural shell and a noble metal oxidation-protection shell. Fabrication techniques for the capsule have been demonstrated, and short-term creep tests have been completed.

Compact Converter. Metal-encapsulated, void-free compact thermoelectric converters have shown excellent improvement in long-term performance and efficiency during 1968. Materials interaction that had previously led to long-term performance degradation in the 1,000° F temperature regime has been eliminated by use of inert materials. Progress in this program has led to the investigation of a multikilowatt reactor-compact converter system for NASA application. Direct loading of isotope fuels into the compact converter and heat pipe-isotope-compact converter concepts are being investigated. Use with high power-density fuels such as curium, polonium, and cobalt-60 appears promising.

ISOTEC. Two nominal 30-watt electrically heated ISOTEC generators have been tested during 1968, performing essentially as expected from earlier data. These generators use lead-telluride thermoelements bonded into a sandwich panel which rejects waste heat directly to space from its outer surface.

Space Nuclear Safety Activities

Work is continuing on the evaluation of the recovered capsule materials and fuel of the SNAP–19 generators to determine the actual behavior of this system in an alien environment.

The safety evaluation of the SNAP–27 system, to be used on the APOLLO Lunar Surface Experiments Package (ALSEP) is continuing.

Programs to evaluate the safety aspects of several new fuel forms have been initiated and are continuing.

Work is progressing on several search, detection, and recovery techniques which it is hoped will become operational in the very near future.

Space Isotopic Fuel Development

Polonium 210—Polonium 210 is being developed as a heat source for 90–150 day missions that demand high specific power (thermal power per unit volume or weight) and a minimum of shielding. Rare earth-polonium compounds now being studied offer improved stability over the pure metal for short missions (several months). This effort is focused on a program to develop and provide a Po–210 fuel form for the SNAP–29 unit.

Curium 244—Curium 244 has the attractive combination of a reasonably high thermal specific power, a relatively long operational life, and the availability of a thermally and chemically stable compound. However, the neutron radiation of Cu-244 does require more shield weight than other alpha fuels under development, such as Pu-238 and Po-210.

During 1968, efforts were continued to characterize this fuel as to chemical, physical, radiation, and other properties. Capsule closure sealing methods and designs are under investigation.

Plutonium 238—During 1968, there was continued development of the oxide of plutonium-238 (87.5 years half-life) for use in radioisotope power units. Development of the process for production of plutonium dioxide microspheres was one of the items of research. Desirable properties of this material are relative chemical and biological inertness; high melting temperature; thermal, chemical, and radiation stability; and ease of handling. A pilot plant of a new microsphere production process known as Sol-gel was demonstrated and installed. Checkout is proceeding, and the pilot plant is expected to be operational in 1969. Using the oxide fuel form, heat sources were fabricated for several generator systems and for evaluation in the fuel technology programs.

During 1968, the DART II (Decomposed Ammonia Radioisotope Thruster), a propulsion device for positioning a spacecraft in space, was designed, fueled, and demonstrated successfully in a simulated space environment.

To meet the requirements of more efficient and demanding conversion systems, studies of new fuel forms, materials, and methods of containment compatible with the required increased temperatures have been initiated.

Satellite-Based Detection Of Nuclear Explosions In Space And In The Atmosphere

The AEC-instrumented VELA Satellite Program continues with the preparation for the fifth launch in 1969 in the planned series of five launches. Four successful launches have placed eight VELA nuclear-test detection satellites into near-circular co-planar orbits of about 65,000 nautical miles radius. The newest pair, placed in orbit with 180° phase separation by a TITAN IIIC booster in April 1967, have an attitude control system to keep one axis oriented toward the Earth, as will the fifth pair, soon to be launched. Earth-orienting the satellites has made it possible to expand the original space surveillance capability to include atmospheric test detection. Sophisticated optical and electromagnetic pulse detection techniques are now included. The fifth pair of satellites will contain major advances in most areas of instrumentation, in keeping with the goals of this program.

The new scientific data collected by the VELA satellites in the course of performing their test-ban monitoring functions have been of great importance to the scientific community in interpreting solar-terrestrial relationships. Since July 1964, when the second satellite pair was launched, the VELA satellites have provided what is probably the most detailed information available on the solar wind characteristics and the state of Earth's bow shock, magnetosheath, and magnetospheric tail.

DEPARTMENT OF STATE

CHAPTER VI

Introduction

The Department of State in 1968 continued its efforts to foster international cooperation in the peaceful uses of outer space and foreign support for various aspects of the U.S. national space program. It played an active role in responding to inquiries from abroad (particularly from Western Europe, where future plans for participation in space programs were under review) about U.S. policies affecting cooperation or assistance. The Department also maintained close consultation with other U.S. agencies concerning further possibilities for future cooperative undertakings in space science and applications with other countries, such as the surveying of Earth resources from satellites.

Among the principal international developments during 1968, noted below, were the entry into force of the Astronaut Rescue and Return Agreement, convening of a United Nations Conference on Outer Space, and further growth of the INTELSAT global commercial communications satellite system.

Astronaut Agreement—The Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched Into Outer Space, was signed by the Secretary of State at a ceremony held on April 22, 1968, in Washington. Signing ceremonies were held on the same date in London and Moscow, the other depositary capitals. More than 75 nations have signed. The Senate advised and consented to U.S. ratification by a vote of 66–0 on October 8, 1968. On December 3, the President announced that the Agreement had gone into force.

Activities Within the United Nations—The United Nations sponsored a Conference on the Exploration and Peaceful Uses of Outer Space, which was held in Vienna August 14–27. The purpose of the conference was to identify and describe, primarily for the benefit of developing countries, the practical applications of space technology. Seventy-eight countries and 13 specialized agencies and international organizations participated in the conference. American scientists, government officials and industry representatives delivered 49 scientific papers and evening lectures, about one-fourth of the total number of papers presented.

At its 1968 session in Geneva, the United Nations Outer Space Committee's Legal Subcommittee continued negotiations of a convention on liability for damage done by objects launched into outer space. Several issues proved insurmountable obstacles to completion of the draft at the Legal Subcommittee session, making it unlikely that the United Nations would meet the deadline it had set for itself, the 23d General Assembly. The Legal Subcommittee held another brief discussion of the question of defining "outer space" and questions relating to various uses of outer space, notably direct broadcast satellites.

When the parent U.N. Outer Space Committee met in October, it again discussed direct broadcast satellites and decided to establish a Working Group to study first the technical aspects and then the political, legal, and other implications of the subject.

Earth Resources Survey Program—An agreement was concluded in September with the Government of Brazil, confirming arrangement between NASA and the Brazilian space commission for a cooperative research program in remote sensing for Earth resources surveys. A principal purpose of the program is to develop techniques and systems for acquiring, interpreting and utilizing Earth resources data from aircraft. The Department of Agriculture, the Geological Survey and the Navy Oceanographic Office are participating with NASA in carrying out U.S. responsibilities under the agreement.

An agreement for a similar program with Mexico was concluded in December.

Tracking Networks—The facilities abroad that are part of NASA's global tracking network were maintained during 1968 under bilateral agreements previously concluded with the countries concerned. These facilities consist of stations supporting the manned space flight program, a tracking and telemetry network for scientific satellites, and deep-space antennae at four locations around the world. Also, an agreement with the United Kingdom concerning the establishment of a tracking facility on the Island of Grand Bahama entered into force in May. An extension of the agreement with the Malagasy Republic was effected by an exchange of notes in December 1967.

In September, an agreement was concluded with Mauritius which permits deployment to that island of aircraft specially equipped to conduct airborne monitoring of certain aspects of APOLLO missions.

The ESRO (European Space Research Organization) satellite telemetry and command station—established near Fairbanks, Alaska, under the terms of an agreement concluded in November, 1966—became operational in 1968.

An agreement was concluded with Japan in September providing for the establishment and operation in Okinawa of a Japanese satellite tracking station.

Contingency Recovery of Astronauts—As in the case of each of the manned GEMINI flights, the Department of State and its overseas posts maintained a state of alert throughout the APOLLO 7 and 8 flights, to support NASA and DOD in case of an emergency recovery requiring such support. A Task Force was organized so as to enable the Department, in the event of an unintended landing or other emergency, to call immediately upon the appropriate posts abroad to arrange through the respective host governments for such assistance as might be indicated by the nature of the emergency. Similar arrangements will be made for all manned APOLLO flights.

Before each manned space flight mission, the Department through our embassies abroad also facilitates the positioning of Air Force Search and Rescue and other support units at appropriate locations around the globe.

Cooperation With Department of Defense—The Department of State continued to work closely with the Department of Defense during 1968 on international aspects of space-related programs of particular interest to DOD, such as the Initial Defense Communications Satellite Program (IDCSP).

Communications Via Satellites—Membership in the International Telecommunications Satellite Consortium (INTELSAT), the global commercial communications satellite system, grew to 63 during the year with the addition of three new countries. Several others are expected to join in the coming months. The nations now represented in INTELSAT account for a major portion of the world's total international telecommunications traffic.

INTELSAT's global capabilities were enhanced in 1968 by an increase in the number of ground stations in the various member countries from 15 to 22. Many others are under construction. There are 14 stations in the Atlantic area and 8 in the Pacific region. This total is growing steadily and should reach 45 to 50 by 1970.

The first of a third generation of higher-capacity communications satellites was successfully launched in December. Other launches will follow as soon as possible, since additional capacity is urgently required.

A still more advanced generation of satellites, the fourth, was authorized by INTELSAT's governing body in October. The first of these space vehicles is scheduled for launch in 1971.

During 1968, the Government, together with the Communications Satellite Corporation (the U.S. entity in INTELSAT), continued preparations for a 1969 international conference which is to develop permanent arrangements for INTELSAT. The original 1964 agreements establishing interim arrangements for INTELSAT call for convening a conference in 1969 to formulate definitive arrangements.

CHAPTER VII

Introduction

This year as in the past, the contributions made by the National Science Foundation to the Nation's space effort consisted for the most part of support given to basic research projects at colleges and universities, to national programs, and to national research centers throughout the country. Facilities such as radio telescopes and scientific balloons are also provided by NSF for scientific research related to outer space.

National Radio Astronomy Observatory (West Virginia)—The facilities of the National Radio Astronomy Observatory, at Green Bank, W. Va., were used by 141 visitors from 46 different institutions during the year. Spectral-line work continued to be a very active area of research; in fact, a previously undiscovered line at 6.3-centimeter wavelength was detected by visitors using the 140-ft.-diameter radio telescope. The new line arises from an energy level transition in an excited state of the OH molecule.

In collaboration with other observatories in this country and abroad, very long base-line interferometry experiments have been conducted. Experiments using the 140-ft. radio telescope and a smaller telescope in Sweden have measured components of an intense radio source and have found them to be as small as 0.002 seconds of arc in diameter.

Visitors using the 300-ft.-diameter transit telescope discovered a new pulsar source, and there is a possible identification of two others. The pulsars are the newly discovered radio sources which pulsate in intensity with periods from a fraction of a second up to two seconds, depending on the source observed. They pulsate at an extremely uniform rate.

The three-element interferometer at Green Bank was in much demand by vistors, and a visitor program was commenced with the 36-ft. millimeter wave antenna at Kitt Peak.

E. O. Hulbert Center for Space Research at the Naval Research Laboratory, Washington, D.C.—NSF supported several university staff members, who proposed astronomical research programs using rockets and satellites, to work with the staff and facilities of the Center. In addition, it supported theoretical interpretation and analysis of data.

The Kitt Peak National Observatory (Arizona)—The following reflecting telescopes continued in full operation for research in astronomy by visitors and staff members: two 16-inch photometric telescopes, two 36-inch photometric and spectroscopic instruments, a 50-inch remotely controlled telescope which is programmed for photometric work, and an 84-inch general-purpose reflector; also, a long-focus solar telescope of 63-inch aperture, the world's largest. In addition, a program of rocket astronomy is conducted for staff and visitors. Work was started during the year on a new 150-inch reflecting telescope as a major addition to the observatory equipment. The telescope is scheduled for completion in 1972.

Cerro Tololo Inter-American Observatory (Chile)—Five telescopes were in operation during the year for visitor and staff observing programs: two 16-inch telescopes used mainly for photometric work, 36-inch and 60-inch telescopes which had both photometric and spectroscopic capability, also a 24-inch Schmidt-type wide-angle camera on long-term loan from the University of Michigan. Contracts were let for the optics and mounting and also the dome structure for the 150-inch reflecting telescope which is being built under joint support of the NSF and the Ford Foundation. Completion of this Southern Hemisphere telescope is expected in 1973. Significant savings in cost have resulted because of the simultaneous construction of the two 150-inch telescopes for Kitt Peak and Cerro Tololo.

National Center for Atmospheric Research (Colorado)—Several studies of the Sun and interplanetary medium received continued attention during Fiscal Year 1968 at the High-Altitude Observatory of NCAR. These analyses are devoted towards an increased understanding of the solar photosphere, solar chromosphere, solar corona, and solar activity as well as of the solar wind and its interaction with the Earth's magnetosphere. Among the advances of the year were:

1. The successful observation of the brightness of the Sun in the far-infrared (wavelength 50–300μ). These measures allow the temperature at the coolest part of the solar atmosphere to be established and have a direct bearing on our further understanding of the structure of the solar atmosphere.
2. The successful operation of a dense-plasma focus machine to produce temperatures of up to 300 million degrees absolute. This machine places at the disposal of our research staff plasma of a temperature equal to or in excess of those found in the most excited regions of the solar corona.
3. A successful theoretical model of the flow of the solar wind through the magnetic fields penetrating the solar corona. The model is able to reproduce many of the characteristics of the structure of the solar coronal streamers, which have been observed at eclipses for centuries.

Solar-Terrestrial Program—The primary objective of the Solar-Terrestrial Program is the study of the interaction between solar behavior and terrestrial phenomena. The Program supports over 70 research programs in this aspect of space-related sciences. The following research received emphasis during FY 1968:

1. The generation and characteristics of solar flares and their effects on terrestrial magnetic storms and anomalous radio communications;
2. The structure of the interplanetary medium as revealed by the modulation of cosmic rays received at the ground;
3. The development of models for Earth's magnetosphere, radiation belts and plasma flow from theoretical studies based on surface and satellite measurements;
4. The coupling mechanisms between the magnetosphere and the atmosphere. Most investigations of the aurora contributed to the study. For instance, the Foundation supported observations of auroral X-rays and luminosity at the foot of the magnetic field line on which the geosynchronous satellite ATS–1 is located.

Engineering—The Engineering Division supports a number of research programs related to aeronautics and space activities. An example of some engineering research is the work being carried on at the University of California. With the assistance of NSF research grants, a group at the University of California, Berkeley, has developed a rarefied gas facility of extraordinary flexibility and capacity. This facility was planned with several objectives in view. It is designed to extend the range of current rarefied gas dynamics investigations to lower-density ranges while preserving previous mass flow capability at test-section pressures of 70 to 80 microns. New investigations will be implemented in areas of nearly-free-molecule flows, dilute plasmas, and collision processes. Additionally, it is designed to provide a suitable environment for free molecule testing and for the study of molecule interactions at the surface of the gas phase. Numerous studies are under way on supersonic flow, turbulence, flow of ionized gases and wave dynamics.

Another study on low-density flows is under way at Princeton University. A unique new testing facility was designed, built and put into operation with an NSF Engineering Division grant. This facility for low-density, hypersonic, gas dynamic research uses a graphite heater and nitrogen as a test gas. Using a liquid nitrogen-cooled conical nozzle and a test section 12 inches in diameter, Mach numbers of 15 to 22 can be developed with uniform test cores 1 to 4 inches in diameter and 6 to 10 inches long. Satisfactory operation has been obtained for stagnation pressures from 30 to 350 psi at stagnation temperatures from 1,500 to 2,300° K. Studies have been made on flows around flat plates and cones with leading-edge dimensions of less than 0.001 inches. Detailed pressure distributions and flow-field studies were measured, using special probes developed during the studies.

U.S. Antarctic Research Program—The U.S. space effort has several ties with Antarctica. Data on the ionosphere and magnetosphere which are obtainable only in the high latitudes, owing to the configuration of the Earth's magnetic field, are obtained through use of a 21-mile-long antenna, satellite readout stations, and cosmic ray monitors. Satellites are also monitored for the space programs of several agencies and countries to help determine the shape of the geoid, refine orbital paths, acquire gravity data, and establish geodetic ties.

Antarctic environmental factors provide useful parallels to those hypothesized for extraterrestrial bodies. NASA, with the cooperation of Foundation grantees performing research in the ice-free areas, tests hardware and techniques being developed for space exploration, such as life-detecting samplers and lunar drills. Logistical aspects of the conduct of a research program in a remote and hostile environment have led to a close study of the U.S. programs in Antarctica by several NASA groups.

DEPARTMENT OF COMMERCE

CHAPTER VIII

Introduction

The Department of Commerce has four major organizational units engaged in activities that contribute to the National Space Program. Three science and technology bureaus contribute directly: the Environmental Science Services Administration, the National Bureau of Standards, and the Office of State Technical Services. The fourth bureau, the U.S. Patent Office, contributes indirectly through the issuance of patents on inventions with space applications.

Environmental Science Services Administration

The Environmental Science Services Administration fulfills the Department's responsibility to describe, understand, and predict the state of the atmosphere, the oceans and the space environment, and the size and shape of the Earth. ESSA has five major subunits which contribute either directly or indirectly to space technology: the National Environmental Satellite Center, the Weather Bureau, the Coast and Geodetic Survey, the ESSA Research Laboratories, and the Environmental Data Service.

Highlights of 1968—Two Environmental Survey Satellites—ESSA 7 and 8—were launched during 1968 to maintain the operational weather satellite system established in February 1966. April 1 marked the eighth anniversary of the launch of TIROS I, the first weather satellite to send back useable cloud pictures. The one-millionth satellite picture was received on May 27, 1968.

With the cooperation of NASA experimenters, ESSA used the ATS–III satellite to obtain closely timed pictures of both tornadoes and hurricanes. Films made from these pictures, taken every 15 minutes during periods of maximum lighting, were used to study details of the development and life cycles of these storms. Equipment has been designed to permit timely acquisition of these pictures for operational use.

The satellite-interrogated ocean buoy program was advanced by the successful test of a prototype moored in 14,500 feet of water at 35° N. 48° W. in the North Atlantic. After remaining on station successfully for 4 months, the mast broke during an unusually severe storm and the buoy was recovered. The test demonstrated the stability of the buoy and the durability of the mooring, which remained intact.

A special facsimile transmission was added to an established U.S. network to relay Automatic Picture Transmission photographs from receiving stations to 23 Weather Bureau and 28 military stations on the network. This relay of APT photos has greatly increased dissemination and operational use of satellite data.

The Weather Facsimile Experiment transmission of satellite and standard meteorological data from the United States to APT stations in Europe, Africa, and South America via the ATS III satellite started experimentally in July, and by October had become semi-operational. WEFAX transmissions to the Pacific via ATS–I continued during 1968. Response from recipients is enthusiastic.

Meteorological Satellites—The National Operational Meteorological Satellite System (NOMSS) was likewise maintained during 1968 by the launch of ESSA 7 and 8. These satellites furnished worldwide pictorial coverage of the Earth and its cloud systems daily, except in areas of polar night.

The ESSA series of satellites partially fulfills one of the main objectives of the NOMSS—daily observation of global weather conditions—but does not permit nighttime observations of cloud systems or temperature patterns. TIROS–M, the operational prototype of the ITOS (Improved TIROS Operational Satellite) system satellites, will add a nighttime cloud surveillance and day-and-night temperature mapping capability by means of a scanning radiometer. This spacecraft also will combine the functions now performed separately by two ESSA satellites, with a consequent saving in costs because fewer launches will be required each year. The launch of the TIROS–M spacecraft, planned for the middle of Calendar Year 1969, will be followed by the launch of ITOS operational spacecraft starting late in 1969.

Operations of the ESSA Satellites—ESSA satellites orbit the Earth in about 114 minutes at average altitudes of 760 nautical miles.

One type of ESSA satellite is equipped with two Advanced Vidicon Camera System (AVCS) units, each of which is capable of maintaining global cloud-cover surveillance. One camera is used operationally; the second is held in reserve, thus materially increasing the useful lifetime of the satellites. The pictures from AVCS-equipped satellites are transmitted to ground stations in Alaska and Virginia, relayed to a central processing unit at Suitland, Md., processed, and made available to the United States and international meteorological community.

Equipment for the other type of ESSA satellite is also redundant; each of the two Automatic Picture Transmission (APT) cameras can take and immediately transmit pictures of the area beneath the satellite to simply equipped ground stations within a 2,000-mile range of the spacecraft. The APT pictures furnish local forecasters with a fresh (3½-minute-old) view of the cloud patterns over or adjacent to the local area; these are used widely by U.S. meteorological agencies. Meteorologists in many countries have become accustomed to using APT pictures for operational forecasting. Thus the APT-equipped satellites have become an integral part of the World Weather Watch, an international meteorological observation system now under development. Mosaics covering the United States and adjacent areas are prepared daily from APT pictures received at Suitland. Copies are distributed to local and national news services, and are used daily by many newspapers and television stations in the United States.

NIMBUS II—APT pictures from the NIMBUS II R. & D. satellite were used operationally until the system ceased functioning near the beginning of April 1968, more than 22 months after launch.

Applications Technology Satellites—APPLICATIONS TECHNOLOGY SATELLITES (ATS–I and ATS–III, launched respectively on Dec. 6, 1966, and Nov. 5, 1967, by NASA) have successfully demonstrated the potential of a geostationary satellite for environmental observation. Both satellites contain spin-scan cloud cameras which can take pictures approximately once every 20 minutes. ATS–I photographs the Pacific basin and ATS–III photographs the Atlantic. The ATS–III camera was designed for color photography, using three separate color channels. The system worked well for several months, but subsequent malfunction of the red channel has reduced ATS–III to essentially black-and-white photography. Details on the uses of these cameras and the transponders aboard these satellites are given elsewhere.

Computer-Processed Cloud Mosaics—Cloud photographs are processed routinely by computer for operational use; the pictures are digitized, rectified, and fit into global mosaics for routine transmission via facsimile to all U.S. Weather Stations. Some have been transmitted experimentally (and successfully) to APT stations in Europe, Asia, Australia, the Pacific Ocean area, and North and South America by means of transmitters on board the ATS satellites. Special mosaics of the tropics are sent to the National Hurricane and the Tropical Analysis Centers in Miami during the hurricane season. The mosaics are also printed in catalogues of cloud photography to make the information accessible to research scientists.

Operational Applications of Satellite data—Routine and reliable receipt of data from both types of ESSA spacecraft has resulted in widespread usage of satellite information in daily operations both in the United States and abroad. Data available are those centrally processed in the United States, and the pictures received locally from the satellites equipped with Automatic Picture Transmission cameras. APT photographs are used operationally for analyses, local and area forecasts, and for briefing pilots on weather conditions over long transocean routes.

Satellite photography is particularly useful for tracking weather systems across the vast areas of Earth where conventional observations are lacking. The most spectacular use is in the discovery and tracking of tropical storms, typhoons, and hurricanes wherever they may occur. During 1968, 33 of these storms had been seen by the satellites, and advisories had been sent to foreign countries and U.S. installations worldwide. A method devised for estimating maximum winds in these tropical storms from characteristics seen in the satelitte pictures has been used successfully for several years. Tracking of storms in middle and high altitudes has resulted in improved advisory service to coastal areas and to shipping on the high seas.

Winds in the 30,000–40,000-foot levels as estimated from ESSA photographs are used routinely in computer analyses, and are transmitted daily to users worldwide. These experimental winds provide information over tropical and subtropical areas that are almost completely devoid of conventional upper-level wind information.

Research and development programs of the National Environmental Satellite Center—In 1968 work continued on a number of long-term projects, and was initiated on several new projects. The research included studies to increase basic understanding of atmospheric processes, the objectives of which are to improve weather analysis and forecasting; the development of new instrumentation for measuring environmental data from satellites; and the development of new methods and procedures for using satellite data in daily operations. Among the more than 50 investigations under way, the following are of particular interest:

a. A number of instruments are being designed to obtain measurements of the vertical structure of the atmosphere. The Satellite Infrared Spectrometer (SIRS), developed by NESC and funded by NASA, is to be tested on NIMBUS B2, scheduled for launch by the middle of 1969. The Infrared Temperature Profile Radiometer, an adaptation of SIRS, is under development for testing on NIMBUS E. This instrument has a spatial scanning capability to permit operation over partly cloudy skies.

b. Procedures for obtaining the extent and depth of snow fields from satellite pictures are being investigated. An operational guide for mapping the extent of snow cover was developed under an NESC contract in 1968. Large-scale mapping of snow cover and sea ice by means of satellite pictures is being done experimentally.

c. Procedures developed for making time-lapse motion picture film from ATS–I and ATS–III photographs have enabled research meteorologists to study details of tornado and hurricane development. The ATS pictures, available at either 15-, 24- or 30-minute intervals, provide views of these storm systems heretofore unavailable. A major research effort is being directed toward devising more efficient and timely methods for the extraction of multilevel wind information from the ATS spin-scan cloud camera pictures and films.

d. Digitized daily records of cloud data are being used to supply various products such as average 5-day, monthly, and seasonal cloud charts, and brightness charts. Films of the daily digitized charts show broad-scale motions in both the tropics and mid-latitudes, and show climatic regimes in a graphic fashion. These charts and films are proving useful for heat-balance studies, radiation studies, ice mapping, and long-period variations in large-scale weather features; they also show promise of being useful for developing improved global cloud climatologies.

e. Plans are under way for intensive investigations of the ocean surface, the interactions between the sea and the atmosphere, and the temperature structure of the ocean by means of satellite sensors. The state of sea surface is being estimated by analysis of reflection of the Sun seen in satellite pictures; analyses such as these will yield estimates of surface wind speeds in remote areas. Temperature fields and ocean currents will be mapped and the information used in meteorological and oceanographic investigations.

International Cooperation—The continued worldwide availability of Automatic Picture Transmission (APT) pictures and the experimental semi-operational transmission of satellite data through the Weather Facsimile Experiment (WEFAX) on the ATS satellites has helped to maintain the image of the United States as an unstinting sharer of scientific results in space programs. At the end of 1968, 52 foreign countries reported 108 APT stations in operation. Application of satellite products was discussed and demonstrated daily by United States participants at the International Conference on the Peaceful Uses of Space in Vienna. Current and planned satellite products were also discussed at the International Cloud Physics Conference in Toronto and at the International Union of Geodesy and Geophysics—World Meteorological Organization (IUGG–WMO) meetings in Bergen, Norway, during August 1968. U.S. participants furnished major contributions to the WMO satellite meteorology workshop held in Melbourne, Australia, during November and December 1968. The National Environmental Satellite Center provided training and study facilities for WMO, NATO, and AID fellows from China, Greece, Hungary, India, Indonesia, the Philippines, Switzerland, and Thailand, and briefings for many other foreign scientists during 1968.

Washington-Moscow Data Exchange—Pursuant to the 1962 bilateral agreement between the United States and the U.S.S.R., exchange of satellite data continued over the Washington-Moscow data link during 1968. The U.S.S.R. furnished data from their COSMOS 184, launched in 1967, and COSMOS 206 and 226, launched in 1968. The United States furnished satellite photographs and nephanalyses (cloud maps) based on ESSA 3, 5, and 7 data; these products are used in daily analysis operations at the World Weather Center, Moscow. Traffic from Moscow includes satellite photographs, nephanalyses, and radiation analyses.

ESSA Research Laboratories

The ESSA Research Laboratories, with main offices in Boulder, Colo., and a number of Laboratories in field stations elsewhere, conduct research and provide services in support of the broad ESSA mission requirements. Activities include a number of scientic disciplines: oceanography, Earth sciences, geomagnetism, tropospheric and ionospheric and magnetospheric physics. Programs include tropospheric radio and optical wave propagation, ionospheric radio propagation, monitoring and forecasting solar activity and its effects in Earth's vicinity, and research on solar radiation interactions with the magnetosphere.

The ERL Space Disturbance Laboratory monitors and predicts fluctuations and disturbances in Earth's space environment associated with solar activity. Research activities support these services and increase understanding of the manner in which solar particles affect Earth's environment.

A facility at Anchorage, Alaska, is now operational as part of the Space Disturbance Forecasting Center. This facility is a center for a net of stations used to detect the precipitation of solar protons into the high atmosphere in the Arctic region.

Solar X-ray data are obtained on a timely basis from the SOLAR RADIATION SATELLITE, SOLRAD 9, for use in making disturbance forecasts. Data are obtained with the cooperation of the Naval Research Laboratories.

In cooperation with Canadian scientists, SKUA rockets intrumented to monitor radiation in the 1.27×10^{-3} millimeter wave length range, are used to obtain measurements of the diurnal variations and height profiles of molecular oxygen in the excited state. Several successful flights have been made from Fort Churchill, Canada, and data obtained are being analyzed. These results are important in understanding the electron balance of the lower ionosphere.

Auroral zone absorption events observed from the Earth's surface are compared with energetic particle observations obtained by NASA satellites while passing through the tail of the Earth's magnetosphere at about 17 Earth radii. These comparisons indicate that the particle source producing the absorption is relatively close to the Earth.

A preliminary study has established the feasibility of providing forecasts of solar activity for the APOLLO Applications Program-Astronomical Telescope Mount (AAP-ATM) program. The aims of this program are to supply to the ATM astronauts forecasts of the probabilities of occurrence and probable location of solar flares so that high-resolution instruments can be activated and properly oriented to obtain measurements. The Space Disturbance Forecasting Center will also collect and disseminate solar data for use during postflight analyses of data obtained in the ATM program.

The ERL Aeronomy Laboratory conducts research on the ionosphere and the magnetosphere. The Laboratory operates, in cooperation with Peruvian scientists, a facility using radio techniques based on the scattering of radio waves by electrons to obtain measurements of the high ionospheric region. Recently, the technique has been used to measure electric fields in the high ionosphere, measurements previously obtained at great expense and for short time periods only, by rockets. The current method is based on monitoring the vertical electron drift in the ionosphere and makes possible continuous studies from a ground facility. This station also makes measurements of ionospheric parameters, such as electron and neutral temperatures. In some cases, comparisons between these measurements and those obtained by satellites show significant discrepancies. Since other evidence indicates that the scatter results obtained from the ground are accurate, the uncertainties may be associated with the satellite measurements.

Ultraviolet data from the NRL SOLRAD satellites are monitored during periods of atmospheric occultation and analyzed to obtain oxygen density in the vicinity of 62 miles. The results show that summer densities are about 1.5 larger than winter densities.

Theoretical studies were undertaken which successfully explain the ionospheric resonances observed by satellite radio sounders. This theoretical development, which involves echoes from the plasma in the near field of the antenna, explains certain aspects of these resonances, which have been difficult to explain by previous theory.

Part of the Aeronomy Laboratory rocket program is conducted in cooperation with the rocket program of the Space Disturbances Laboratory. The rockets are instrumented to obtain the electron density in the ionosphere by means of radio signals transmitted from the rocket using Faraday rotation techniques.

A method for obtaining atomic oxygen measurements by using thin films of silver has been developed for use on rockets. These thin films, exposed to the atmosphere during the rocket's flight, produce silver oxide, thereby changing the electrical resistance. The data thus obtained yield atomic oxygen profiles.

Data obtained from the ALOUETTE I and II topside sounders and the earlier EXPLORER XX are analyzed to determine the effects of magnetic storms on ionospheric electron density. A new method developed this year provides electron density and temperature profiles from topside sounder data more precisely than in the past.

Further theoretical developments on the effects of electric charge on satellite probes have increased accuracies of data from these probes. This theory takes into account effects such as secondary emission produced by photons and the contamination in the emission from energetic particles.

Magnetic storms and subvisual optical emissions, known as red arcs, are studied by comparing simultaneous data from several satellite electron-density measurements with ground-based optical experiments. These analyses show that the electron density within the arc is less than that outside the arc. These studies are expected to lead to an explanation of the red arc and other ionospheric effects.

The Tropospheric Telecommunications Laboratory conducts studies to develop and improve communications by means of satellites. The operational use of satellites for air traffic control is under consideration to help alleviate overcrowding of radio frequency bands currently in use. One objective is to define interference protection ratios required to maintain adequate intelligibility over communications circuits. Air traffic control transmissions are simulated, using conventional circuits under varying conditions. Both subjective and objective evaluations of the transmissions are made.

Communications and telemetry with satellites sometimes suffer interference by scatter of signals from other communications links which are precipitated into the satellite acquisition systems. A program to analyze this problem has been undertaken; computations have been made of precipitation scatter, relating levels of received power to probability of occurrence.

Electromagnetic wave devices used for tracking objects in space and for measuring geodetic distances and angles have accuracies which are limited by the time-space variation of radio or optical refraction. Measurements of refraction effects taken in Colorado and in Hawaii are being used to study the correlation of range and angular position errors with refractive-index data obtained from a variety of sensing elements. These studies will improve accuracy in geodetic measurements and missile tracking.

Another approach to this problem is being studied by the Wave Propagation Laboratory. This laboratory has used radiometers to measure the emissivities of atmospheric water in its various forms at several frequencies in the millimeter wave region. The measurements were made together with periodic meteorological observations and observations by the Tropospheric Telecommunications Laboratories of radio phase path.

Since the accuracy of radar tracking of missiles, satellites, and other objects is limited by these effects, comparative analysis of the various observations may yield a new method, employing radiometry, to improve tracking accuracy. The data will also be analyzed to establish the effects of atmospheric water on satellite remote sensing in the millimeter wave region.

Satellite photographs are used by the Atlantic Oceanographic Laboratories in the study of low-level convective cloud patterns in the eastern Caribbean and western tropical Atlantic Ocean. These patterns will be related to observations of temperature, pressure, wind and other meteorological parameters obtained during the Barbados experiments. Ocean thermal data obtained by the ESSA research vessels in the vicinity of the Gulf Stream will be correlated with high-resolution infrared radiation data from NIMBUS II.

The Air Resources Laboratory has established microphone networks for measurements of sonic booms from supersonic aircraft. These measurements will be correlated with meteorological data and with aircraft flight configurations.

Coast And Geodetic Survey Operations

The Coast and Geodetic Survey uses satellites operationally in geodesy and precise navigation; is engaged in studies to determine the feasibility of using satellite techniques in performing its assigned tasks; and supports space facilities and activities indirectly through its seismic and geomagnetic activities.

Geometric Satellite Triangulation—The Coast and Geodetic Survey's Geodetic Research Laboratory devoted most of its 1968 activity to support the worldwide Geometric Satellite Triangulation Program being conducted under a cooperative agreement between the Department of Commerce and the Department of Defense. The Laboratory provided technical and scientific support in the areas of data acquisition, laboratory measurements of field records, data reduction procedures and data analysis.

Preliminary results obtained at 25 stations of the worldwide network and from about 350 events indicate that the eventual goal of an accuracy of about ±20 feet in latitude and longitude and 33 feet in height at each station is feasible.

Satellite triangulation computer programs have been revised to provide improved statistical analysis, to eliminate inconsistencies in the raw data, to incorporate range data and to handle fully correlated observations.

The BC-4 camera data, totalling about 150,000 individual directions, have been sent to the NASA Geodetic Data Library. Aggregated reduced directions have been provided to the Smithsonian Astrophysical Observatory.

A series of studies on the need for additional scale measurements in the worldwide network resulted in the conclusion that five such measurements are desirable.

The long-range and high-precision short-range orbit-prediction computer programs for balloon satellites were improved and refined by introducing a flexible gravitational model into the former and a theoretical model to account for solar radiation pressure into the latter. Resonance theory was applied to PAGEOS geodetic satellite orbit to extract numerical values for resonant gravitational harmonics.

A project is under way for determining the high-frequency variations of Earth's gravitational field by applying a surface density layer instead of spherical harmonics. This will bypass the problem of convergence in the latter mathematical representation.

The Satellite Triangulation Division continued data acquisition providing technical supervision for 15 geodetic camera units throughout the world. Eight systems are operated by the Coast and Geodetic Survey, four by the Army Map Service, and one, owned by West Germany, is operated jointly with the Coast and Geodetic Survey. The Survey also operates one system with the United Kingdom and another with South Africa. Thirty-four of the 43 proposed stations have been or are presently occupied.

Time Transfer Tests—The Satellite Triangulation Division together with the National Bureau of Standards and NASA continued tests on transferring time via NASA's APPLICATIONS TECHNOLOGY SATELLITES, ATS I and III, to isolated stations in various parts of the world. Accuracies of ±2 microseconds are now being achieved. This method is now used to transfer time to Tristan da Cunha, South Georgia, and Villa Dolores, Argentina.

A Time Recovery Receiver has been developed to check and establish precise time on five isolated Antarctic stations. Since the range of ATS satellites is not sufficient to reach the Antarctic, U.S. Navy TRANSIT satellites must be used. The result is an accuracy of 50 microseconds.

Earth Resources Program—In connection with NASA's Geodetic-Cartographic sub-program, studies continued on the application of space technology to the Earth Resources Program. Emphasis was placed on the definition of and the specifications for a photogrametric space system for the establishment of geodetic control and determination of the geometric shape of Earth's ocean surfaces. The photogrammetric system consists of two wide-angle mapping cameras, two panoramic cameras, two stellar cameras and a laser or radar altimeter, all in a single rigid package or mount. The C. & G.S. contracted with NASA to be responsible for aircraft flight tests of a camera-laser package for the evaluation of a NASA-developed laser altimeter which is nearing completion.

Activities in Support of the Tsunami Warning System—Continued efforts are being made to improve the operation of the Coast and Geodetic Survey's Tsunami Warning System through faster communications and data telemetry. An experiment is planned for 1969 in which sea-level data will be transmitted via the NASA ATS–III satellite from an underwater platform near Andros Island, in the Bahamas, to NASA's Goddard Space Flight Center.

Seismological Activities—The Coast and Geodetic Survey's Seismology Division has done a series of seismic measurements from propellant explosions to assess potential damage from rockets during launch operations. A report on the results of monitoring 12 intentional explosions of rocket propellants has been submitted to NASA's Advanced Studies Office at the Kennedy Space Center.

The conclusions of this study are:

1. For rocket detonations, the TNT equivalence determined by seismic techniques in the far field (beyond 1,000 feet) area ranged from a low 0.2% for 25,000 pounds of a mixture of liquid oxygen and liquid hydrogen confined by missile failure, to 22% for a solid-propellant explosion with a charge equivalent to 7,000 pounds of TNT.

2. The variation of propellant type, mode of failure, or propellant weight did not produce a statistically significant TNT equivalence for the tests monitored.

3. There were sufficient data to establish a statistical rate of decay of the acoustic signal through the distance range of 2,000 to 10,000 feet.

While there was sufficient evidence to indicate a TNT equivalence of liquid propellants approaching 10%, it was pointed out that there is no assurance that the conditions for maximum efficiency of the propellant explosion were actually met. Therefore, it may be possible to have a rocket detonation with an efficiency greater than 10%.

Among the recommendations included in this report was a call for continuance of the seismic monitoring program in the areas of potential damage during the launch of larger missiles.

Geomagnetism—ESSA's Fredericksburg Geomagnetic Center continued to make calibration and test facilities and services available to NASA as a contribution toward the development of space instrumentation. A 19th century Swiss-made theodolite, having a large, calibrated circle of very high quality, was renovated and modified by the Center for use in accurately aligning space sensors.

All magnetic survey data collected from world-wide sources were screened and evaluated by C. & G.S. These data were used in a continuing, cooperative effort to improve knowledge and understanding of the characteristics and behavior of Earth's magnetic field. These studies proceed through the development of accurate mathematical models of the magnetic field from surface levels to satellite altitudes.

C. & G.S. personnel assisted the World Magnetic Survey Board of the International Union of Geodesy and Geophysics in preparing for an international Symposium, to be held in Washington, on "Description of the Earth's Magnetic Field."

Weather Bureau Operations

The rapid gains made in 1967 by the Weather Bureau in participation in the space program have been consolidated during 1968. Experiments are continuing in data relay, with plans to include test collection of data from ships at sea. Implementation of specific programs for increased operational utilization of satellite data has been intensified, notably in tropical storm forecasting. The Bureau is also providing greater support to various satellite programs both directly and indirectly.

Experiment With ATS–1 Satellite—Experiments in data collection and relay of river stage and rainfall measurements are being continued by the Weather Bureau's Office of Hydrology using NASA's ATS–1 geostationary satellite. Operational experience accumulated from this experiment will furnish a basis for effective planning of future systems.

Experiment With ATS–3 Satellite—The Weather Bureau is providing support for the ATS WEFAX (Weather Facsimile) experiment by having JFK—New York, Miami, New Orleans, and San Juan receive the WEFAX transmissions and submit evaluations of these to National Environmental Satellite Center.

Snow Surveying—Under a contract effort, an "Operational Guide for Mapping Snow Cover from Satellite Photographs" has been developed for the plains areas of the United States. Work is now progressing on developing techniques for mapping snow cover in the mountain States of the West. TIROS and ESSA photographs of the snow cover in the western States are being used in experimental support of the Weather Bureau's River and Flood Forecasting Service.

Sensor Study—A sensor evaluation study is being made under contract to ascertain what satellite sensors hold the most promise of providing useful data in meeting problems confronting the Weather Bureau's hydrologic mission. Results of this study will be used as input to planning the applications of space-derived data to hydrology.

Digitized Cloud Mosaics—The operational program for facsimile transmission of digitalized mosaics has been expanded to provide information not only to the 50 States and Puerto Rico but also to the U.S. Air Force and Navy to fulfill their special requirements.

Automatic Picture Transmission (APT)—Early in 1968 the Weather Bureau began the transmission of raw APT signals interspersed with conventional meteorological charts on a central facsimile network. The APT data are acquired by NESC at Wallops Island, Va., the Weather Bureau at San Francisco, and the Air Force at Kunia, Hawaii, and are relayed through Honolulu to San Francisco by cable.

Meteorological Support—The Space Operations Support Division of the Weather Bureau continued to furnish meteorological services to NASA in support of the manned spaceflight program, including the forecasting of weather and sea conditions for the APOLLO 7 and APOLLO 8 flights. This division furnishes a continuous weather observing and forecasting service in support of activity at Cape Kennedy, supplies specialized forecasts and meteorological support for test and development activities at NASA's Manned Spacecraft Center and Mississippi Test Facility, and develops special studies on weather and climate conditions affecting both space and aeronautical activities of NASA.

The Environmental Data Service

The Environmental Data Service, a major sub-unit of ESSA, archives satellite data after they have been used operationally. Both raw and processed data are placed in the archives of the National Weather Records Center (NWRC), which provides retrieval services for research scientists. Since satellite data are used most frequently in conjunction with other meteorological data, NWRC serves as a convenient one-stop outlet for the users. Government and private-sector scientists, universities, and industry can purchase, at cost, copies of the data in film, picture, or magnetic tape form. Data catalogs are published to provide customers a means to identify the particular items desired. Over 2,800 reels of data were furnished to users in 1968.

National Bureau Of Standards

The National Bureau of Standards, through the development and improvement of a system of precise and consistent measurement, provides technological support for a number of national programs including those in space and aeronautics.

The NBS activities pertinent to these efforts fall into three broad categories:

Basic Measurement and Standards—Work in this area is centered on the development of a complete and consistent system of physical measurements. Special emphasis is placed on those required by the advanced technologies used in aeronautics and space activities, since in these areas far greater accuracies than those needed for general use are often mandatory. In addition, the often unique character of these new technologies makes demands on the measurement system necessitating research and development in heretofore unexplored areas of basic science and technology.

Materials Measurement and Standards—An entirely new series of demands has been created for new and improved materials capable of performing efficiently in space. Highly pure and well-characterized materials are needed. Standard Reference Materials developed at NBS under this activity provide a unifying base for the measurement technology needed for creating, manufacturing and distributing a wide variety of products vital to the space effort. Analysis, particularly failure analysis, of materials that have been exposed to the aerospace environments is also part of this activity.

Technological Measurement and Standards—Concerns of this area are technological or "engineering" measurement and standards which deal with products, commodities, devices, processes and systems. Principles of good measurement, rather well defined in the science area, are applied to the determination of the performance of working systems. As the complexity and technical sophistication of systems increase, particularly in the U.S. space program, it is increasingly important and difficult to define and measure those characteristics of a system which best describe its performance. Major efforts are being made to meet these needs.

Items of particular interest in each of these three major areas are listed below.

1. Basic standards:
   a. Clock synchronization via satellite and Moonbounce radar.
   b. Communications "blackout" during re-entry.
   c. Destructive vibrations in space vehicles.
   d. Fatigue cracks in airframe fasteners.
   e. Radiation detectors in space vehicles.
   f. Laser power and energy.
   g. Lens deterioration in space.
   h. Field pattern of large radar antennas.
   i. Noise in communications devices.
   j. Missile-warhead detection.
2. Materials research:
   a. Liquid rocket fuel.
   b. NASA corrosion problem analysis.
   c. Thermodynamic properties of chemical compounds.
   d. Reaction heat measurements on light element fluorides.
   e. Thermal degradation of polymers.
   f. Physical chemistry of planetary atmospheres.
   g. Electron beam electrolysis.

3. Standard Reference Materials. Standard Reference Materials (SRM's) are well-characterized materials that can be used to calibrate a measurement system or to produce scientific data that can be readily referred to a common base. The SRM's discussed below are typical of the many samples produced at NBS, and sold at cost for use in a wide variety of space and aeronautical work.

- Two high-purity platinum SRM's and two gold SRM's were recently certified for composition. These standards calibrate instruments necessary to measure trace elements in such components as transistors and other solid-state devices used in space applications.
- A wide range of metallo-organic SRM's have been developed and made available for testing the wear of modern jet engines, and predicting failure rates. Metallo-organic standards are used in the air transportation industry to detect engine failures before they occur. Eight standards recently certified contain metals found in the analysis of engine oils.
- Three oxygen and air SRM's were recently certified. They calibrate gas measuring instruments for determining the concentration of oxygen in air, and have applications in measuring content in space capsule environments, aircraft cabins, and other enclosures related to space travel.

- The determination of the thickness of metals plated onto various substrates is important in both the aircraft and space industries. Four new gold-on-nickel thickness standards were issued to permit precise measurements for the thickness of metal coatings. Gold is often plated on electrical components to provide stability and resistance to oxidation and corrosion. In many space and aeronautical applications, metal and non-metal surfaces are plated with metals to enhance performance and durability.

Applied Technology

Techniques for Man-Computer Systems. The Bureau is assisting the NASA Electronics Research Center in the development of techniques for man-computer systems for future space programs. Emphasis is on graphically oriented time-sharing systems—the use of multiple display terminals with computer systems.

Tape Recording Systems for Space Vehicles. Magnetic tape recorders are one of the crucial links in relaying data from the space laboratory or observatory. Premature failure of these recorders is often traced to tape systems or their components. To avoid such failures NBS has designed and built equipment for performance tests of tapes. This equipment simulates in-service conditions and measures changes in electrical and surface characteristics of sample tapes.

Telemetering Transducer Evaluations. NBS carries out a project jointly supported by NASA and other agencies for developing methods of evaluating the performance of telemetering transducers. This contributes to the reliability of information received in the testing of vehicles.

Performance of High-Temperature Thermocouples. In the development of advanced propulsion systems for aircraft, the high-temperature conditions that exist in engines during testing are critically important. NBS is investigating the performance of high-temperature thermocouples used to improve the accuracy of measurements made during tests.

Methods of Measuring Semiconductor Materials, Process Control, and Devices. Semiconductor devices play a key role in all phases of the performance of vehicle, satellite and other systems developed by NASA. It is essential that the performance, interchangeability, and reliability of these devices be enhanced to the highest degree. NBS conducts a program with NASA, other agencies, and industry, for selecting, developing, evaluating and publicizing methods of measurement which permit improved process control.

Development of Space Radiation Detectors. NBS has continued its program for the fabrication and testing of solid-state nuclear radiation detectors used in space exploration. The detectors, not elsewhere available, are used to measure the exposure of satellites to high-energy radiation during flight.

Dissemination of Space Data. The NBS Clearinghouse for Federal Scientific and Technical Information is the Government focal point for public dissemination of R&D reports related to space sciences and technology. It distributes NASA publications and unclassified materials related to space or aeronautics produced by other Federal agencies.

Night-Flying Helicopters. Special electroluminescent lights, unaffected by the severe vibrational environment, have been developed to permit nighttime formation flying of military helicopters. Studies are now under way to determine the feasibility of extending the use of these lights to high-performance aircraft.

Maritime Administration

Maritime Mobile VHF Satellite Communications Test Program

In 1968, the Maritime Administration cooperated with the NASA APPLICATIONS TECHNOLOGY SATELLITE (ATS) Program office in a test of long-distance ship-to-shore communications via an ATS satellite. Communications terminals were the SS SANTA LUCIA and the NASA ATS ground stations at Rosman, North Carolina, and Mojave, California.

The objective was to investigate the feasibility of using a simple, low-cost, shipboard-transceiver communications unit for voice and various data rates. The tests investigated multipath fading, signal strength, and data error. Major emphasis was placed on securing information for leaders in the communications and maritime industries and the Government on the trade-off considerations and work necessary in implementing a service satellite communications relay system for maritime uses. Another objective was to assist in developing a U.S. position on maritime satellite communications for use in international discussions, and in meetings of the State Department with other nations of the International Marine Consultative Office of the United Nations and World Advisory Radio Conference.

The first test trip was from New York via the Panama Canal to Valparaiso, Chile, and return during February and March. The second trip over the same route was made in May and June. A public demonstration of satellite-relayed communications between Baltimore, Md., and the SS SANTA LUCIA as it was approaching Valparaiso was conducted on Maritime Day, May 22.

The test results were generally very good. Attempted resolutions of navigation line-of-position were not definitive and the results indicated that modifications are required in the testing methods. Public announcements of the tests have resulted in early scheduling of international meetings to further resolve radio treaty matters dealing with maritime communications via satellite.

Office Of State Technical Services

During 1968, the Department of Commerce's Office of State Technical Services (OSTS) continued to cooperate with NASA's Technology Utilization Division to make more effective non-Federal application of the advanced technology developed through Federally supported research and development. This cooperation was formalized through a working agreement established in August 1966. The program involves joint participation in national conferences on information dissemination and technology transfer, and a continuing joint review of program planning for the most effective application of information made available through the NASA Regional Dissemination Services and the Technical Reports by the State Technical Services Program. The OSTS makes a continuous effort to relate unique technical needs of local industry with NASA's advanced technology.

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
NATIONAL RESEARCH COUNCIL

CHAPTER IX

Introduction

The National Academy of Sciences is a private organization of scientists and engineers that serves upon request as an official advisor to the Federal Government. These advisory services are carried out largely by the National Research Council, which was established by the Academy to act as an operating agency.

Within the Research Council, guidance in matters relating to the national space program is provided primarily by the Space Science Board, but the counsel of other units is also made available where aeronautical or space activities relate to their fields of specialization. Among those called upon during 1968 were the Divisions of Behavioral Sciences, Biology and Agriculture, Earth Sciences, and Engineering; the Committees on Atmospheric Sciences and on the SST-Sonic Boom; and the Office of Scientific Personnel.

The National Academy of Engineering was established in December 1964. It is independent and autonomous in its organization and in the election of its members, and shares in the responsibility given the National Academy of Sciences under its Congressional Act of Incorporation to advise the Federal Government, upon request, in all areas of science and engineering. The aeronautics and space advisory activities of the National Academy of Engineering are carried out by the Aeronautics and Space Engineering Board.

Space Science Board

The Space Science Board is a consultative group which, in addition to its responsibilities to the Federal Government, furthers space research generally by encouraging discussion of scientific advances and research opportunities. Internationally, the Board represents the U.S. scientific community on the Committee on Space Research (COSPAR) of the International Council of Scientific Unions.

During the past year, the Space Science Board and its specialized committees and panels carried on a series of studies and programs directed toward providing guidance on the problems, opportunities, and implications of space research. The Board itself met four times during the period to discuss outstanding matters in space research with NASA management and senior staff of the National Science Foundation, National Aeronautics and Space Council, President's Science Advisory Committee, and other interested agencies. As is customary, sessions were scheduled to take into account critical times in budget planning and formulation; thus the Board's views have been available to program planners for consideration. Special attention was given to formulating programs and priorities for exploration of the planets by ground-based and space techniques and for study of the near-Earth environment, over the next decade or so. Other studies in progress or completed include the role of sounding rockets in scientific research; the requirements for a large space telescope for astronomical investigations; air and water standards, atmosphere regeneration, and waste management in manned space flight; and evaluation of possibly harmful side effects of proposed space experiments.

Special Studies on the Planets and the Near-Earth Environment—A study on planetary exploration was convened by the Board during June 1968 to recommend scientific priorities for investigations of the planets in the light of new information and current budgetary constraints. Twenty-two scientists representing all interested disciplines participated. The report of the study, *Planetary Exploration, 1968–1975* (July 1968), recommends that the planetary exploration program be presented in terms of the contributions it can make to a wide range of scientific disciplines, and that a substantially increased fraction of the total NASA budget be devoted to unmanned planetary exploration. It recommends that NASA initiate a program of small spacecraft to orbit Venus and Mars at every planetary opportunity and to make exploratory missions to other targets, notably Jupiter and Mercury. A series of missions to Mars stressing biological objectives, including an orbiter in 1971 and a Mariner-type orbiter and lander in 1973, is recommended. Other recommendations include continuing reassessment of sterilization requirements for Venus and Mars landers, and support of ground-based studies, in particular the funding of a major new planetary radar observatory.

Earlier studies on space research conducted by the Board have underlined the importance of ground-based planetary astronomy to complement and support planetary exploration with space vehicles. *Planetary Astronomy: An Appraisal of Ground-Based Opportunities* (NAS Pub. 1688, 1968) presents the results of a 2-year study by a panel of the Board. It evaluates the current state of knowledge in planetary astronomy; indicates fields of ground-based astronomy likely to be particularly productive in the future; assesses and compares investigative techniques now in use or under development; and makes specific recommendations on requirements for personnel, personnel training, and new or improved facilities.

A study on the physics of the near-Earth environment was held at Woods Hole, Mass., in August 1968 with the participation of some 45 scientists. The purpose of the study was similar to that of the planetary exploration study in June: to recommend programs and priorities for investigation of the Earth's neutral and ionized atmsophere, magnetosphere, and effects of and interactions with solar and cosmic radiations and magnetic fields. The study report, *Physics of the Earth in Space: A Program of Research, 1968–1975* (October 1968), defines a program of satellite, space-probe, and sounding-rocket missions for a concerted attack on specific questions related to fundamental physical mechanisms of the Sun-Earth system, in contrast with the exploratory surveys that characterized the past decade. The recommended program, which requires a level of support close to that of the past 6 years, places particular emphasis on coordinated investigations and on the development and utilization of new experimental techniques such as variable-orbit and clustered satellites. The importance of organizing a major observational effort during the period of low solar activity in 1974–1975 is also stressed.

Lunar Science Institute—The establishment of a Lunar Science Institute adjacent to the Manned Spacecraft Center, Houston, was announced by the President on March 1, 1968. It was further announced that the National Academy of Sciences had agreed to help establish the LSI and initially to operate the facility. The Institute will provide a university atmosphere for scientists wishing to have access to the unique facilities of the Lunar Receiving Laboratory, where lunar samples returned by the astronauts will be taken. Close working relationships will be developed between the MSC and the staff and guest workers at the LSI. A specialized library, lunar photographs, office and working space, and conference facilities are planned. LSI is conceived as a broadly based institution, providing an institutional base for scientists interested in lunar research to work with the MSC scientists.

Contamination and Interference Studies—In response to a request from NASA, the Board's Committee on Potential Contamination and Interference from Space Experiments evaluated selected space experiments in terms of their likelihood of producing adverse environmental effects or interfering with other experiments. The list of experiments was derived by NASA's Office of Space Science and Applications from an internal review of all its projects. The experiments fell in four general categories: electromagnetic radiation, energetic elementary particles, ion clouds, and contamination.

The Committee's report, "Evaluation of Possible Adverse Effects of Proposed Experiments," was issued July 1, 1968. No adverse effects are anticipated from the energetic particle or ALSEP experiments. The Committee expressed its concern that experiments in regions of the electromagnetic spectrum adjacent to bands reserved for radio astronomy be carefully controlled. The Committee was also concerned about the SNAP–19 nuclear isotopic system and other radioisotope thermonuclear generator packages and asked to be kept informed on a case-by-case basis of proposed experiments of this type. No evidence is seen that ion cloud experiments produce harmful effects, but the Committee suggests that the entire question of possible adverse effects of chemical releases needs further study.

In response to a request to the Board by the Advanced Research Projects Agency of the Department of Defense, the Committee is evaluating the proposed release of relatively large quantities of barium in the upper atmosphere, from the standpoint of atmospheric contamination or interference with other geophysical activities.

Symposium on BIOSATELLITE II Results—At the request of NASA the Board sponsored a symposium to report to the scientific community preliminary results of the thirteen experiments aboard BIOSATELLITE II. The symposium was held at the Academy, February 23–24, 1968; some 200 scientists attended. Papers presented are published in the June 1968 issue of *BioScience* and the chairman's summary appears in the July 1968 *Proceedings of the National Academy of Sciences.*

Physiology in the Space Environment—The potential effects on the cardiovascular system of stresses associated with long-term manned space flights have been studied by an ad hoc group of the Board's Life Sciences Committee. Their report, *Physiology in the Space Environment, 1: Circulation* (NAS Pub. 1485A, 1968) concludes that currently available biomedical information is not sufficient to meet operational requirements for development and execution of three-year manned space flights. Methods recommended to secure the necessary level of knowledge include a systematic program of ground-based and in-flight experimentation, improved instrumentation, and the utilization of biomedical systems analysis.

The Panel on Air Standards for Manned Space Flight has collected data on over 200 possible contaminants which, in its opinion, might constitute hazards on long-term manned missions and has recommended, where possible, long-term exposure limits. An industry-NASA-Academy review of the panel's report, "Atmospheric Contaminants in Spacecraft" (June 1968), was held to examine the effects of the standards on equipment design.

International Activities—The Eleventh Plenary of COSPAR was held in Tokyo, May 8–21, 1968. In conjunction with the meeting, there was a special session on stratospheric circulation, as well as three major symposia: Solar Flares, Biological Effects of Radiation in Space, and Small Rocket Instrumentation. As is customary, the Space Science Board, through its Committee on International Relations, organized United States participation in the COSPAR meeting. The Committee also reviewed U.S. contributed papers and prepared the annual report and 1,500-reference bibliography on U.S. space research during 1967: *United States Space Science Program: Report to COSPAR.*

Another international function carried out under the aegis of the Board is the World Data Center A subcenter for rockets and satellites. The subcenter collects and exchanges results of research conducted with spacecraft and sounding rockets; these data are made available to interested persons on request. Six-month catalogs of accessions are issued; announcements of satellite launchings and monthly reports of sounding rocket firings are distributed internationally. In accordance with the organizational patterns that have evolved for other subcenters of WDC–A—that they be located within the establishments conducting extensive research in the relevant disciplines—the Academy and NASA have discussed the feasibility of transferring WDC–A: R/S operations to the (NASA) Goddard Space Flight Center's Space Science Data Center. Broad policy matters would continue under the responsibility of the Academy's Data Center Coordination Office.

Committee On Atmospheric Sciences

The NAS Committee on Atmospheric Sciences examines the current status in the atmospheric sciences and undertakes reviews and studies in specialized or new areas for which particular needs or a potential for rapid progress are emerging. Scientific fields that have received special attention by the Committee are interaction between the oceans and the atmosphere, atmospheric ozone, experimental atmospheric measurement techniques, problems in small- and large-scale weather modification, and the numerical modelling of the global general circulation. A result of the latter study has led to national and international planning for a Global Atmospheric Research Program (GARP), and the establishment of a U.S. Committee for GARP. The Committee is presently completing a one-year study on the status and potential of a number of remote probing techniques.

U.S. Committee for the Global Atmospheric Research Program—The Committee, established in March 1968, serves as the principal focus for the U.S. scientific and technological communities in the planning and development of U.S. participation in GARP. The objective of the program is to increase our understanding of the global general circulation of the atmosphere; its ultimate aim is to develop the physical and mathematical basis for extended prediction. The USC–GARP has identified several scientific problem areas as crucial to this aim, and notes that engineering and technological developments in atmospheric sensing and processing are equally important to the attainment of the scientific goals. An observational system utilizing a large variety of surface-, air-, and space-based platforms, will be necessary to define the entire atmosphere below 18.6 mi. This is an essential step in understanding the dynamics and thermodynamics of major atmospheric processes over the land and ocean areas of the world.

Office Of Scientific Personnel

The NAS–NRC Office of Scientific Personnel administers for NASA the NASA International University Fellowships in Space Science and the NASA Postdoctoral and Senior Postdoctoral Resident Research Associateships. The fellowships are open to foreign graduate students and postdoctoral scientists who are sponsored by their national or regional space agency, research council, or ministry of education. Fellowship appointments for study or research at one of the 33 participating U.S. universities are for twelve months, with possibility of renewal for a second year. From the start of the fellowship program in 1961, to December 31, 1968, there have been 212 fellows from 19 countries, at 28 U.S. universities. During 1968 there were 77 fellows (62 graduate and 15 postdoctoral) from 13 countries at 23 universities in the United States. These fellowships are cooperatively financed by NASA and the foreign sponsoring agency.

The associateships, financed by NASA, are open to United States or foreign investigators of unusual ability, for research in areas of science having to do with space exploration. Eight NASA centers now participate in the program, which was initiated in 1959, and about 475 scientists from 37 countries have held appointments. Appointments are for one year, with the possibility of renewal. During 1968 appointments for approximately 190 man-years were made, about half of these being renewal appointments.

In addition to administering these programs, the Office of Scientific Personnel arranged for three space scientists from U.S. universities to attend and present lectures at the Latin American School for Space Research in January–February 1968 at Bariloche, Argentina. The program was cosponsored by the Argentine National Commission for Space Research.

Division of Behavioral Sciences

Committee on Hearing, Bioacoustics, and Biomechanics (CHABA)—A new Committee working group on aircraft collision avoidance was formed in 1968 to study two questions: whether the supersonic transport will require warning lights during the supersonic portion of its flight, and the problem of anticollision devices for general aviation aircraft.

Committee on Vision—During 1968, the Committee's working group on space simulation conducted on-site evaluations of 10 NASA-supported projects on vision research. NASA has also asked for Committee suggestions to aid in formulating the agency's long-range vision research plans.

Division of Biology and Agriculture

The Committee on Remote Sensing for Agricultural Purposes has nearly completed a monograph on this subject that will present the present status of aerial sensing, including techniques and equipment. The report will be illustrated with color plates showing the potential application of the art. The usefulness of such remote sensing for rapid and accurate inventory of agricultural and natural resources, and in estimating current levels of productivity, is discussed. Publication by the Academy is expected by mid-1969.

Division of Earth Sciences

NAS–NAE Committee Advisory to ESSA—The NAS–NAE Committee Advisory to the Environmental Science Services Administration reviews and advises on ESSA programs; among them, weather modification and data handling for weather and oceanographic needs are directly related to ESSA satellite programs.

Committee on Space Programs for Earth Observation—The Committee advises on remote sensing activities of the U.S. Geological Survey. The USGS acts as coordinator of the Department of Interior's Earth Resources Observation Satellite (EROS) program, and carries on in-house and external contract studies which are reviewed by the Advisory Committee. Subcommittees have been established in five discipline areas: geography; cartography; geology and mineral resources; hydrology and water resources; and oceanography and marine resources. Principal interest during the year focused on applications to be derived from two recommended systems: a long-life satellite with advanced TV cameras providing repetitive observation of the Earth's surface, for the purpose of assessing Earth's resources; and a short-life satellite providing one-time observation of the Earth's surface with a physical film-recovery system, for the purpose of control extension and map compilation.

Committee on Remote Sensing of Environment—The Committee is concerned with evaluating the status and research potential of sensor technology, including its space applications, and with providing guidance for a strong national program in this field. Its Subcommittee on Security Classification Review has explored security restrictions to facilitate the utilization of sensory techniques for tasks requiring unclassified equipment and data. The Subcommittee suggests that civilian scientific consultants be utilized to help resolve classification issues so that more rapid civilian application of advanced remote sensing techniques may be assured.

Division Of Engineering

Summer Study on Space Applications—Now nearing completion, the final report of the Summer Study on Space Applications conducted under the auspices of NRC's Division of Engineering will be issued early in 1969 and will reflect the work of participants in the Study's two summer sessions at Woods Hole during 1967 and 1968. Made at the request of NASA, the Study obtained the recommentations of highly qualified scientists and engineers on the nature and scope of the research and development program needed to provide the technology required to exploit the applications of Earth-oriented satellites.

There were some 60 active participants at the July 1968 session, during which two new technical panels—on points-to-point communications and on systems for remote sensing information and distribution—met; and the work of earlier technical panels in the fields of forestry, agriculture, geography, geology, hydrology, meteorology, oceanography, sensors and data systems, point-to-point communications, broadcasting, navigation and traffic control, and geodesy and cartography was reviewed and modified in the light of recent progress. The central review committee revised its interim report, issued in early 1968, and made major rceommendations relating to research and development, funding, organization, communications, and program emphasis. A presentation on the work of the Study was made July 31 to representatives of NASA and such Federal user agencies as the Departments of Agriculture, Commerce, Housing and Urban Development, Interior, State, and Transportation. A series of seminars on special aspects of the program was also held on August 1, 2, and 3.

Materials Advisory Board—The Materials Advisory Board provides advisory services for the Academies-Research Council in the field of engineering materials and material processes, responding to requests from the Government and the national private sector. A large part of its effort over the past ten years has been concerned with the problems of materials for aerospace. Two major problem areas are (1) the extremely high temperatures encountered in power plants and re-entry surfaces, and (2) materials of highest ratio of strength-to-density and stiffness-to-density.

Following are typical examples of MAB studies, completed in 1968 or under way, which bear directly on aerospace. Report MAB–231, "Long Range Aerospace Manufacturing Development," describes techniques and methods that will have to be developed to fabricate structures with the aerospace materials predicted for the 1975–85 period. *Ceramic Processing* (NAS Pub. 1576) charts research and development necessary for production of improved ceramics for high temperature and other applications. Report MAB–243, "Infrared Transmitting Materials," explores the feasibility of producing melt-formed glasses to transmit in the 8–14 micron range under elevated temperature conditions. Report MAB–206M(7), "Metalworking Processes and Equipment," provides recommendations to stimulate progress toward the advances in metalworking that are needed to utilize the new, difficult-to-work materials such as titanium and refractory alloys. Report MAB–236, "Structural Design with Fibrous Composites," defines the design problems unique to these new materials in aerospace applications.

A study, requested by NASA, is nearing completion on coatings for the high temperature oxidation protection of superalloys, refractory metals, and graphite; another study is being initiated on the attack of high strength superalloys by sulfur-containing gases in turbines (above 1800° F). A 2-year study, requested by the Air Force, is now concluding on improved techniques for systematic and optimal selection of materials for specific applications and for definition of the materials test data necessary for screening, selection, or design. A high-priority study of methods for hardenings of materials for re-entry vehicles has been under way since July 1968 and will be reported in 1969.

Committee on SST-Sonic Boom

During 1968, the Committee's Research Subcommittee completed and published its "Report on Generation and Propagation of Sonic Boom." Although the Subcommittee did not rule out the possibility that future commercial supersonic aircraft designs may yield significant reductions in sonic boom intensities, it did conclude that the most realistic prospect for reducing the boom from commercial SST's lies in the area of successive small reductions brought about by refinements in conventional aircraft design, better understanding of boom theory, and improvements in propulsive efficiency and operating procedures. The Subcommittee singled out five areas requiring additional work: Theoretical and analytical studies of shock wave propagation through turbulent layers of the atmosphere, effcts on the boom of different types of natural and man-made topography, effects of aircraft acceleration and maneuver on shock wave generation and propagation, aircraft design studies to minimize sonic boom effects, and statistical compilations of boom over-pressure and impulse type data.

A "Report on Physical Effects of the Sonic Boom" was issued by the Subcommittee on Physical Effects. The Subcommittee called for immediate development of facilities in which damage-susceptible materials and components could be exposed to simulated sonic booms in order to develop much needed statistics on probabilities of damage to normal building materials and structures. The Subcommittee also called for further work on boom propagation theory and analysis as a basis for determining how assembled buildings are likely to react to such phenomena as the air and ground pressure waves produced by wind gusts and natural and man-made microseismic disturbances.

The Subcommittee on Human Response, in its "Report on Human Response to the Sonic Boom," has concluded that "While physiological studies to date indicate little cause for concern, a review of field studies of the psychological impact of the sonic boom shows a growing consensus that is discouraging for the use of the current version of the commercial supersonic transport over populated areas at speeds at which it will be generating a sonic boom." Nevertheless, "there is little likelihood that residents of our major metropolitan centers will hear a sonic boom generated by the currently proposed version of the commercial supersonic transport arriving at or departing from commercial airports, such as those serving intercontinental flights in the vicinity of our large metropolitan centers." Since the Subcommittee expressed "cautious optimism in its belief that in the future it may be possible to design and build a commercial SST that will, when flying supersonically, generate a boom of acceptable characteristics," recommendations were made for research that would provide the aircraft designer with human-response type design criteria essential to his future work. Such recommendations include a continuation of laboratory studies of the annoying properties of the boom, and of studies of both individual and community reactions to both varied levels of the boom and repeated booms over a period of time, "if and when scheduled supersonic military flight training programs provide opportunities."

Aeronautics and Space Engineering Board

The National Academy of Engineering established the ASEB in May 1967 for the primary purpose of applying the expertise of the national engineering community to significant policy and program issues of concern to NASA and other Federal agencies in the field of aeronautics and space engineering. The Board will recommend to the Government the priorities that it believes should be assigned to engineering objectives, propose ways to bring engineering talents more effectively to bear on aerospace problems of national importance, and suggest methods to improve engineering education in the aerospace field.

The Board completed its first major study on August 13, 1968, with publication of its report on "Civil Aviation Research and Development: An Assessment of Federal Government Involvement." The report recommends over 100 actions aimed at helping to solve the major problems hindering the growth of civil aviation. The recommendations range from general consideration of Government agency relationships and responsibilities to specific actions for increased aeronautical research and development.

As a related activity, on July 30–31, 1968, the Aeronautics and Space Engineering Board arranged a joint Army–NAS–NAE conference on helicopter and V/STOL noise generation and suppression. The conference was requested and supported by the U.S. Army Research Office, Durham, N.C., and involved selected representatives from industry, Government, and universities. Major problems of aircraft noise reduction were discussed, and actions were recommended for deriving a better understanding of the noise generation mechanism in rotor aircraft and of the factors determining noise detectability and annoyance. A report of the conference was published in November.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY

CHAPTER X

Introduction

Among activities of the Smithsonian Astrophysical Observatory (SAO) this year were the following:

a. Completion and launch of Celescope on OAO–A–2, and initial data acquisition by the experiment.

b. Participation in the National Geodetic Satellite Program, including observations of GEOS 2 flashes.

c. Cooperation with satellite-tracking programs in France, Great Britain, the U.S.S.R., Greece, Switzerland, and Australia.

d. Installation of three observing instruments at SAO's new Mt. Hopkins Observatory near Tucson, Arizona.

e. Establishment of a new research program in atomic and molecular astrophysics.

f. Analysis of four years of photographic meteor observations, leading to several possibilities that challenge earlier assumptions.

Project Celescope

NASA's second ORBITING ASTRONOMICAL OBSERVATORY, OAO–A–2, containing the Smithsonian's Celescope experiment as well as an experiment of the University of Wisconsin, was launched on December 7, 1968.

The Celescope experiment consists of four telescopic television photometers. Its purpose is to map the sky in four ultraviolet color bands. OAO spacecraft subsystems provide power, command, and data-handling capability, and control the pointing of the Celescope experiment. The OAO is controlled by a complex ground system consisting of a centrally located computer facility and a worldwide tracking and data-acquisition network.

All spacecraft subsystems are operating excellently and in the manner required for conducting the Celescope observing program. The Celescope checkout period, Dec. 14–17, was devoted primarily to determining the observational limits required to provide safe and accurate data acquisition. During this period, scientifically valuable data were obtained on one star field in Draco, containing two B stars and seven A stars, and in two star fields in Lyra, each containing about 15 stars of types A and B. During this checkout period it was determined that observations cannot be safely made when the sun shines on the OAO. In course of this checkout, Celescope Camera No. 2 received some damage in the form of false stars, as a result of overexposure during daylight.

From Dec. 18 to 24, the University of Wisconsin had control of the OAO for scientific data acquisition. On December 25, SAO began control of the satellite. High-quality data were obtained on 10 to 30 stars in five star fields during real-time operations from the Rosman, N.C., STADAN station. SAO then began operating from overseas STADAN stations, using the OAO command memory to allow data acquisition when the satellite was in the dark. It was discovered that this mode of operation led to charge buildup in Camera No. 2, resulting in some additional damage. Control of the OAO was temporarily transferred back to the University of Wisconsin pending detailed analysis of the damage mechanism. At present, it is believed that the damage mechanism applies only to Camera No. 2, which is of a different design from the other cameras, and that it can be controlled by restricting operations to real-time dark.

The Celescope experiment has demonstrated its ability to fulfill its scientific objectives; it has already obtained exciting new data on the ultraviolet brightness of stars of types B, A, G, and K; it is obtaining interesting data regarding Lyman-alpha radiation in Earth's outer atmosphere. The damage to Camera 2 has slowed down the *speed* at which data can be acquired, but not compromised the scientific program.

Satellite Tracking

Operations—The Observatory has strengthened its worldwide network of astrophysical observing stations by collecating laser systems with three of its 12 Baker-Nunn cameras. These stations, which are situated in 11 countries, are augmented by more than 150 Moonwatch stations in 24 countries. The network provides satellite launch and tracking support for national space programs and furnishes data for scientific research, particularly atmospheric physics and geodesy.

SAO is participating vigorously in the National Geodetic Satellite Program. This year the network made more than 2,500 photographic observations of GEOS 2 flashes. The Observatory also has various agreements by which it receives photographic data from many nations, including France, Great Britain, Switzerland, and the U.S.S.R.

Laser systems at SAO sites at Mount Hopkins, Ariz.; Maui, Hawaii; and Dionysos, Greece, participated in an international program with the French Centre National d'Etudes Spatiales, the Greek National Technical University, the Australian Weapons Research Establishment, and NASA's Goddard Space Flight Center. The resultant precise range information on five retroreflector satellites supplements eight files of intensive observation by the SAO Baker-Nunn cameras.

These optical and laser observations, as well as data from several other tracking stations, form the base for the 1968 Standard Earth, now in preparation.

After providing on-site training to Argentine nationals, SAO turned over the Villa Dolores K–50 camera station to the Observatory's cooperating agency, the Comision Nacional de Investigaciones Espaciales, for continued geodetic work.

One of the more interesting applications of satellites could be their use to track wild animals. This technique would lead to new knowledge concerning animal navigation, migratory behavior, and territoriality. An understanding of these phenomena is of both practical and theoretical interest. Animal guidance systems, for example, are of theoretical interest as a biological process and have potential relevance to man's physical problems of navigation. The biology staff of the Smithsonian Institution and scientists of the Observatory have determined the means by which a Doppler system would allow an animal carrying a one-half-pound package to be tracked anywhere in the world.

Upper Atmospheric Studies—The density variations of the upper atmosphere during the intense magnetic storms of May 1967 have been studied by analyzing the drag of six satellites with perigee heights between 210 and 621 mi., deduced from positions obtained by the precise reduction of Baker-Nunn photographs. The study has confirmed that the density variations can be explained by an increase of the atmospheric temperature during the magnetic storm; the dissipation of the additional energy that causes the temperature increase must occur in the lower thermosphere, at a height close to that where most of the extreme-ultraviolet radiation is absorbed.

Much work has been done to construct plausible models of the variable structure of the upper atmosphere above 56 mi. Several shortcomings have been found in the past 2 years in the models currently in use throughout the world. The new models are intended to eliminate the defects. Satisfactory results have been obtained with a set of empirical static models in which the temperature at 56 mi. varies in phase with the exospheric temperature, with a range equal to 2.5 percent of the latter. Purely theoretical models of the diurnal variation are being developed in parallel, to gain insight into the dynamics of the upper atmosphere. All these models are based to a great extent on the results of satellite-drag analysis; 8 to 10 satellites are constantly tracked by the Baker-Nunn cameras to provide the raw material for these studies. Observations now cover a complete sunspot cycle, i.e., the full range of upper-atmosphere temperature.

Meteoritics

SAO has a broad research program in meteoritics, which includes the analysis of observations of meteors, as well as laboratory studies of meteorites and other meteoric material. These investigations contribute to our understanding of the origin and composition of the solar system and have a direct practical application in providing information on the hazards of meteoroid collision with manned spacecraft.

The meteor radar system at Havana, Ill., has been improved by calibrations of antenna patterns and other electronic equipment. These calibrations will permit a quantitative measure of the ionization of a meteor, and thus of its magnitude.

Located near Urbana, Ill., a newly developed system utilizing image-orthicon television will make observations of the light of faint meteors simultaneously with the meteor radar system.

Analysis of 4 years of photographic meteor observations by the Prairie Network has led to several possibilities that challenge earlier assumptions. The mass flux of large meteoroids entering the Earth's atmosphere is one or two orders of magnitude larger than expected. From present best estimates of the relation between the luminosity and the mass of these bodies, their average density is 0.4 g/cm^3, while the average value for meteoritic stone is 3.5. Also, the terminal masses of these bodies are very small, suggesting a near-catastrophic ablation in the atmosphere. Finally, the rate of meteorite fall may not exceed 0.1 per year of bodies 1 kg or larger. These conclusions support the possibility that most meteoric bodies, regardless of size, are low-density, fragile objects of cometary origin. Unanswered are basic questions concerning the source, frequency distribution, and ablation processes of meteorites.

Mesosiderites, the smallest, most obscure class of meteorites, and one generally ignored, are now being closely studied. If they represent a form of primitive matter, they are of special interest because they have nearly the right mass density and the right potassium and uranium contents to represent samples of the primitive material from which the Earth was formed. Present research is concentrated on their mineralogy and metallurgy.

Mineralogical investigation of dust samples of Greenland ice 100 to 250 years old showed no extraterrestrial materials, while that of samples from ice 50 to 100 years old did. These results suggest that the influx of extraterrestrial material is mostly sporadic rather than continuous and that large proportions of measurable cosmic dust fall in discrete events that may not have worldwide effects. Specifically, the younger samples from Greenland ice may contain material from the Tunguska explosion in Siberia in 1908.

The Mount Hopkins Observatory in Relation to the Space Program

The new Mt. Hopkins Observatory of SAO is situated 35 miles south of Tucson, in the Coronado National Forest. At altitudes above 7,000 ft, the site enjoys superior seeing and sky transparency in both the visible and the infrared.

Three instruments are already operating on a 7,600-ft ridge. One is the unique 33-foot-diameter optical reflector used for gamma-ray astronomy. Very high-energy gamma rays interact with the atmosphere to produce flashes of light detectable on the Earth. They occur in the form of very faint, extremely short-lived light pulses seen only in the direction of an arriving gamma ray. SAO constructed the optical reflector to count such light pulses and to establish whether certain suspected celestial sources, e.g., supernova remnants, radio galaxies, and the recently discovered pulsars, do in fact radiate gamma rays.

The second instrument is a prototype laser, which is being evaluated and improved with a view toward deployment of such lasers at other stations of the SAO satellite-tracking network. The laser measures to within a meter the distances to satellites thousands of miles away. Its pointing mount is accurate enough to acquire satellites when they are in the Earth's shadow and are consequently invisible. In fact, the laser can be used to illuminate a dark satellite sufficiently to permit it to be photographed against a star background.

The third instrument is a Baker-Nunn camera, with associated equipment, moved from Las Cruces, N. Mex., to this new site.

A fourth major instrument, a 60-in. reflecting telescope, is being constructed for installation in 1969. It will be used to obtain high-resolution spectra of stars, nebulas, and planets. The last observations will be used for improved determinations of the physical and chemical properties of the planetary atmospheres.

Atomic and Molecular Astrophysics

Recognizing the growing importance of studies of planetary atmospheres, SAO has established a research program in atomic and molecular astrophysics.

The temperatures of the electrons and positive ions in the ionosphere of a planet are important physical parameters. They result from a balance between various heating and cooling processes. The dominant cooling process in the upper atmosphere of the planet was identified and then embodied in a new theoretical description of the thermal balance. A new nocturnal heating process has also been identified.

Completion of the analysis of the absorption of sunlight by carbon dioxide in the Martian atmosphere showed that its density is, at most, 1% that of Earth's and that carbon dioxide must be the main constituent, being at least 60% of the total, and more likely nearly 100%. A search has begun for emission of light by oxygen atoms in the Cytherian upper atmosphere, which should give us a clue to the puzzle of the absence of any appreciable amount of oxygen on Venus. These observations should be continued in 1969 when Venus comes close to Earth.

DEPARTMENT OF TRANSPORTATION

CHAPTER XI

Introduction

The Department of Transportation engages in aeronautical research and development through one of its major components, the Federal Aviation Administration. This work supports the mission of insuring safe and efficient use of the Nation's airspace by both civil and military aircraft, and the broader, more general mandate to foster civil aeronautics and air commerce. Civil aviation has grown rapidly in recent years, and concurrently new problems have been posed and old ones aggravated. This situation calls for continued progress now and in the future, particularly in research and development.

Aviation Safety Research and Development

In-Flight Safety—Notable progress was made in 1968 toward reduction or elimination of the following in-flight hazards:

a. Fire. Three items stand out: (1) Duplication of turbine fire from combustion-chamber failure, or "combustor burn-through," was achieved by FAA during the year, under controlled test-stand conditions. The resultant improved understanding of the engineering considerations involved is enabling the agency to evaluate various means of preventing or protecting against this most severe type of fire. (2) FAA disseminated to industry and to other Government agencies the test results from two full-scale fire-test programs completed in 1967. The results were achieved with a pod-mounted turbofan engine in configurations simulating those of new-generation jumbo jets as well as those of current in-service aircraft. (3) FAA was, at the end of 1968, nearing completion of a comprehensive handbook on use of gas analyzers for ascertaining the adequacy of aircraft fire-extinguishing systems. In this area, only recently entered by industry, FAA has had almost exclusive experience.

b. Midair collision. FAA continued the efforts of prior years, in cooperation with industry, to achieve an operationally and economically sound means of reducing this hazard, both inside and outside the United States. Efforts are directed toward: (1) standardization of aircraft exterior marking and lighting; (2) development of simple pilot-warning instruments (PWI's); and (3) development of a sophisticated collision-avoidance system (CAS). Among FAA's responsibilities are formulation of the technical requirements, including civil-military compatibility, that a CAS must meet for U.S. operations, and coordination (in cooperation with the State Department) of U.S. with foreign efforts in this area of research to assure international acceptance of a common CAS. Progress in 1968 included: (1) Manufacturers developing CAS equipment for airline and FAA evaluation reached the fabrication stage; (2) FAA negotiated with the Air Transport Association (ATA) to define FAA's role in initial flight-testing of CAS equipment; (3) FAA completed negotiations for contractual effort in the computer-simulation field aimed at enhancing for users the benefits from simultaneous operation of collision-avoidance and air-traffic-control systems; and (4) it also completed negotiations for contractual study of a) ways to make aircraft easier to see and b) areas suitable for use of pilot-warning instruments.

c. Weather. There are four notable items. (1) With data analysis completed in early 1968, the year saw the publication of results from tests (ended in 1967) in which more than 100 jet pilots from the airlines, industry, and the military services "flew" under varied but closely controlled conditions of severe turbulence in the U.S. Navy's Johnsville (Pa.) centrifuge simulation facility. While showing current turbulence penetration techniques to be adequate, the test results demonstrated the potential of an instrumentation system for achieving smoother and safer penetrations. Flight-testing of this instrumentation system is scheduled for 1969. (2) The year saw satisfactory completion of design and testing of a digital weather-outline generator, a device which removes the undesirable weather clutter from the air traffic controller's radarscope and replaces it with clear outlines of storm areas. This feature, included in FAA's general modernization program, eventually will improve controllers' capability to guide airplanes around heavy storm areas. (3) In mid-1968, FAA signed a contract aimed at repairing the relative lack of engineering-quality data, in scheduled air carrier operations, on occurrences such as encounters with turbulence. (This lack is in contrast with the abundance of data on performance and handling characteristics of airplanes as flown by engineering pilots during test and certification programs.) The contract calls for instrumenting three jet transports with recording systems capable of providing the kind of data desired. By the end of 1968, installation of one of the three systems had been completed. The other two will be installed in 1969. and data-taking will continue until mid-1970. (4) Efforts continued toward development of devices for detecting and avoiding clear-air turbulence (CAT), a hazard more often encountered at the higher altitudes flown by jets than at the lower flight levels. The device nearest to operational practicality is an infrared remote-air sensor. It depends on correlation between remote-air temperatures, which it measures, and the presence of CAT. Under current scheduling, preparation of a technical standard for this device is about two years away.

d. Aircraft wake turbulence. Vortexes in the wake of large aircraft in flight can be hazards to following aircraft. In 1968, FAA continued a program begun in 1967 to develop solutions to this problem. The search for solutions will follow determination of (1) the characteristics of the vortex field flow behind the airplane generating it, and (2) effects of the vortex on encountering aircraft. Progress in 1968 included (1) completion of negotiations to procure a three-tower sensing and recording system, and (2) the conducting of tests that confirmed feasibility of the sensing and recording system, provided a basis for realistic programming of future effort, served FAA needs in litigation resulting from alleged wake-turbulence incidents, and provided documentation for consideration by the International Civil Aviation Organization's Special Planning Group in assessing wake turbulence in relation to aircraft separation criteria for North Atlantic operations.

e. Propeller failure. At year's end, FAA was flight-testing the prototype of a device—a propeller-blade-vibration recording system—that may fill the existing need for better evaluation of propellers for general-aviation airplanes. In the past several years, there have been some 100 failures of such propellers, all unpredictable by present standards of evalution.

f. Sabotage. Though several promising methods of detecting concealed explosives in passenger luggage have been tested by FAA since 1960, no practical and economically feasible method has been developed; the search continues, however, in close coordination with other Government agencies and the air transport industry. In 1968, there were two notable steps. (1) The contractor delivered for evaluation by FAA's National Aviation Facilities Experimental Center, at Atlantic City, an engineering model of a "chemosensor" device for detecting explosive vapors; the evaluation will be completed by mid-1969. (2) FAA initiated a project to explore the feasibility of a detection system based on analysis of neutron activation.

g. Hijacking. An effort was launched in 1968 to develop a practical and economically feasible method of detecting concealed weapons on airline passengers before they board the aircraft. The effort will coninue until a satisfactory method is achieved.

h. SST emergency cockpit temperatures. FAA completed in 1968 a program begun the previous year to determine the tolerable upper cockpit temperature during cooling emergencies in supersonic transports. Profiles of performance degradation at high temperatures were prepared for the tentative SST airworthiness standards.

i. Any of foregoing. Efforts are under way to develop a method of recording the display on air traffic controllers' radarscopes, to make it possible to review the display at any time in case of an accident or other incident. During 1968, several types of recorders were evaluated, and it was determined that radar video could be shown on a helical scan recorder at a reasonable price. Completion of procurement arrangements for, and the fabrication and delivery of, a prototype are expected to take about two years.

Postcrash Safety—FAA continued in 1968 various R&D efforts aimed at increasing the likelihood of occupants surviving aircraft crashes. Notable progress was made in programs concerned with:

a. Cabin interior materials. Data from testing of such materials in earlier years, combined with results from similar testing by aircraft and aircraft-material manufacturers, supported an amendment to the Federal Aviation Regulations, effective in late 1967, imposing new standards of fire resistance for materials used in aircraft cabin interiors. Continuing such testing in 1968, FAA placed specific emphasis on smoke and toxicity hazards.

b. Safety fuels. In 1964, FAA began developing thickened fuels as a way to reduce the fire hazard following a survivable aircraft accident; in 1968, this effort progressed to the completion of detailed jet engine fuel-nozzle and combustor-component laboratory tests. A jet engine was successfully started and operated on a new gelled fuel exhibiting promising safety characteristics. Compatibility of this fuel and of an emulsified fuel with jet engine fuel systems is being tested to identify problem areas and develop solutions. These tests are expected to show system modifications that may be necessary before flight test of safety fuels, currently scheduled for 1971.

c. Protective hood for passengers. In 1968, continuing work begun two years earlier, FAA devised an improved sealed hood for use of passengers surviving an aircraft crash followed by fire; the hood is designed to protect eyes and lungs against smoke or fire damage during the time required to evacuate the aircraft. Final tests were begun to perfect operational details.

d. Emergency evacuation. In June 1968, FAA completed a year-long study aimed at developing new concepts for emergency evacuation of transport aircraft following survivable accidents. The study describes and theoretically evaluates 51 such concepts, which will undoubtedly be used in the development of future aircraft.

Airport Safety—FAA continued various programs during 1968 to prevent aircraft accidents at or in the vicinity of airports, or to minimize the consequences of such accidents. Notable efforts were concerned with:

a. Runway grooving. Continuing work of previous years, this program aims at improving aircraft braking traction on wet or slush-covered pavements; it is conducted in cooperation with the National Aeronautics and Space Administration, the Department of Defense, and foreign organizations. Progress in 1968 included (1) completion of design criteria for optimum grooving pattern, from testing of 18 groove patterns cut in taxiways at several airports, and (2) the grooving of a runway at Chicago's Midway Airport (runways had previously been grooved at Washington National, Kansas City Municipal, and John F. Kennedy International Airports).

b. Airports surface detection equipment (ASDE). This equipment is designed to provide controllers with a radar display of airport ground traffic when direct viewing is impeded, as by darkness or weather. The usefulness of early models was limited because, to eliminate outside light and reflections, the controller had to view the display under a hood. In 1968, FAA completed data collection for evaluating performance of a recently developed bright-display model, usable without a hood, in operation at Chicago's O'Hare Airport traffic control tower. The prospect is for a favorable report and a resultant national program to improve operational ASDE's.

c. Jet transport aircraft landing characteristics. In line with its continuing responsibility for monitoring routine air carrier operations to determine areas where regulatory or procedural improvements are needed, FAA began in 1967 a program to photograph and analyze operational performance of civil jet transports during approach and landing. The data-taking phase of the program, carried out at six different jet airports, was completed in 1968. Data reduction and analysis will continue into 1969, to be followed by issuance of the final report. Program results will be used as the basis for re-establishing certification performance criteria for transport aircraft.

d. Engine protection from bird ingestion. The sucking of birds through jet-engine intakes is an occasional hazard, especially in the vicinity of airports. In 1968, FAA test-flew an FAA aircraft equipped with a promising engine-inlet protective device resulting from a contract negotiated in 1967.

General—Notable R&D projects not mentioned above to promote aviation safety included the following:

a. Objective private-pilot flight test. FAA continued in 1968 work begun in 1967 to develop an objective certification flight test for private pilots. The present test, in use for more than 35 years, may, despite numerous modifications, be outmoded; in any case, its administration is straining the resources of FAA's field offices. What is wanted from the test under developments is reliable identification of competent pilots at minimum inconvenicence, delay, and expense to both the applicant and the Government. Progress in 1968 included completion of the first phase of development—the study and profiling of the private-pilot population—and the start of the second phase—development of the test itself—which is expected to be completed in 1969.

b. Integrated VFR–IFR pilot-training. The purpose of this program, begun in 1967 and completed in 1968, was to develop and experiment with a curriculum combining the teaching of flying under visual flight rules (VFR) with flying under instrument flight rules (IFR). The results included the first objective evidence that this method of giving pilots the greater resourcefulness of IFR capability is advantageous, and therefore promotes aviation safety.

c. Pilot-training with angle-of-attack instrument. Completed in 1968, this program was part of the broad objective to find new means and procedures for reducing the number of general-aviation accidents, particularly those (often fatal) resulting from stalls. The program showed that use of the angle-of-attack instrument in training student pilots produced superiority in certain flying skills as compared with training not including the instrument.

d. Analysis of airframe and landing-gear strength. FAA completed in 1968 a comprehensive study of loads imposed on the airframe of an aircraft by maneuvers involved in taxiing, thus providing data needed for developing improved structural design criteria. A companion study provided information useful for designing more efficient landing-gear systems; it gathered data on fatigue and fracture toughness of steel having a tensile strength of 300,000 pounds per square inch, a prime material for transport landing-gear structures.

e. More crash-resistant flight-data recorders. FAA began a two-year effort in June 1968 to improve the crash survivability of magnetic tape or other recording materials used in aircraft flight-data recorders and cockpit voice recorders. Information from such recorders is of vital importance to FAA and the National Transportation Safety Board in the investigation of aircraft accidents.

f. Underwater location beacon. During the year, FAA completed evaluation of, and issued a final report on, an acoustic underwater location beacon. This device can be attached to flight-data or cockpit voice recorders carried in aircraft, and holds promise for locating specific parts of such recorder equipment following the crash of an aircraft in water.

g. Safer civilian sport parachuting. The recent increase in accidents among civilians undergoing training in "skydiving," or parachuting for sport, prompted FAA in 1968 to start development of a device for remote control of the student jumper's reserve parachute. This safety device, to be operated by the parachute jump instructor, is expected to be completed by mid-1969.

Other R&D Programs Fostering Civil Aeronautics

Air Traffic Control

a. Advanced radar traffic control system (ARTS II and III). ARTS II (originally referred to as DAIR, for direct altitude and identity readout) is a joint enterprise of FAA and the Department of Defense, under a 1967 civil-military contract calling for development and production of a prototype. Intended for use at civil airports and Air Force and Navy installations of low air-traffic density, it will show aircraft altitude and identity on controllers' radarscopes in numerals only; it is designed, however, to be expandable to the capability of presenting additional or more complex information, using letters as well as numerals (alphanumerics). In 1968, the ARTS II equipment, after demonstration at the contractor's plant, was delivered to FAA's National Aviation Facilities Experimental Center, at Atlantic City, for joint FAA–DOD test and evaluation. ARTS III is the current designation of equipment originally referred to by the term TRACON (terminal radar approach control) and an alphabetic letter to indicate degree of sophistication. For use at medium-density terminals, ARTS III presents flight data to the controller in alphanumeric form. At the end of 1968, it was ready to enter the production phase.

b. STOL and VTOL air traffic. Through dynamic simulation studies at FAA's National Aeronautics Facilities Experimental Center, new procedures were developed to permit mixing of the growing STOL (short takeoff and landing) and VTOL (vertical takeoff and landing) air traffic with standard air traffic, especially in the controlled airspace areas in the vicinity of airports.

c. Satellite-supported air traffic control system. FAA continued, with others, efforts of the previous year aimed at use of satellites to improve high-frequency communications for aircraft flying over oceanic and sparsely populated areas. Analysis of APPLICATIONS TECHNOLOGY SATELLITE test data from flights over the Pacific and Alaska indicated the feasibility of very-high-frequency communication via satellites.

Navigation and Navigational Aids

a. All-solid-state VOR transmitter. The VOR (very-high-frequency omnidirectional radio range) is the key navigational aid for aircraft flying en route between airports. During 1968, a contractor virtually completed development of a prototype of an all-solid-state VOR transmitter. The new transmitter, when available for operational use instead of the current vacuum-tube type, will provide more reliable service—and at the same time reduce maintenance costs by saving personnel time and obviating costly tube replacements.

b. Improved Doppler VOR monitor. In 1968, FAA satisfactorily tested and completed production specifications for an improved Doppler VOR monitor. The new monitor is expected to bring maintenance time and effort for Doppler VOR's, now considered excessive, into line with maintenance experience with standard VOR's. (The Doppler VOR is a modification of the standard VOR adapting it to sites otherwise unusable because of terrain or other unfavorable factors.)

c. Area navigation. Present instrument-weather air traffic moves basically along fixed airways in line with one of the radials from a VOR. Because this tends to cause airway congestion and is not necessarily the shortest distance between an aircraft's departure point and destination, a more flexible, off-airway type of navigation is desirable. In 1968, such a system, employing pictorial displays and course-line computers, underwent joint FAA/airline-industry operational testing in the Washington-New York-Boston airspace. At year's end, definition of flight and control procedures, a prerequisite to operational implementation of the system, was under way.

d. All-weather landing system. Work of previous years continued on the three technical components of an all-weather landing capability for aircraft: (1) electronic ground-based guidance, (2) airborne equipment, and (3) approved lighting. The objective is to integrate these components so that, while the pilot remains the decision-maker, the automatic landing capability is at his disposal under Category III weather conditions (zero-zero visibility in the final step of the category). Progress in 1968 included: (1) partial testing of the Category III guidance system, after installation at the National Aviation Facilities Experimental Center, (2) completion of tests of an automatic landing system developed for the C–141 (the Air Force's Lockheed-built aircargo transport, FAA-certificated for commercial version in 1965) and start of testing of a similar system developed for the civil transport four-engine jet CV–880, and (3) testing of lighting systems and recommendation that they be reconfigured.

Supersonic Transport Development Program—During January 1968, the Government and the airlines conducted an evaluation of the design submitted for construction of two prototype aircraft. As a result of this evaluation, it was determined that the variable-sweep-wing design was deficient in range and payload and thus would not provide an adequate technical foundation for a commercial supersonic transport for airline use. Therefore, the program was delayed approximately one year to permit the airframe contractors to undertake further design work to make technical changes.

That effort proceeded on schedule, and in September a fixed-wing design was selected. The remainder of the year was spent in further developing that design for evaluation by the Government and the airlines with the aim of beginning prototype construction in 1969.

The SST engine development program proceeded satisfactorily.

FEDERAL COMMUNICATIONS COMMISSION

CHAPTER XII

Introduction

Three more countries joined the International Telecommunications Satellite Consortium in 1968, and, as of December 31, 1968, 63 countries were members of the Consortium. Additional Earth terminal stations became operational, bringing that total from 16 to 22, and others were planned or under construction in Europe, Africa, South America and Asia. Additional satellites with larger capacity than those presently in orbit are expected to be launched in 1969.

Regulatory Activities

The Communications Satellite Corporation (ComSat) was granted authority to participate in the testing and launching of the first satellite of the INTELSAT III series of communication satellites. The Commission also granted ComSat authority to participate in the construction of four new satellites to be owned by the International Telecommunications Satellite Consortium.

The first of the three INTELSAT IV series of satellites is planned for launch into synchronous orbit in the first quarter of 1971 and will provide increased capacity for the global communications systems.

The new satellite will be designed to carry in excess of 5,000 two-way voice grade circuits or a combination of different kinds of communication transmission. The life expectancy of each INTELSAT IV satellite is about seven years.

The Commission has under consideration comments filed by various companies, associations or individuals in the Commission's Notice of Inquiry into the possible use of communication satellites for domestic purposes.

Activities of the International Radio Consultative Committee (CCIR)

An international Interim Meeting of Study Group IV (Space Systems and Radio Astronomy) of the CCIR (International Radio Consultative Committee) was convened in October, 1968, at Geneva. This Committee (encompassing 14 such Study Groups) serves as advisor to the International Telecommunication Union (ITU) on technical matters involving the use of radio. For the Study Group IV meeting, the FCC provided the spokesman for the U.S. Delegation, who also served as International Chairman of Working Group IVB, dealing with sharing problems for the communication satellite service. Developments of major interest included: (a) A new study program concerned with efficient utilization of the geostationary orbit and the formation of an International Working Party to deal with this subject; (b) the formation of a new Working Group IVD on "communications between space and maritime or aeronautical stations"; and (c) the future use of frequencies above 10 GHz by the space services. Also, there was considerable interest in the broadcasting-satellite service and a technical report on the subject was revised substantially.

Forthcoming ITU Conference on Radio Astronomy and Space Services

The Commission has been in frequent consultation with the Office of Telecommunications Management to prepare for the forthcoming ITU (International Telecommunication Union) World Administrative Radio Conference on matters pertaining to radio astronomy and space services. The ITU Administrative Council, in May 1968, adopted a Resolution calling for such a conference in late 1970 or early 1971, and set forth a tentative agenda for comments. In response to the Resolution, the FCC issued a Notice of Inquiry

(Docket 18294) in August 1968, which dealt with (a) the conference agenda, and (b) the possible reallocation of spectrum space above 10 GHz to provide additional frequency bands for the communication-satellite service, based on joint studies with the Office of Telecommunications Management (OTM). A Second Notice of Inquiry in this docket which was released in October 1968, concentrated on matters relating to the conference agenda, and set forth new concepts with respect to the future role of the ITU in regulatory matters pertaining to the space services. It is expected that further Notices of Inquiry will be issued, as the conference prepartory work progresses, so as to permit development of the Preliminary Views of the United States regarding the conference for distribution abroad in January, 1969.

Space Techniques for the Maritime Mobile Service

The Commission, working with the Inter-Governmental Maritime Consultative Organization (IMCO) Sub-Committee on Radiocommunications, the International Radio Consultative Committee (CCIR), the Radio Technical Commission for Marine Services (RTCM), industry and other Government agencies, is studying the potential value of adapting satellite relay techniques to the communications requirements of the maritime mobile service.

The RTCM, an organization in which Government and industry cooperate in studies of existing and proposed systems of maritime communications, established a Special Committee SC–57 "Maritime Mobile Satellite Communications" to investigate the possibilities of utilizing satellites for marine communications and navigation. A test program was developed which was subsequently adopted by the Maritime Administration as a basis for tests conducted during early 1968 in which VHF communications were relayed via NASA's ATS–1 and 3 satellites between U.S. ground terminals and the SS SANTA LUCIA enroute from Port Newark, N.J. through the Panama Canal to Valparaiso, Chile, and return. These tests together with those performed during 1967 through 1968, by the U.S. Coast Guard from the cutters USCGC KLAMATH, STATEN ISLAND, GLACIER, and CASCO have demonstrated the feasibility of communicating with ships at sea via satellite.

The ITU World Administrative (Maritime) Radio Conference, Geneva, September–November 1967 adopted Recommendation No. MAR 3 relating to the utilization of space communication techniques in the maritime mobile service. The recommendation invited administrations, IMCO and the CCIR, respectively, to undertake a study of maritime operational requirements for a safety and navigation radiocommunications system via satellite and the technical aspects of such systems.

Commission staff representatives participated in the preparation of guidance material for and served on the U.S. Delegation to the Fourth Session of the IMCO Sub-Committee on Radiocommunications, London, April 1968, and the Interim Meeting of CCIR Study Groups IV–C and D, Geneva, September–October 1968, which considered inter alia maritime radiocommunications via satellite. The IMCO Sub-Committee developed a questionnaire which is being circulated to participating member governments to develop information necessary for the determination of the operational requirements and technical aspects of maritime communications via satellite. Such information will be used in the national and international planning on this subject.

The World Administrative Radio Conference (WARC) of the ITU, scheduled for late 1970 or early 1971, is expected to give consideration to maritime communication needs using satellite techniques. The ITU Radio Regulations (Paragraphs 273A and 352B, EARC for Space, Geneva, 1963) presently contain authority for the aeronautical mobile service to use space communication techniques, whereas no provisions exist for the maritime mobile service.

Aeronautical Development

The Commission, in discharging its statutory responsibilities with respect to non-Government uses of radio for aviation, prescribes the manner and conditions under which frequencies may be assigned for aeronautical telecommunications. In addition, the Commission assigns frequencies to aircraft radio stations, aeronautical enroute, radionavigation, aeronautical advisory, and other stations comprising the aviation radio services.

Commission staff representatives have continued working nationally with other Government agencies and the aviation industry, and internationally with the International Civil Aviation Organization (ICAO) and the International Radio Consultative Committee (CCIR), towards development of system parameters and the application of space radiocommunication techniques to help satisfy the communication and navigation requirements of domestic and international civil aviation.

The air transport industry, under the authorization of the Commission, continued tests which were begun in 1966 to access the relative merits of AM versus FM modulation techniques and normal power versus substantially higher power aboard aircraft as elements between an aeronautical station and aircraft stations via satellites. The Commission staff continued study of the results of those tests as well as the results of other studies in order to determine the most suitable technique to be used in aeronautical satellite systems.

The Commission staff representatives have participated in the preparation of material to be used as guidance material for the use of U.S. representatives to international conferences including the CCIR and the ICAO. Members of the staff served on the U.S. Delegation to the CCIR Interim Meeting, Geneva, September–October 1968 which treated inter alia aeronautical satellites. The staff is preparing documentation for the forthcoming ITU Space WARC scheduled to convene in late 1970 or early 1971.

The Commission authorized Aeronautical Radio, Inc., and various scheduled airlines to participate in tests using NASA's APPLICATIONS TECHNOLOGY SATELLITES (ATS). Tests using the ATS satellites are continuing. Satisfactory communications were exchanged, relayed via satellite, over both the Atlantic and the Pacific between ground terminals and aircraft. Continued testing and analysis of the results is in progress.

UNITED STATES
INFORMATION AGENCY

CHAPTER XIII

Introduction

U.S. exploits in space captured headlines around the world in 1968. Telling that story abroad with words, pictures, and exhibits was the U.S. Information Agency.

More than 2 million viewers in 11 countries saw USIA-provided exhibits about the U.S. space program during the year. The Voice of America produced more than 1,200 features on space and space science which were carried on 6,126 different broadcasts in as many as 36 languages. Backed by USIA-produced pamphlets, books, films, and daily output of the Wireless Files, America's achievements in space were publicized more heavily than in any preceding year.

Guidelines

USIA used the following as guidelines for treatment of space news:

a. The U.S. seeks to develop *all* phases of space technology—manned and instrumented exploration, space science, and space applications—to produce benefits for man, not just to land a man on the Moon.

b. Through cooperation with other nations in developing space for peaceful uses, the United States is dedicated to peace in space through measures for rule of law and arms control.

c. The United States conducts its civilian space program in an open manner.

d. Crew safety is given major attention in all U.S. manned space flight operations.

e. The U.S. space effort is a means of acquiring new information to put space to work for man; space technology and its range and innovations are being adapted to advance the industrial arts and seek practical applications.

Treatment

Apollo Program—Voice of America's on-the-scene coverage of the launch and recovery of APOLLO 7 and APOLLO 8 was carried in many languages to both sides of the Iron Curtain. Motion pictures and TV productions depicting the achievement were disseminated abroad to more than 100 countries where USIA maintains posts.

Magazines, pamphlets, and the Wireless Files were used to focus world attention on the significance of the achievements.

U.S. space exhibits were featured at the Cultural Festival in Mexico City (October 19–November 30) at the 1968 Olympic Games. Viewers pronounced the exhibit as "far and away the best" there.

Other Achievements—USIA also publicized abroad such successful U.S. space achievements as SURVEYOR 7, the Earth environmental satellite EXPLORER 38, and the ORBITING GEOPHYSICAL OBSERVATORY. The cooperative efforts being expended by Free World nations in the peaceful use of outer space were emphasized. The solar studies satellite PIONEER, now in orbit around the Sun, was given wide play through all Agency media, as was the practical application of ATS–3 in carrying the Olympics and live coverage of the APOLLO 7 and 8 launches.

Press and Publications—The Agency's Press Service coverage of U.S. space activities began in 1968 with a review of the program during its first 10 years, and ended with intensive reporting on the APOLLO flights. Pamphlets included "The International Role of U.S. Weather Satellites" and "Above and Beyond: The United States' Space Program."

America Illustrated for Russia carried four features and one shorter item in special positions. In production at year's end was a five-page layout on "Our First Day on the Moon—What Will It Be Like?" *Topic* for Africa carried five features with one in the planning stage.

Three packets: "America in Space—The First 10 Years," "APOLLO 7, First Manned Flight for America's Moonship," and "APOLLO 8, Three Astronauts Aim for the Moon," were completed and disseminated.

The Wireless Files carried thousands of words almost daily on virtually every phase of America's space program. Black-and-white and color newsphotos were sent to every post for placement in the press or display on television or in exhibits.

Assistance was provided to more than 80 foreign journalists covering the manned APOLLO launches at Cape Kennedy.

Radio—Special on-the-spot broadcasts enabled the Voice of America to provide language coverage to the world on the APOLLO launches. Features on other aspects of the space program also were broadcast via VOA facilities.

Like the special space documentary, "The Years of Apollo," a considerable number of VOA's extensive space programs received double play—first on Voice broadcasts and later through placement on local radio stations around the world.

Not only does VOA package its space programs for replay locally, but it also creates additional radio series on science for initial use by foreign stations. For example, more than 100 programs on space are offered in the Latin American Division's *Capsula Cientifica* series—currently broadcast by an estimated 250 radio stations.

VOA broadcasts of space flights are estimated to reach more than a third of a billion radio listeners throughout the world—seven times the number reached during an average news week. Current statistics are unavailable, but UNESCO estimated that 300 million persons heard VOA broadcast John Glenn's flight in 1962. Since then, addition of powerful transmitting complexes such as those in Greenville, N.C., Monrovia, Liberia, and Bangkok, Thailand, have enabled VOA to reach still greater audiences. For example, the 1965 GEMINI broadcasts carried by our Greenville transmitters reached an estimated 100 million listeners in Latin America alone.

Motion Pictures and Television—USIA's Motion Picture and Television Section not only produced a wide variety of special films on the space program using its own facilities, but it successfully garnered the output of many other government and private agencies and helped disseminate the footage abroad. Highlighting its production was a 15-minute animated color film on the meaning of the space program to the man-on-the-street. It was titled "And, Of Course You."

"APOLLO 7 the Second Decade," a 27-minute film, was released worldwide about 75 hours after splashdown. It was distributed to 115 countries and translated into Spanish, French, Portuguese, and Arabic.

Exhibits—In addition to the successful Mexico City exhibit, USIA staged a touring space show in Ecuador, where viewers included all five of the governors of the provinces visited, and all seven of the mayors of the cities in which the exhibit was shown, plus leading officials of each city and province. Afghanistan's royal family were among many who saw the U.S. Space Exploration Exhibit in Kabul. Greece and Togo also were successful space exhibit locations.

Information Centers—Nearly three dozen books on space and space science were suggested to posts in 1968, and five books and 23 other publications were automatically distributed to USIA libraries abroad.

Six books on space were translated into six languages for distribution to USIA posts around the world.

A 52-slide series was produced to illustrate a special packet containing three lectures on aspects of America's space program.

ARMS CONTROL AND DISARMAMENT AGENCY

CHAPTER XIV

Introduction

The Arms Control and Disarmament Agency continues to have a strong interest in space programs, both national and international, and expects to be closely involved with many of them for the foreseeable future. The Agency maintains an active research effort in this area, participates in preparing U.S. positions on international space issues, and joins with other agencies on several space committees and panels.

ACDA believes there is an urgent requirement that space be reserved for peaceful purposes and therefore participated in the negotiation of the Outer Space Treaty, supported the follow-on Astronaut Assistance and Return Agreement, and is interested in the current negotiations on a liability convention. These measures reinforce the concept of a rule of law in space and the cooperative international nature of space activities.

Space programs meet many of ACDA's objectives through providing exciting and prestigious peaceful outlets for national ambitions, through focusing national energies on peaceful uses of space rather than weapons programs, and through nurturing international cooperation and stimulating healthy competition. These programs can and have increased the stature and the effectiveness of international organizations, particularly those within the United Nations structure, and so have materially improved the machinery for dealing with arms control issues or problems on a world-wide basis.

The Space Treaty

The Outer Space Treaty has become one of the several important arms control achievements of our era, along with the Antarctic Treaty, the Limited Nuclear Test Ban Treaty, and the recently negotiated Non-Proliferation Treaty.

ACDA has been concerned, along with other agencies, in the necessary follow-on actions related to the infant Outer Space Treaty. Among these have been the Astronaut Assistance and Return Agreement, the current negotiations on a liability convention, and actions such as the preparation of instructions for U.S. overseas posts to ensure that the provisions of Outer Space Treaty are uniformly complied with.

Since this Treaty came into force there have been no indications that any nation has willfully or inadvertently violated any of its provisions. Nevertheless, there have been questions about a Soviet test program involving a possible fractional orbital bombardment system (FOBS). It is clear, however, that a FOBS violates neither the spirit nor the letter of Article IV of the Space Treaty, which declares: "States parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies or station such weapons in outer space in any other manner." An FOBS is a land-based (not a space-based) system, essentially similar to an ICBM. It does not pose a continuing threat of bombardment from outer space against nations. In any event, it is deployment of stationing of nuclear weapons in space which is prohibited by the treaty and there is no prohibition, actual or implied, against research or development of a space weapons systems by any nation. Moreover, there is no evidence that any FOBS has carried a nuclear warhead.

Defining Space

The problem of defining outer space, in part spotlighted by the Outer Space Treaty, has been recently examined in such forums as the U.N. Scientific and Technical Subcommittee, where it was found that there are no satisfactory physical criteria on which to base a definition of space or to locate its boundaries.

The U.S. position has been that it is premature to establish a definition, that further experience in space operations is essential before a satisfactory solution can be found. Although no practical difficulties have yet arisen over the absence of a space definition, ACDA continues to be involved in developments on this issue in light of its importance to various verification concepts of concern to the Agency.

Space Cooperation

ACDA has supported such efforts as the European Launcher Development Organization, has generally encouraged multinational cooperative space activities and currently, along with other U.S. agencies, is studying the merits and drawbacks of an international space agency. The Agency also joins other U.S. organizations in studying the feasibility of satellite Earth resource survey programs.

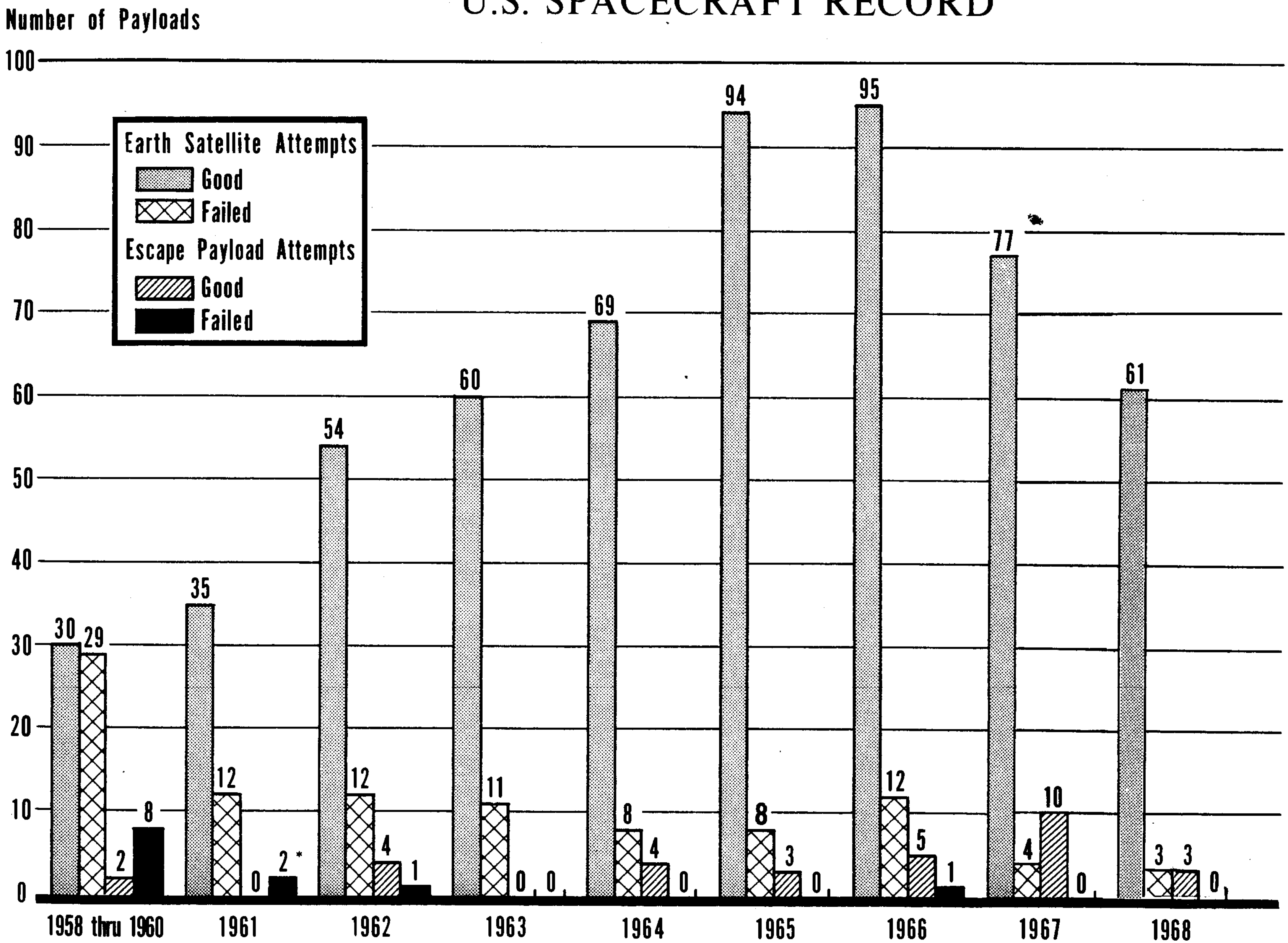
Verification and Inspection

ACDA has maintained a research program aimed at improving both technological and organization capabilities for verifying arms control agreements through potential space surveillance systems. Current efforts center on remote sensing technology, but ACDA is also studying such future concepts as a possible U.N. arms control satellite inspection system.

Use of Satellite Communication Systems to Reduce Risk of War

ACDA's research into methods to reduce the risk of war resulting from accident or miscalculation has included an investigation of the potential application of satellite communication techniques in this role. The existing "hot line" between Washington and Moscow, based on more conventional means of communication, has already demonstrated the usefulness of rapid and private means of communication between heads of state. Through the development of satellite communication capabilities, the "hot line" concept may eventually be extended on a worldwide basis.

U.S. SPACECRAFT RECORD



* INCLUDED IN EARTH SUCCESSES

NASC STAFF

U.S. Spacecraft Record

Year	Earth orbit Success	Earth orbit Failure	Earth escape Success	Earth escape Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	[1] 2
1962	54	12	4	1
1963	60	11	0	0
1964	69	8	4	0
1965	94	8	3	0
1966	95	12	5	[1] 1
1967	77	4	10	0
1968	61	3	3	0
Total	575	100	31	12

NOTES

The criterion of success or failure used is the attainment of Earth orbit or Earth escape rather than a judgment of mission success.

This tabulation includes spacecraft from cooperating countries which were launched by U.S. launch vehicles.

[1] These Earth escape failures did attain Earth orbit and therefore are included in the Earth-orbit success totals.

U.S.S.R. Spacecraft Successfully Launched

Year	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	Total
Spacecraft	2	1	3	3	7	21	18	38	73	51	67	74	358

Notes: U.S.S.R. tabulation combines successfully launched Earth-orbit and Earth-escape spacecraft. In the total of 357 are included 21 spacecraft launched on Earth-escape missions, 12 spacecraft intended for escape missions but attaining only Earth orbit, and 23 spacecraft used as launching platforms in low parking orbits for higher-orbit missions or Earth escape.

Successful U.S. Launches—1968

Launch date (GMT) Spacecraft name COSPAR designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)—Period (minutes)—Inclination to Equator (degrees)	Remarks
Jan. 7 SURVEYOR VII 1A Atlas-Centaur	Objective: Soft-land on Moon near crater TYCHO on "ejecta" blanket lurain; obtain post-landing TV pictures of lunar surface; operate Alpha Scatter experiment to determine chemical characteristics of soil; and dig into soil with surface sampler tool. Spacecraft: Triangular three-legged frame 10′ high, and 14′ between legs; solar cell power supply. Landing weight: 639 lbs.	Soft-landed on moon.	SURVEYOR VII successfully soft-landed on the Moon in its designated target area, transmitted over 20,000 excellent photos, and successfully accomplished the Alpha Scatter and soil digging experiment.
Jan. 11 GEOS II 2A Thor-Delta	Objective: To establish one world datum and to adjust all local datums to the common center-of-mass of the Earth, providing geodetic control station to ±10 meters relative to a center-of-mass coordinate system. Spacecraft: Eight-sided truncated pyramid 48″ wide and 32″ high with extendable 60′ gravity-gradient stabilization boom with magnetically anchored eddy current damper on end of boom; three independent solar cell power supplies. Weight: 460 lbs.	978 671 112.2 105.8	Excellent geodetic data was obtained. Spacecraft is still providing useful data.
Jan. 17 DEFENSE 4A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	335 285 94.5 75.1	Still in orbit.
Jan. 18 DEFENSE 5A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	254 77 89.8 111.4	Decayed Feb. 4, 1968.
Jan. 22 APOLLO 5 7A Saturn IB	Objective: To verify opeation of the Lunar Module (LM) descent and ascent propulsion systems, including restart; to evaluate the Lunar Module staging; and to evaluate the S–IVB and Instrument Unit (IU) orbital performance. Spacecraft: The Lunar Module is made up of two stages: the descent stage, which carries the LM from lunar orbit to landing, and the ascent stage, which lifts the LM from the surface to the rendezvous with the Command and Service Modules in lunar orbit. Battery power supply. Weight: 31,700 lbs. fully fueled.	138 107 89.9 31.6	Flight verified descent and ascent stages propulsion system, including restart and throttle operations. Also evaluated Lunar Module staging and S–IVB/IU orbital performance.
Jan. 24. DEFENSE 8A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	269 112 90.6 81.5	Decayed Feb. 27, 1968.
Jan. 24 DEFENSE 8B Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	338 294 94.9 81.7	Still in orbit.
Mar. 2 DEFENSE 12A Scout	Objective: To provide a navigation satellite capability. Spacecraft: Not announced.	711 640 106.9 89.9	Still in orbit.

Mar. 4 OGO–V 14A Atlas-Agena D	Objective: To acquire correlative scientific data in the magnetic fields, energetic particles, and plasma disciplines from a stabilized platform as apogee sweeps from the forward leading quadrant of the magnetosphere into the geomagnetic tail, with data being obtained both in the interplanetary medium and within large sections of the magnetosphere. Spacecraft: Rectangular box 67″ long, 32″ wide, and 31″ deep. Active 3-axis and spin stabilization; solar cell power supply. Weight: 1,347 lbs.	91, 188 181 3, 744 31	Spacecraft is operating normally and providing significant data.
Mar. 5 EXPLORER XXXVII (SOLRAD IX) 17A Scout	Objective: To monitor into the ascending portion of the solar cycle the Sun's energetic X-ray emissions; measure the time history of X-ray emission intensity and spectral quality of solar flare emissions; correlate these measurements with those of optical and radio ground-based observatories; and provide real-time solar data to interested participants. Spacecraft: Twelve-sided cylinder, 30″ diameter and 27″ high; spin stabilization; solar cell power supply. Weight: 195 lbs.	549 317 98. 7 59. 4	Spacecraft is operating normally and providing significant data.
Mar. 13 DEFENSE 18A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	260 82 89. 9 99. 9	Decayed Mar. 24, 1968.
Mar. 14 DEFENSE 20A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	242 114 90. 2 83. 0	Decayed Apr. 10, 1968.
Mar. 14 DEFENSE 20B Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	326 299 94. 6 83. 1	Still in orbit.
Apr. 4 APOLLO 6 25A Saturn V	Objective: To demonstrate structural and thermal integrity and compatibility of the launch vehicle and spacecraft and to confirm launch loads and dynamic characteristics; to demonstrate separation of S–II from S–IC and S–IVB from S–II; to evaluate performance of the space vehicle; and to demonstrate support facilities and operations. Spacecraft: Payload consisted of S–IVB stage, Instrument Unit, Command and Service module, Spacecraft Lunar Module Adapter, and a Lunar Module Test Article. Total weight at insertion into orbit: 265,050 lbs.	223 107 89. 8 31. 6	Two of the five second stage engines shut down prematurely; third stage restart ignition sequence failed. In spite of these anomalies, a successful mission was flown, leading to the perfect Apollo 7 flight.
Apr. 6 OV 1–13 26A Atlas	Objectives: To determine flexibility of cadmium sulfide solar cells in a space environment and to measure proton/electron energy spectra and angular distribution of electrons. Spacecraft: Cylinder 30″ by 27″ diameter. Weight: 290 lbs.	5, 789 346 199. 5 100. 5	Still in orbit.
Apr. 6 OV 1–14 26B Atlas	Objective: To obtain high-resolution measurements of proton/electron flux, spectra, decay and time variations. Spacecraft: Cylinder 30″ by 27″ diameter. Weight: 300 lbs.	6, 173 348 207. 8 100. 0	Still in orbit.
Apr. 17 DEFENSE 31A Titan III B	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	262 79 89. 9 111. 4	Decayed April 29, 1968.

May 1 DEFENSE 39A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	176 115 88. 6 83. 1	Decayed May 15, 1968.
May 16 ESRO–II 41A Scout	Objective: To investigate X-ray radiation emitted by the Sun, to reach a better understanding of the Sun itself and to correlate X-ray flux changes with heating and ionization of the ionosphere; to investigate corpuscular radiation of the Sun, particles trapped in the magnetic field of Earth, and cosmic ray particles; and to investigate the electron component of primary cosmic radiation. Spacecraft: Twelve-sided cylinder, 33.5″ high and 30″ in diameter. Solar cell power supply. Weight: 153 lbs.	673 204 98. 9 97. 2	Six of the seven experiments are providing useful data.
May 23 DEFENSE 42A Thor-Burner II	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	561 509 102. 1 98. 9	Still in orbit.
June 5 DEFENSE 47A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	262 85 89. 9 110. 5	Decayed June 17, 1968.
June 13 IDCSP 19, 20, 21, 22, 23, 24, 25, and 26 50A, B, C, D, E, F, G, and H Titan IIIC	Objective To extend an interim defense communication satellite system. Spacecraft: Symmetrical 24 face polyhedron, 36″ diameter by 32″ high; spin-stabilized; 40 watt solar cell power supply; low channel capacity; X-band. Weight: Each spacecraft 100 lbs.	21, 027 to 21, 401 20, 954 to 20, 976 1, 335. 5 to 1, 350. 6 00. 1	Spacecraft are operating in a near-synchronous constellation along with 18 earlier spacecraft previously launched.
June 20 DEFENSE 52A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	251 113 90. 3 85. 0	Decayed July 16, 1968.
June 20 DEFENSE 52B Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	322 273 94. 1 85. 1	Still in orbit.
July 4 EXPLORER XXXVIII (RAE–A) 55A Thor-Delta	Objective: To Monitor low-frequency radio signals in space from sources including the Milky Way, the Sun, Jupiter, and Earth's environment. Spacecraft: Cylindrical structure 31″ high and 36″ in diameter with 4 extendable X-shaped 750′ antennas, gravity-gradient stabilization. Weight: 607 lbs.	3, 652 3, 639 224. 4 59. 2	The spacecraft is operating normally and has provided significant data.
July 11 OV 1–15 59A Atlas	Objective: To measure density of the atmosphere from 160 to 500 Km and its variations with position and time. Spacecraft: Cylinder 30″ by 27″ diameter. Weight: 300 lbs.	1, 032 94 103. 0 89. 8	Decayed Nov. 6, 1968.
July 11 OV 1–16 59B Atlas	Objective: To measure density of the atmosphere from 65 to 110 nm. Spacecraft: High-density ball ("Cannon Ball") with omnidirectional accelerometer.	286 82 90. 4 89. 8	Decayed Aug. 19, 1968.
Aug. 6 DEFENSE 63A Atlas-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	24. 769 19, 685 1, 436. 0 9. 9	Still in orbit.

Aug. 6 DEFENSE 64A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	266 88 90. 5 109. 5	Decayed Aug. 16, 1968.
Aug. 7 DEFENSE 65A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	161 100 88. 7 82. 1	Decayed Aug. 17, 1968.
Aug. 8 EXPLORER XXXIX 66A	Objective: To extend measurements of latitudinal, seasonal, and solar cycle variations in the upper-air density. Spacecraft: A 12-foot diameter, inflatable sphere, constructed of a 4-ply laminate consisting of alternating layers of ½ mil aluminum foil and polyethylene-terephtholate plastic film; battery and solar cell power supply; no stabilization. Weight: 20.5 lbs.	1, 548 425 117. 9 80. 6	Spacecraft performed normally.
Aug. 8 EXPLORER XL (INJUN EXPLORER) 66B	Objective: To make direct measurement of the downflux of charged particles into the atmosphere; to study geomagnetically trapped charged particles with emphasis on their spectra, spatial distribution, and time variations; and to study the very-low-frequency radio emissions in the ionosphere. Spacecraft: Hexagonal cylinder 29″ high and 30″ diameter; magnetic stabilization; solar cell power supply. Weight: 153 lbs.	1, 573 424 118. 3 80. 6	Spacecraft is operating normally and providing significant scientific data.
Aug. 11 ATS–4 68A Atlas-Centaur	Objective: To conduct a carefully instrumented gravity-gradient orientation experiment directed toward providing basic design information and, thus, to determine the feasibility and usefulness of gravity gradient as a means of stabilizing synchronous-orbit applications satellites in the presence of perturbing effects generated within the satellite or caused by environment. Spacecraft: Cylindrical 6′ high and 4′8″ in diameter with extendable booms measuring 25′ across; gravity-gradient and active stabilization; solar cell power supply. Weight: 860 lbs.	405 139 93. 3 29. 0	Failure of the Centaur stage to ignite for a second burn prevented achievement of the transfer orbit prior to injection into synchronous orbit. No useful data obtained.
Aug. 16 TOS-E/ESSA-VII 69A Thor-Delta	Objective: To operate two Advanced Videcon Camera Systems in a Sun-synchronous orbit, crossing the equator between 2:35 and 2:55 p.m. daily, to obtain daily global cloud photos and a flat plate radiometer to measure the heat balance of the atmosphere. Spacecraft: Cylindrical 37″ diameter by 35″ high; spin stabilized; solar cell power supply. Weight: 145 lbs.	918 885 114. 9 101. 7	All systems are functioning normally, and ESSA is obtaining excellent data.
Sept. 10 DEFENSE 74A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	200 89 89. 1 106. 0	Decayed Sept. 25, 1968.
Sept. 18 DEFENSE 78A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	243 111 90. 1 83. 0	Decayed Oct. 8, 1968.
Sept. 18 DEFENSE 78B Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	318 312 94. 7 83. 2	Still in orbit.

Sept. 26 OV 2–5 81A Titan IIIC	Objective: To investigate radiation at synchronous altitude. Spacecraft: Near-cubic 23″ by 23″ by 24″. Weight: 250 lbs.	22, 232 21, 827 1, 418. 1	Still in orbit.
Sept. 26 OV 5–2 81B Titan IIIC	Objective: To investigate radiation in the Van Allen belt. Spacecraft: Octahedron. Weight: 21.5 lbs.	22, 236 115 630. 8 26. 4	Still in orbit.
Sept. 26 OV 5–4 81C Titan IIIC	Objective: To measure transfer of heat in liquid Freon in a zero-G environment. Spacecraft: Weight: 28.4 lbs.	22, 225 22, 220 1, 435. 8 3. 0	Still in orbit.
Sept. 26 LES–6 81D Titan IIIC	Objective: To provide test data on an expanded UHF tactical communications satellite operating with various types of aircraft/ship/ground terminals. Spacecraft: Cylinder 5-½′ by 4′ diameter; spin stabilized; geo-stationary. Weight: 360 lbs.	22, 236 22, 233 1, 435. 9 2. 9	Still in orbit.
Oct. 3 ESRO I-A 84A Scout	Objective: To perform an integrated study of the high-latitude ionosphere, including particle experiments, auroral photometry, and ionospheric experiments. Spacecraft: Cylindrical 30″ diameter and 39″ high with sensor booms extending tip-to-tip 95.6″ and 60″ height. Passive magnetic stabilization; solar cell power supply. Weight: 189 lbs.	932 171 102. 6 94	The spacecraft is functioning normally and providing significant data.
Oct. 5 DEFENSE 86A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	316 300 94. 5 74. 9	Still in orbit.
Oct. 11 APOLLO 7 89A Saturn IB	Objective: To verify proper operation of the Command and Service Module (CSM) systems and operational capabilities of the CSM, crew, and manned space flight network support facilities in an Earth-orbital environment. To qualify heat shield; to determine Environmental Control System radiator performance and coating degradation; to perform transposition and simulated docking; and to evaluate CSM active rendezvous activities. Spacecraft: Payload consisted of Command Module and Service Module; active stabilization; three 31-cell Bacon-type hydrogen-oxygen fuel cells plus battery power supply. Total weight at injection into initial orbit: 69,345 lbs. Weight of CSM at injection: 32,557 lbs.	177 138 89. 6 31. 6	Crew consisted of Walter M. Schirra, Commander; Don F. Eisele, Command Module pilot; and Walter Cunningham, Lunar Module pilot. All primary and secondary objectives of the flight successfully accomplished. Length of flight: 260 hours, 8 minutes, 15 seconds. Service Propulsion System restarts: 8.
Oct. 23 DEFENSE 92A Thor-Burner II	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	529 497 101. 3 99. 0	Still in orbit.
Nov. 3 DEFENSE 98A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	177 108 88. 8 82. 1	Decayed Nov. 23, 1968.
Nov. 6 DEFENSE 99A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	249 90 89. 8 106. 0	Decayed Nov. 20, 1968.

Nov. 8 PIONEER IX 100A Thor-Delta	Objective: To obtain solar plasma, magnetic field, and cosmic-ray measurements in the region of space which is inward toward the Sun from the orbital path of Earth. Spacecraft: Cylindrical structure 37″ diameter and 35″ high; active stabilization; solar cell power supply. Weight: 147 lbs.	.99AU .75AU 297.55 days .09	The spacecraft is functioning normally and is returning significant scientific data.
Nov. 8 TTS 100B Thor-Delta	Objective: To provide a pre-mission checkout for manned space flight network stations; to provide training of MSFN ground system crews; to provide routine mission simulations; and to develop and verify acquisition and hand-over techniques. Spacecraft: Octahedral shape, approximately 14″ on a side; passive magnetic stabilization; solar cell power supply. Weight: 40 lbs.	584 231 97. 9 33	The spacecraft is functioning normally.
Dec. 4 DEFENSE 108A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	454 94 89. 3 106. 2	Decayed Dec. 12, 1968.
Dec. 5 HEOS–A 109A Thor-Delta (ESRO procured)	Objective: To investigate interplanetary magnetic fields, and study solar and cosmic-ray particles outside the magnetosphere during a period of maximum solar activity. Spacecraft: ESRO developed, designed, and constructed; cylindrical shape 48.6″ diameter and 27.3″ high; spin stabilized; solar cell power supply. Weight: 240 lbs.	138, 841 263 6, 749 28. 3°	Spacecraft is functioning normally and is providing significant scientific data.
Dec. 10 OAO–2 110A Atlas-Centaur	Objective: To make precise astronomical observations from above Earth's atmosphere of stars, planets, nebulae, galaxies, and the interplanetary and interstellar matter in the regions of their electromagnetic radiation spectrum that do not penetrate Earth's atmosphere, i.e., ultraviolet, X-ray and gamma ray. Spacecraft: Octagonal body 10′ high and 7′ wide with 2 external solar panels and other appendages; active stabilization; solar cell power supply; Weight: 4,400 lbs.	486 479 100. 4 35°	Spacecraft is functioning normally, and significant scientific data is being received.
Dec. 12 DEFENSE 112A Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	148 109 88. 6 81. 0	Decayed Dec. 28, 1968.
Dec. 12 DEFENSE 112B Thor-Agena D	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	916 862 114. 4 80. 3	Still in orbit.
Dec. 15 TOS–F/ESSA VIII 114A Thor-Delta	Objective: To operate 2 Automatic Picture Transmission (APT) camera systems in a Sun-synchronous orbit crossing the equator between 08:40 and 09:00 a.m. daily Spacecraft: Cylindrical 42″ diameter and 23″ high; spin stabilized; solar cell power supply. Weight: 286 lbs.	907 881 114. 7 102°	All systems are functioning normally and ESSA and other APT ground station operators are receiving excellent pictures.
Dec. 19 INTELSAT III 116A Thor-Delta	Objective: To provide equivalent of 1,200 2-way voice circuits or 4 color TV channels to carry communications traffic between North America, Europe, South America, and Africa. Spacecraft: Cylindrical 56″ diameter and 78″ high; spin-stabliized; solar cell power supply. Weight: 303 lbs.	22, 255 22, 241 1, 436 . 775°	The spacecraft has been positioned on the equator in synchronous orbit at 31° West longitude near the eastern tip of Brazil.

Dec. 21 APOLLO 8 118A Saturn V	Objective: To verify crew, space vehicle, and mission support facilities on a manned lunar orbit flight plan; to demonstrate performance of nominal and selected backup Lunar Orbit Rendezvous mission activities, including trans-lunar injection, Command and Service Module navigation, communications, and midcourse corrections, and Command and Service Module consumables assessment and passive thermal control. Spacecraft: Payload consisted of Command Module and Service Module; active stabilization, 3 31-cell Bacon-type hydrogen-oxygen fuel cells plus battery power supply Total weight at injection into lunar orbit: 46,444 lbs.	lunar orbit 70. 1 69. 7 119. 0 12. 33°	Crew consisted of Frank Borman, Commander; James A. Lovell, Jr., Command Pilot; and William A. Anders, Lunar Module Pilot. The flight completed 10 lunar orbits and successfully returned to Earth and was recovered in the Pacific Ocean on Dec. 27, 1968. Total flight time: 147 hours, 41 seconds.

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL AERONAUTICS AND SPACE COUNCIL
WASHINGTON

December 31, 1968

Major United States And Soviet 'Firsts'

One of the indexes used to compare the space programs of the United States and the Soviet Union are the "firsts" achieved by each nation. Since it measures the quantity but not the quality of achievement, such compilation can be misleading. However, when broken down into meaningful areas, it can help in judging emphasis and even relative progress if coupled with other evidence.

Regardless of whether a "first" gives either country a significant lead in a particular area of space technology, the fact of being first is significant in the formation of public opinion. In fact, regardless of actual technological competence, the relative position of the United States and the U.S.S.R. in space is often judged by the "firsts" achieved by each.

A list of all of the "firsts" scored by each side would be long and meaningless. An effort has been made to select those actions or accomplishments which seemed to be of major importance, bearing in mind that because of the closed nature of some space activities, the list of major "firsts" may be incomplete.

This list is divided into five broad categories of space interest. It is not a comparison of space competences but rather a cataloging based upon the timing of events.

Major Space 'Firsts'

United States

Event	Satellite	Launch date
Science		
Van Allen radiation belts	Explorer I	2/ 1/58
Earth shape measured	Vanguard I	3/17/58
Orbiting solar observatory	OSO I	3/ 7/62
Data from Venus	Mariner II	8/27/62
Geodetic satellite	Anna IB	10/31/62
Lunar close-up pictures	Ranger VII	7/28/64
Mars pictures	Mariner IV	11/28/64
Micrometeorite satellite	Pegasus I	2/16/65
Lunar orbit pictures	Orbiter I	8/10/66
Lunar trenching	Surveyor III	4/17/67
Color picture of full Earth face.	DODGE	7/ 1/67
Lunar soil chemical analysis	Surveyor V	9/ 8/67
Point-stabilized Orbiting Astro-Observatory.	OAO-2	12/10/68
Live lunar TV broadcast	Apollo 8	12/21/68
Applications		
Active communications	Score	12/18/58
TV pictures from space	Explorer VI	8/ 7/59
Weather satellite	Tiros I	4/ 1/60
Navigation satellite	Transit IB	4/13/60
Missile detection	Midas II	5/24/60
Passive communications	Echo I	8/12/60
Nuclear explosion detection	Vela Hotel	10/17/63
Manned viewing of lunar far side	Apollo 8	12/21/68
Bio and Manned Flight		
Manned orbital maneuver	Gemini III	3/23/65
Controlled extravehicular activity.	Gemini IV	6/ 3/65
Manned space rendezvous	Gemini VI, VII	12/ 4/65
Manned docking	Gemini VIII-Agena	3/16/66
Manned lunar orbit	Apollo 8	12/21/68
Manned lunar return re-entry	Apollo 8	12/21/68
Manned Earth escape	Apollo 8	12/21/68
Space flight and Propulsion		
Multiple spacecraft payload	Transit/Solrad	6/22/60
Payload recovery	Discoverer XIII	8/10/60
Synchronous satellite	Syncom II	7/26/63
Hydrogen rocket orbited	Centaur II	11/27/63
Docked spacecraft maneuver	Gemini X-Agena	7/18/66
Lunar lift-off	Surveyor VI	11/ 7/67
Lunar-velocity re-entry	Apollo I	11/ 9/67
Constant deceleration re-entry	Apollo 8	12/21/68
Auxiliary Power Systems		
Solar cells	Vanguard I	3/17/58
Isotope power	Transit IVA	6/29/61
Nuclear reactor in orbit	Snapshot I	4/ 3/65
Fuel cell	Gemini V	8/21/65

Union of Soviet Socialist Republics

Event	Satellite	Launch date
Science		
Orbiting geophysical lab	Sputnik III	5/15/58
Farside lunar picture	Luna III	10/ 4/59
Cosmic ray measurements	Proton I	7/16/65
Lunar surface pictures	Luna IX	1/31/66
Lunar surface bearing test	Luna XIII	12/21/66
Venus atmospheric probe	Venera IV	6/12/67
Applications		
Bio and Manned Flight		
Biosatellite	Sputnik II	11/ 3/57
Recovery, orbited animals	Sputnik V	8/19/60
Recovery, orbited man	Vostok I	4/12/61
Multi-manned spacecraft	Voskhod I	10/12/64
Extravehicular activity	Voskhod II	3/18/65
Recovery, circumlunar live animals.	Zond V	9/21/68
Space Flight and Propulsion		
Space flight	Sputnik I	10/ 4/57
Earth escape spacecraft	Luna I	1/ 2/59
Lunar impact	Luna II	9/12/59
Orbital platform launch	Sputnik V	2/12/61
Venus flyby	Venera I	2/12/61
Mars flyby	Mars I	11/ 1/62
Venus impact	Venera III	11/16/65
Lunar soft landing	Luna IX	1/31/66
Lunar orbiter	Luna X	3/31/66
Automatic docking	Cosmos 186/188	10/27–29/67
Recovery, lunar payload	Zond V	9/21/68
Auxiliary Power Systems		
Battery power	Sputnik I	10/ 4/57

U.S. Applications Satellites 1958–1968

COMMUNICATIONS

Date	Name	Launch vehicle	Remarks
Dec. 18, 1958	Score	Atlas B	First comsat, carried taped messages.
Aug. 12, 1960	Echo I	Thor-Delta	100-foot balloon served as first passive comsat, relayed voice and TV signals.
Oct. 4, 1960	Courier 1B	Thor-Able Star	First active-repeater comsat.
Dec. 12, 1961	Oscar I	Thor-Agena B	First amateur radio "ham" satellite.
June 2, 1962	Oscar II	Thor-Agena B	
July 10, 1962	Telstar I	Thor-Delta	Industry-furnished spacecraft in near-Earth orbit.
Dec. 13, 1962	Relay I	Thor-Delta	Active-repeater comsat.
Feb. 14, 1963	Syncom I	Thor-Delta	Successfully injected into near-synchronous orbit but communication system failed at orbital injection.
May 7, 1963	Telstar II	Thor-Delta	
July 26, 1963	Syncom II	Thor-Delta	First successful synchronous orbit active-repeater comsat. After experimental phase, used operationally by DOD.
Jan. 21, 1964	Relay II	Thor-Delta	
Jan. 25, 1964	Echo II	Thor-Agena B	135-foot balloon, passive comsat, first joint use by U.S. and U.S.S.R.
Aug. 19, 1964	Syncom III	Thor-Delta	Synchronous-orbit comsat; after experimental phase, used operationally by DOD.
Mar. 9, 1965	Oscar III	Thor-Agena D	
Apr. 6, 1965	Intelsat I (Early Bird)	Thor-Delta	First Intelsat (ComSat Corp.) spacecraft, 240 two-way voice circuits; commercial transatlantic communication service initiated June 28, 1965.
Dec. 21, 1965	Oscar IV	Titan IIIC	
June 16, 1966	IDCSP 1–7	Titan IIIC	Initial Defense Communication Satellites Program. Active-repeater spacecraft in near-synchronous orbit, random-spaced.
Oct. 26, 1966	Intelsat II–F1	Thor-Delta	First in Intelsat II series spacecraft; 240 two-way voice circuits or one color TV channel. Orbit achieved not adequate for commercial operation.
Jan. 11, 1967	Intelsat II–F2	Thor-Delta	Transpacific commercial communication service initiated Jan. 11, 1967.
Jan. 18, 1967	IDCSP 8–15	Titan IIIC	
Mar. 22, 1967	Intelsat II–F3	TAD	Positioned to carry transatlantic commercial communication traffic.
July 1, 1967	IDCSP 16–18	Titan IIIC	
July 1, 1967	LES 5	Titan IIIC	Tactical military communication tests with aircraft, ships, and mobile land stations from near-synchronous orbit.
Sept. 27, 1967	Intelsat II–F4	Thor-Delta	Positioned to carry commercial transpacific communication traffic.
June 13, 1968	IDSCS 19–26	Titan IIIC	
Sept. 26, 1968	LES 6	Titan IIIC	Continued military tactical communications experiments.
Dec. 18, 1968	Intelsat III	Thor-Delta	First in Intelsat III series of spacecraft. 1,200 two-way voice circuits or four color TV channels. Positioned over Atlantic to carry traffic between North America, South America, Africa, and Europe. Entered commercial service on Dec. 24, 1968.

NAVIGATION

Date	Name	Launch vehicle	Remarks
Apr. 13, 1960	Transit 1B	Thor-Able Star	First navigation satellite. Used Doppler frequency shift for position determination.
June 22, 1960	Transit 2A	Thor-Able Star	
Feb. 21, 1961	Transit 3B	Thor-Able Star	
June 29, 1961	Transit 4A	Thor-Able Star	Used the first spacecraft nuclear SNAP–3 as a secondary power supply.
Nov. 15, 1961	Transit 4B	Thor-Able Star	
Dec. 18, 1962	Transit 5A	Scout	Operational prototype, power failed during first day.
June 15, 1963	NavSat	Scout	Used gravity-gradient stabilization system.
Sept. 28, 1963	NavSat	Thor-Able Star	Used first nuclear SNAP–9A as primary power supply.
Dec. 5, 1963	NavSat	Thor-Able Star	
June 4, 1964	NavSat	Scout	
Oct. 6, 1964	NavSat	Thor-Able Star	
Dec. 13, 1964	NavSat	Thor-Able Star	
June 24, 1965	NavSat	Thor-Able Star	
Aug. 13, 1965	NavSat	Thor-Able Star	
Dec. 22, 1965	NavSat	Scout	
Jan. 28, 1966	NavSat	Scout	
Mar. 25, 1966	NavSat	Scout	
May 19, 1966	NavSat	Scout	
Aug. 18, 1966	NavSat	Scout	
Apr. 13, 1967	NavSat	Scout	
May 18, 1967	NavSat	Scout	
Sept. 25, 1967	NavSat	Scout	
Mar. 1, 1968	NavSat	Scout	

WEATHER OBSERVATION

Date	Name	Launch vehicle	Remarks
Apr. 1, 1960	Tiros I	Thor Able	First weather satellite providing cloud-cover photography.
Nov. 23, 1960	Tiros II	Thor-Delta	
July 12, 1961	Tiros III	Thor-Delta	
Feb. 8, 1962	Tiros IV	Thor-Delta	
June 19, 1962	Tiros V	Thor-Delta	
Sept. 18, 1962	Tiros VI	Thor-Delta	
June 19, 1963	Tiros VII	Thor-Delta	
Dec. 21, 1963	Tiros VIII	Thor-Delta	First weather satellite designed to transmit continuously local cloud conditions to ground stations equipped with APT receivers.
Aug. 28, 1964	Nimbus I	Thor-Agena B	Carried Advanced Videcon Camera System, APT, and a high-resolution infrared radiometer for night pictures.
Jan. 22, 1965	Tiros IX	Thor-Delta	First weather satellite in a Sun-synchronous orbit.
July 2, 1965	Tiros X	Thor-Delta	
Feb. 3, 1966	ESSA I	Thor-Delta	First operational weather satellite; carried two wide-angle TV camera systems.
Feb. 28, 1966	ESSA II	Thor-Delta	Complemented ESSA I with two wide-angle APT cameras.
May 15, 1966	Nimbus II	Thor-Agena B	
Oct. 2, 1966	ESSA III	Thor-Delta	Odd-numbered ESSA spacecraft carry two Advanced Videcon Camera Systems. Even-numbered spacecraft carry two Automatic Picture Transmission camera systems.
Dec. 6, 1966	ATS–1	Atlas-Agena D	Provided continuous black-and-white cloud-cover pictures from a synchronous orbit, using a Soumi camera system.
Jan. 26, 1967	ESSA IV	Thor-Delta	
Apr. 20, 1967	ESSA V	Thor-Delta	
Nov. 5, 1967	ATS–3	Atlas-Agena D	Provided continuous color cloud-cover pictures from a synchronous orbit, using three Soumi camera systems.
Nov. 10, 1967	ESSA VI	Thor-Delta	
Aug. 16, 1968	ESSA VII	Thor-Delta	
Dec. 15, 1968	ESSA VIII	Thor-Delta	

GEODESY

Date	Name	Launch vehicle	Remarks
Oct. 31, 1962	Anna 1B	Thor-Able Star	Used three independent measuring techniques: Doppler frequency shift, flashing lights, and radio triangulation.
Jan. 11, 1964	Secor I	Thor-Agena D	Uses radio triangulation and trilateration.
Oct. 10, 1964	Beacon-Explorer XXII	Scout	Conducted reflecting-light geodetic measurements.
Mar. 9, 1965	Secor III	Thor-Agena D	
Mar. 11, 1965	Secor II	Thor-Able Star	
Apr. 3, 1965	Secor IV	Atlas-Agena D	
Apr. 29, 1965	Beacon-Explorer XXVII	Scout	
Aug. 10, 1965	Secor V	Scout	
Nov. 6, 1965	GEOS–I Explorer XXIX	Thor-Delta	
June 9, 1966	Secor VI	Atlas-Agena D	
June 23, 1966	Pageos I	Thor-Agena D	Spacecrafti s a 100-foot-diameter balloon used as a photographic target to make geodetic measurements.
Aug. 19, 1966	Secor VII	Atlas-Agena D	
Oct. 5, 1966	Secor VIII	Atlas-Agena D	
June 29, 1967	Secor IX	Thor-Burner II	
Jan. 11, 1968	GEOS II	Thor-Delta	

DEFENSE SUPPORT

Date	Number of Spacecraft	Launch vehicle used	Remarks
Apr. 13, 1959 to Dec. 31, 1968.	10	Thor-Agena A	This list does not include communications, navigation, or geodetic satellites specifically identified above in the application categories.
	31	Thor-Agena B	
	106	Thor-Agena D	
	4	Thor-Able Star	
	5	Thor-Altair	
	6	Thor-Burner II	
	4	Atlas-Agena A	
	12	Atlas-Agena B	
	67	Atlas-Agena D	
	17	Titan IIIB-Agena D	
	3	Titan IIIC	

History of U.S. and Soviet Manned Space Flights

Spacecraft	Launch Date	Crew	Flight time	Highlights
Vostok 1	Apr. 12, 1961	Yuri A. Gagarin	1 hr. 48 mins.	First manned flight.
Mercury-Redstone 3	May 5, 1961	Alan N. Shepard, Jr.	15 mins.	First U.S. flight; suborbital.
Mercury-Redstone 4	July 21, 1961	Virgil I. Grissom	16 mins.	Suborbital; capsule sank after landing.
Vostok 2	Aug. 6, 1961	Gherman S. Titov	25 hrs. 18 mins.	First flight exceeding 24 hrs.
Mercury-Atlas 6	Feb. 20, 1962	John H. Glenn, Jr.	4 hrs. 55 mins.	First American to orbit.
Mercury-Atlas 7	May 24, 1962	M. Scott Carpenter	4 hrs. 56 mins.	Landed 250 mi. from target.
Vostok 3	Aug. 11, 1962	Andrian G. Nikolayev	94 hrs. 22 mins.	First dual mission (with Vostok 4)
Vostok 4	Aug. 12, 1962	Pavel R. Popovich	70 hrs. 57 mins.	Came within 3.1 mi. of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr	9 hrs. 13 mins.	Landed 5 mi. from target.
Mercury-Atlas 9	May 15, 1963	L. Gordon Cooper, Jr.	34 hrs. 20 mins.	First long U.S. flight.
Vostok 5	June 14, 1963	Valery F. Bykovsky	119 hrs. 6 mins.	Second dual mission (with Vostok 6)
Vostok 6	June 6, 1963	Valentina V. Tereshkova	70 hrs. 50 mins.	First woman in space; within 5 mi. of Vostok 5
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Dr. Boris G. Yegorov	24 hrs. 17 mins.	First 3-man crew.
Voskhod 2	Mar. 18, 1965	Aleksei A. Leonov Pavel I. Belyayev	26 hrs. 2 mins.	First extravehicular activity (Leonov, 10 minutes)
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	4 hrs. 53 mins.	First U.S. 2-man flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White, 2d	97 hrs. 56 mins.	21-minute extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	190 hrs. 55 mins.	Longest-duration manned flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	330 hrs. 36 mins.	Longest-duration manned flight.
Gemini 6–A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	25 hrs. 51 mins.	Rendezvous within 1 foot of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	10 hrs. 41 mins.	First docking of 2 orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9–A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	72 hrs. 21 mins.	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	70 hrs. 47 mins.	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	71 hrs. 17 mins.	First initial-orbit rendezvous; first tethered flight; highest Earth-orbit altitude (853 miles).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	94 hrs. 35 mins.	Longest extravehicular activity (Aldrin, 5 hours 37 minutes).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	26 hrs. 40 mins.	Cosmonaut killed in re-entry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	260 hrs. 8 mins.	First U.S. three-man mission.
Soyuz 3	Oct. 26, 1968	Georgi Beregovoy	94 hrs. 51 mins.	Maneuvered near unmanned Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	147 hrs.	First manned orbit(s) of Moon; first manned departure from Earth's sphere of influence; highest speed ever attained in manned flight.

	U.S.	U.S.S.R.		U.S.	U.S.S.R.
Total manned spacecraft hours	1,434	556	Manned space dockings	7	0
Total man-hours in space	3,215	631	Manned flights	18	10
Total extravehicular activity	12 hrs.	10 mins.	Multi-manned flights	12	2
Rendezvous	12	2	Maneuverable spacecraft	12	1

United States Space Launch Vehicles

Vehicle	Stages	Propellant	Thrust (in thousands of pounds)	Max. dia. (feet)	Height less spacecraft (feet)	Payload (pounds)		
						300 NM orbit	Escape	First launch
Scout	1. Algol (IIB)	Solid	100.9	3.3	64.4	320	50	[1] 1965 (60)
	2. Castor II	Solid	60.7					
	3. Antares II	Solid	20.9					
	4. Altair III or FW4.	Solid	5.9					
Thrust-augmented Thor Delta.	1. Thor (SLV-2A) plus	LOX/RP	172	11	90	1,200	250	1966 (60)
	three TX 33-52	Solid	[2] 54					
	2. Delta (DSV-3)	IRFNA/UDMH	7.5					
	3. FW-4D	Solid	5.9					
Thrust-augmented Thorad-Delta.	1. Thor (SLV-2J) plus	LOX/RP	[3] 170	11	105	1,900	590	1968 (60)
	three TX 354-5	Solid	[2] 52					
	2. Delta (DSV-3)	IRFNA/UDMH	7.8					
	3. FW-4D	Solid	5.9					
Thrust-augmented Thorad-Agena.	1. Thor (SLV-2H) plus.	LOX/RP	170	11	80	2,900	....	1966 (60)
	three TX 354-5	Solid	[2] 52					
	2. Agena	IRFNA/UDMH	16					
Atlas-Agena	1. Atlas booster and sustainer (SLV-3A).	LOX/RP	450	10	100	7,500	1,430	1968 (60)
	2. Agena	IRFNA/UDMH	16					
Titan IIIB-Agena	1. Two LR-87	N_2O_4/Aerozine	440	10	112	8,000	1,550	1966
	2. LR-91	N_2O_4/Aerozine	100					
	3. Agena	IRFNA/UDMH	16					
Titan IIIC	1. Two 5-segment 120" diameter.	Solid	2,400	10x30	110	23,000	5,200	1965
	2. Two LR-87	N_2O_4/Aerozine	440					
	3. LR-91	N_2O_4/Aerozine	100					
	4. Transtage	N_2O_4/Aerozine	16					
Atlas-Centaur	1. Atlas booster and sustainer.	LOX/RP	450	10	100	9,100	2,700	1967 (62)
	2. Centaur (Two RL-10).	LOX/LH	30					
Uprated Saturn I	1. S-IB (Eight H-1).	LOX/RP	1,600	21.6	142	40,000@ 105 NM	....	1966
	2. S-IVB (One J-2).	LOX/LH	200					
Saturn V	1. S-IC (Five F-1)	LOX/RP	7,570	33	[4] 281	285,000@ 105 NM	101,500	1967
	2. S-II (Five J-2)	LOX/LH	1,125					
	3. S-IVB (One J-2).	LOX/LH	225					

NOTES: Definitive data are difficult to compile. Payload capacity data vary according to the place and direction of launch as well as intended orbital altitude. Vehicles still under development may fall short of or exceed their projected capacities, both in payload and in engine thrust. First stage thrust shown is sea level value. Modifications of existing vehicles have already raised their performance, and future modifications may be expected in several cases. In general, these data apply to the latest versions now under development.

[1] The date of first launch applies to this latest modification with a date in parentheses for the earlier version.

[2] Each.

[3] Plus.

[4] 363 feet, including Apollo modules and Launch Escape System.

Propellant abbreviations used are as follows: Liquid Oxygen and a modified Kerosene—LOX/RP; Solid propellant combining in a single mixture both fuel and oxidizer—Solid; Inhibited Red Fuming Nitric Acid and Unsymmetrical Dimethylhydrazine—IRFNA/UDMH; Nitrogen Tetroxide and Aerozine—N_2O_4/Aerozine; Liquid Oxygen and Liquid Hydrogen—LOX/LH.

Values marked......... are either zero or not pertinent for the vehicle.

Nuclear Power Systems for Space Applications

Designation	Electrical power (watts)	Design life	Application	Fuel	Status
SNAP–3	2.7	5 years	Navigation satellites (DOD)	Plutonium-238	Units launched in June and November, 1961. June unit still operating in orbit, but quantitative performance data not available.
SNAP–9A	25	5 years	Navigation satellites (DOD)	Plutonium-238	Units launched in September and December, 1963, are still operating, but at a lower power level. Third satellite failed to orbit in April, 1964.
SNAP–11	25	90 days	Moon Probe (NASA)	Curium-242	First fueling of a generator with Curium-242 accomplished in July, 1966. In October fueled unit completed 90-day test under simulated conditions. Generator not used; since no 90-day lunar missions approved.
SNAP–19	30	1 year	NIMBUS B weather satellite (NASA)	Plutonium-238	Nimbus B launch aborted; Pu–238 fuel recovered from offshore waters. Replacement unit delivered for use in Nimbus B–2.
SNAP–27	50	1 year	Apollo Lunar Surface Experiment (ALSEP) (NASA)	Plutonium-238	Five complete power units delivered for ALSEP integrated system tests.
SNAP–29	500	90–120 days	Manned and unmanned space applications (DOD and NASA)	Polonium-210	Detailed design and subcomponents development initiated. Fueled systems scheduled for ground test during 1969–70 period.
Isotope-Brayton System.	5,500	5 years with replacement of components.	Manned stations, lunar base (DOD and NASA)	Plutonium-238	AEC will develop isotope source for joint AEC–NASA system ground test in early 1970's.
Navigation Satellite Generator.	20	5 years	Navigation Satellites (DOD)	Plutonium-238	Development program initiated.
SNAP 10A	500	1 year	Unmanned missions	Zirconium hydride reactor.	Tested in orbit in 1965.
Reactor-Thermoelectric or Mercury Rankine.	1–100 kw	1–5 years	Manned and unmanned mission	Zirconium hydride reactor.	Subsystem Technology under development.

Space Activities of the United States Government

HISTORICAL SUMMARY AND 1970 BUDGET RECOMMENDATIONS JANUARY 1969—NEW OBLIGATIONAL AUTHORITY

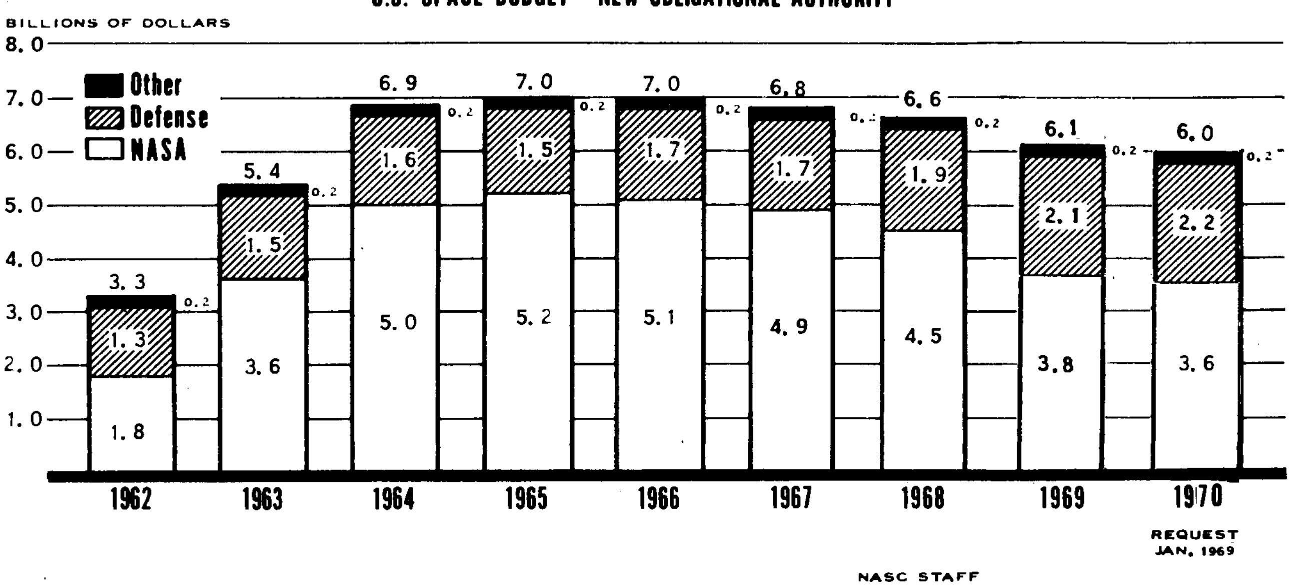
[In millions of dollars]

	NASA		Department of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total space
	Total	Space [1]							
1955	56. 9	56. 9	3. 0						59. 9
1956	72. 7	72. 7	30. 3	7. 0				7. 3	117. 3
1957	78. 2	78. 2	71. 0	21. 3				8. 4	178. 9
1958	117. 3	117. 3	205. 6	21. 3				3. 3	347. 5
1959	305. 4	235. 4	489. 5	34. 3					759. 2
1960	523. 6	461. 5	560. 9	43. 3				. 1	1, 065. 8
1961	964. 0	926. 0	813. 9	67. 7				. 6	1, 808. 2
1962	1, 824. 9	1, 796. 8	1, 298. 2	147. 8	50. 7			1. 3	3, 294. 8
1963	3, 673. 0	3, 626. 0	1, 549. 9	213. 9	43. 2			1. 5	5, 434. 5
1964	5, 099. 7	5, 046. 3	1, 599. 3	210. 0	2. 8			3. 0	6, 861. 4
1965	5, 249. 7	5, 167. 6	1, 573. 9	228. 6	12. 2			3. 2	6, 985. 5
1966	5, 174. 9	5, 094. 5	1, 688. 8	186. 8	26. 5	4. 1		3. 2	7, 003. 9
1967	4, 967. 6	4, 862. 2	1, 663. 6	183. 6	29. 3	3. 0		2. 8	6, 744. 5
1968	4, 588. 8	4, 452. 5	1, 921. 8	145. 1	28. 1	2. 0	0. 5	3. 2	6, 553. 2
1970 budget:									
1969	3, 994. 9	3, 844. 8	2, 082. 5	117. 2	20. 2	2. 2	. 7	3. 3	6, 070. 9
1970	3, 760. 5	3, 599. 0	2, 218. 7	105. 5	9. 7	6. 0	3. 6	3. 7	5, 946. 2

[1] Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA–NACA aircraft and space activities not separately identifiable prior to 1959.

NOTE: Details may not add to totals because of rounding.
Source: Bureau of the Budget.

U.S. SPACE BUDGET · NEW OBLIGATIONAL AUTHORITY



Space Activities of the United States Government

HISTORICAL SUMMARY AND 1970 BUDGET RECOMMENDATIONS, JANUARY 13, 1969—EXPENDITURES

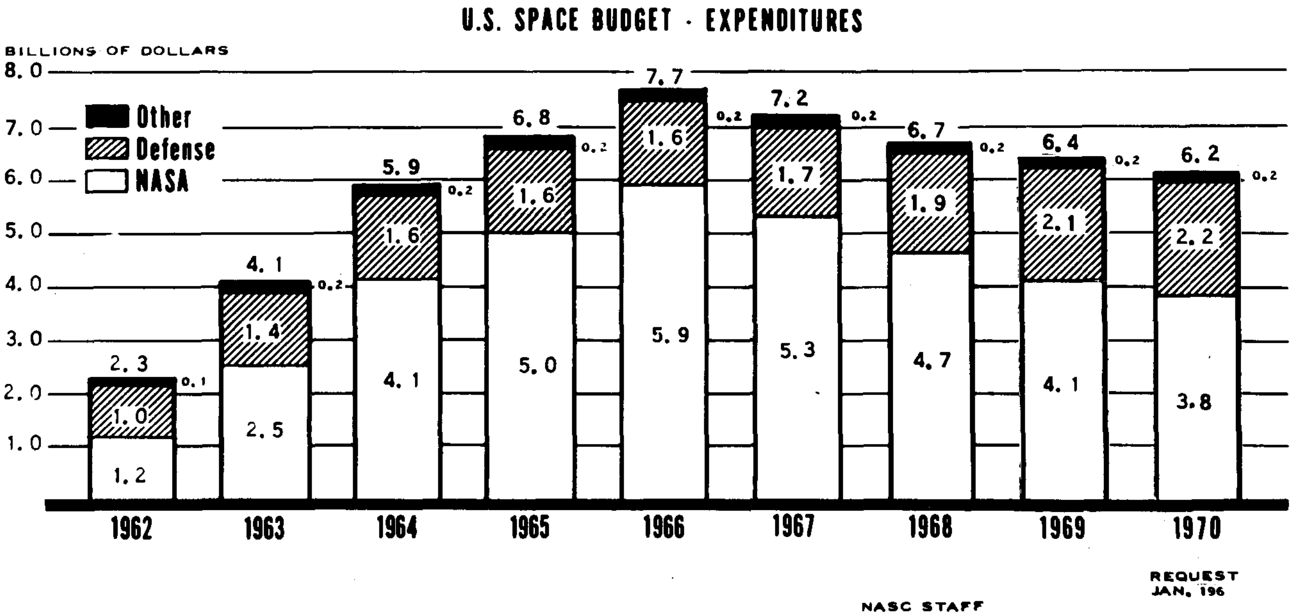
[In millions of dollars]

	NASA		Department of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total space
	Total	Space [1]							
1955	73.8	73.8	1.5						75.3
1956	71.1	71.1	16.5	6.3				6.2	100.1
1957	76.1	76.1	47.5	19.2				7.3	150.1
1958	89.2	89.2	135.5	20.2				4.0	248.9
1959	145.6	58.8	341.0	32.6				1.5	433.9
1960	401.0	329.2	518.1	41.1					888.4
1961	744.3	693.6	710.0	64.3					1,467.9
1962	1,257.0	1,225.9	1,028.8	130.0	1.0			.9	2,386.6
1963	2,552.3	2,516.8	1,367.5	181.0	12.2			1.1	4,078.6
1964	4,171.0	4,131.3	1,563.5	220.1	12.3			2.6	5,929.8
1965	5,092.9	5,035.0	1,591.8	232.2	24.1			3.0	6,886.1
1966	5,933.0	5,857.9	1,637.4	188.3	28.1	4.0		2.8	7,718.5
1967	5,425.7	5,336.7	1,673.1	183.6	38.6	2.9		2.4	7,237.3
1968	4,723.7	4,595.3	1,890.2	146.5	29.0	2.0	0.5	3.2	6,666.7
1970 budget:									
1969	4,249.7	4,097.5	2,095.0	117.0	27.4	2.2	.7	3.2	6,343.0
1970	3,950.0	3,791.3	2,175.0	107.7	32.3	3.0	3.5	3.5	6,116.3

[1] Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA–NACA aircraft and space activities not separately identifiable prior to 1959.

NOTE: Details may not add to totals because of rounding.

Source: Bureau of the Budget.



Space Activities Budget

1970 BUDGET DOCUMENT, JAN. 13, 1969

[In millions of dollars]

	New obligational authority			Expenditures		
	1968 actual	1969 est.	1970 est.	1968 actual	1969 est.	1970 est.
Federal space programs:						
NASA [1]	4, 452. 5	3, 844. 8	3, 599. 0	4, 595. 3	4, 097. 5	3, 791. 3
Department of Defense	1, 921. 8	2, 082. 5	2, 218. 7	1, 890. 2	2, 095. 0	2, 175. 0
Atomic Energy Commission	145. 1	117. 2	105. 5	146. 5	117. 0	107. 7
Department of Commerce	28. 1	20. 2	9. 7	29. 0	27. 4	32. 3
Department of Interior	2. 0	2. 2	6. 0	2. 0	2. 2	3. 0
Department of Agriculture	0. 5	0. 7	3. 6	0. 5	0. 7	3. 5
National Science Foundation	3. 2	3. 3	3. 7	3. 2	3. 2	3. 5
Total	6, 553. 2	6, 070. 9	5, 946. 2	6, 666. 7	6, 343. 0	6, 116. 3
NASA:						
Manned space flight	3, 154. 9	2, 510. 2	2, 339. 3	3, 096. 6	2, 756. 6	2, 412. 6
Scientific investigations	511. 0	406. 1	488. 9	583. 7	469. 5	478. 6
Space applications	130. 5	124. 9	169. 6	115. 8	126. 9	148. 9
Space technology	379. 8	336. 6	340. 3	409. 6	380. 6	358. 3
Aircraft technology	136. 3	150. 2	161. 5	128. 4	152. 2	158. 7
Supporting operations	327. 4	349. 4	378. 4	389. 7	363. 4	393. 3
Adjustments to NOA basis	−51. 1	+117. 5	−117. 5	....	....	....
Total	4, 588. 8	3, 994. 9	3, 760. 5	4, 723. 7	4, 249. 7	3, 950. 0

[1] Excludes amounts for aircraft technology.

Source: Bureau of the Budget.

Aeronautics Budget

[In millions of dollars]

	New obligational authority		
	1968	1969 est.	1970 est.
Federal aeronautics programs:			
NASA [1]	136. 3	150. 2	161. 5
Department of Defense [2]	1, 125. 5	987. 4	1, 349. 3
Department of Transportation [3]—Federal Aviation Agency	142. 4	−30. 0	0. 0
Total	1, 404. 2	1, 107. 6	1, 510. 8

[1] R&D, RPM, C. of F.
[2] RDT & E aircraft and related equipment.
[3] R&D, SST. Unobligated balances rescinded in 1969.

Source: Bureau of the Budget.

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