Aeronautics and Space Report of the President

TRANSMITTED TO THE CONGRESS
JANUARY 1970

1969

Aeronautics and Space Report of the President

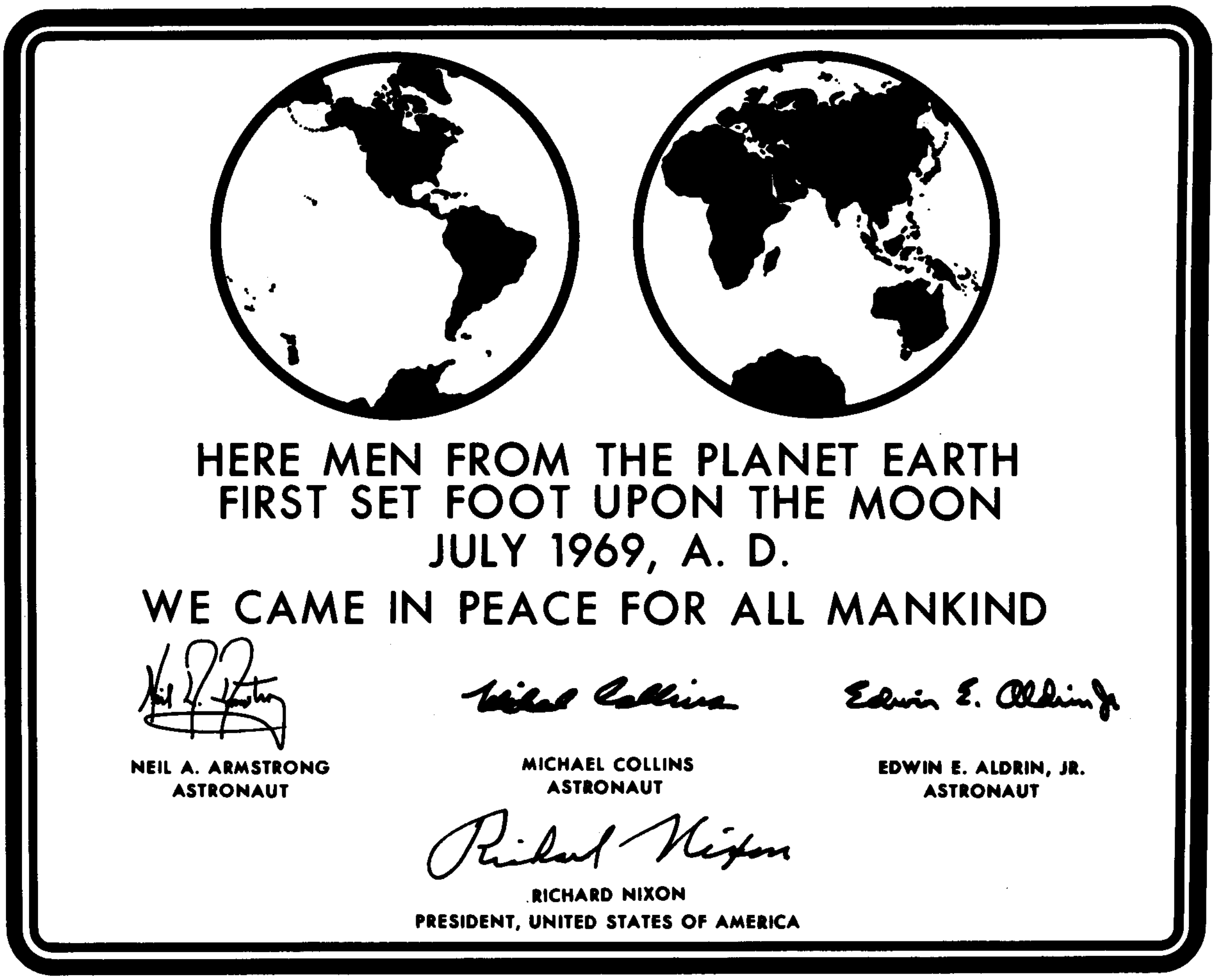
1969

TRANSMITTED TO THE CONGRESS
JANUARY 1970

Executive Office of the President

National Aeronautics and Space Council

Washington, D.C. 20502



PRESIDENT'S MESSAGE OF TRANSMITTAL

To the Congress of the United States:

The year 1969 was truly a turning point in the story of space exploration—the most significant of any year in that still brief history. I am pleased to transmit to the Congress this report on the space and aeronautics activities of our Government in the past 12 months. As I do so, I again salute the thousands of men and women whose devotion and skill over many years have made our recent successes possible.

This report tells the remarkable and now familiar story of man's first and second landings on the Moon. It recounts, too, the exciting Mariner voyage which took the first closeup photographs of the planet Mars. But it also discusses the space triumphs of 1969 which were less well-publicized, successes which also have great significance. It tells, for example, of the progress made in our communications satellite, weather satellite and Earth resources satellite programs. It discusses the scientific and military implications of all our recent advances. It details the progress we have made toward achieving greater international participation in our space adventures. And it reports, too, on our advances in aeronautical technology.

In 1969 we achieved the most prominent of our goals in space—one which had long been a focus for our energies. As we enter a new decade, we must now set new goals which make sense for the seventies. The space budget that I am submitting to Congress reflects my view of a balanced space program, one which will build on the progress we have already made.

Our space and aeronautics program has benefited this Nation in many ways. It has contributed to our national security, to our educational, transportation, and commercial strength, to our scientific and medical knowledge, to our international position and to our sense of the dignity and the capacity of man. And the story is only beginning. We have made long strides into the future during the past year; now we must build on those accomplishments in the coming years and decades.

Richard Nixon

THE WHITE HOUSE,
January 1970.

ADDENDUM TO THE PRESIDENT'S ANNUAL REPORT

Since the material for this report was prepared, the National Aeronautics and Space Administration (NASA) has redirected certain portions of the space program to bring the agency's total operations in line with its budget for fiscal year 1971. The following alterations in the text reflect the budgetary changes:

Page 8, first column, paragraph 5, text reads: "Three Apollo launches are scheduled for 1970."

Should read: "Two Apollo launches are scheduled for 1970."

Page 8, second column, paragraph 6, line 4, text reads: "The launch rate was reduced from 2-month launch intervals to 4-month intervals * * *."

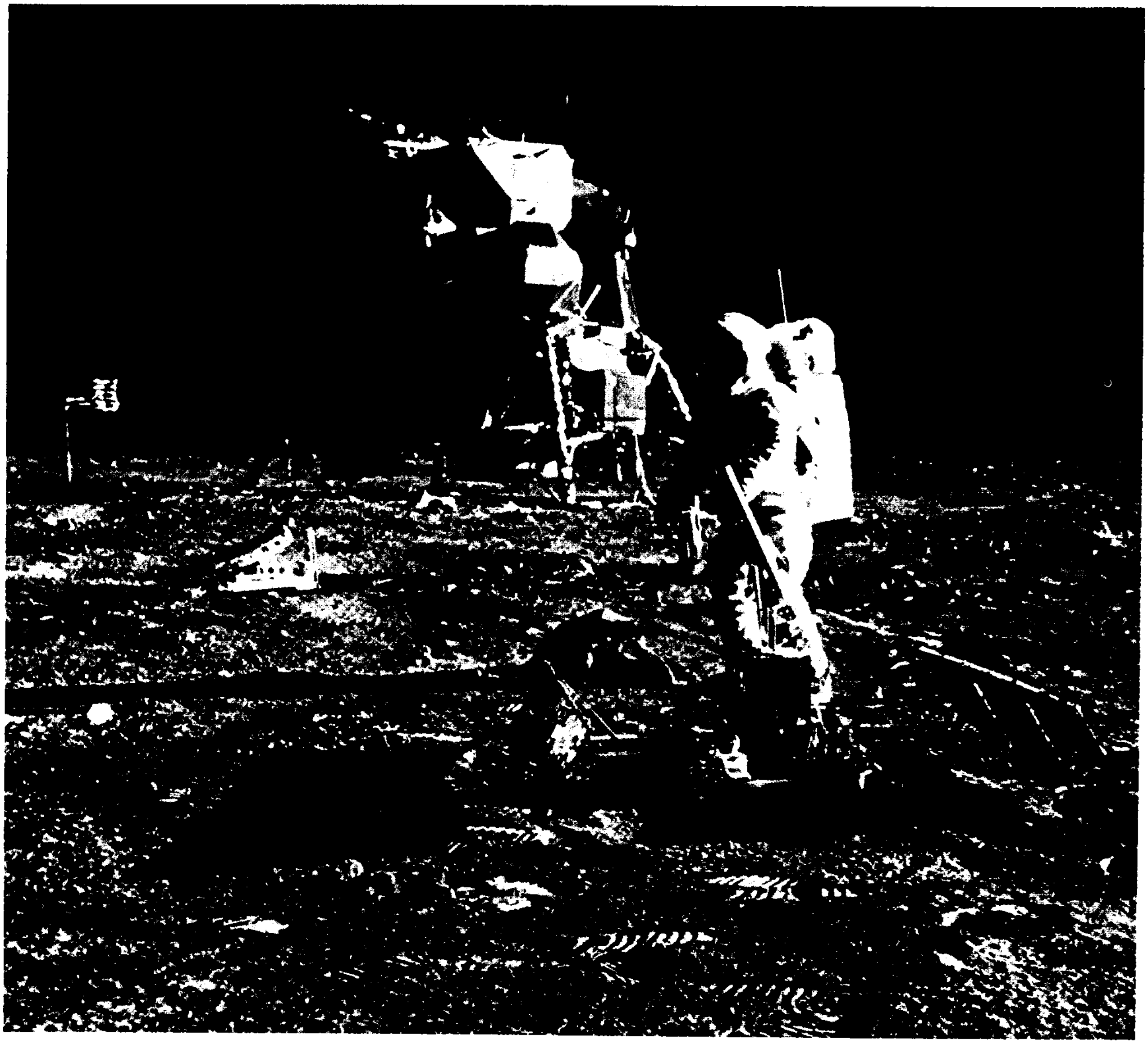
Should read: "The Apollo lunar missions will be rescheduled to 6-month intervals * * *."

Page 14, first column, paragraph 5, text reads: "*Viking*—NASA also plans (through its Viking project) to send two instrumented spacecraft to Mars for 90 days in 1973."

Should read: "The unmanned Viking lander will be launched to Mars in 1975."

Table of Contents

Appendixes



"That's one small step for a man, one giant leap for mankind."

I Progress Toward U.S. Aeronautics and Space Goals in 1969

Introduction

Nineteen hundred and sixty-nine was truly a significant year for both aeronautical and space endeavors. Man for the first time set foot on another celestial body, began its exploration, and returned safely to Earth. History will record this generation as the one that overcame the bounds of this planet and opened up the vast reaches of space to both man and his machines. This accomplishment, which was the primary goal and the dominant theme of our space activities during the past decade, caused a spiritual uplifting for man that has transcended national boundaries. Within the Earth's atmosphere, we flew the first of many large, wide-bodied jet aircraft for civil use and initiated development of several new advanced aircraft for military use. These aeronautical milestones ushered in a new era of efficiency and comfort in air transportation and strengthened our posture for national defense.

During the first half of 1969 the Apollo lunar landing system completed final phases of test and demonstration. Apollo 9, during a 10-day flight starting on March 3, successfully simulated in Earth orbit the operation of the lunar module through a lunar landing and take-off demonstration. Next, on May 18, Apollo 10 started an 8-day flight during which the manned lunar module made two low orbit passes approaching within 47,000 feet of the lunar surface. These flights were over the prospective lunar landing site in preparation for the first manned touchdown.

On July 16, a large and varied audience of distinguished visitors from all over the world assembled at the Kennedy Space Center to view the countdown and departure of the first successful manned landing and exploration of another celestial body. Man's first step on the lunar surface was taken by Astronaut Armstrong in full television view of all mankind. Astronauts Armstrong and Aldrin spent over 21 hours on the lunar surface before they rejoined Astronaut Collins for a safe return to Earth. Even though the primary purpose of this flight was to verify the capability of the Apollo system, the scientific data from this mission have served as a major advance in the exploration of our solar system.

On November 14, Apollo 12, now a proven space exploration system, took departure from Earth on man's second journey to the Moon. With pinpoint accuracy, Astronauts Conrad and Bean landed on the Ocean of Storms within a few feet from the edges of a crater in which Surveyor III landed in April 1967. During two surface excursions by the two astronauts, major advances were made in our understanding of the Moon and its history. The astronauts, along with their scientific bounty, safely returned to Earth on November 24.

While the Apollo system was in its final demonstration phases, the unmanned Mariner VI and VII were en route on their 6-month-long journey to Mars to give us our first detailed TV type look at our nearest planetary neighbor. This dual unmanned mission demonstrated a highly effective planetary exploration system and provided a major step forward in our understanding of Mars.

The primary goal of the first decade to develop a space exploration capability has been accomplished. Challenging and profitable steps lie ahead.

In addition to the primary goal, our space activities have focused on the goals of service to mankind, enhancement of national security, scientific exploration of our solar system, development of new capabilities, and encouragement of international cooperative effort. These five goals have guided our efforts during the past decade and will serve to direct our future efforts.

Major achievements can be recorded toward each of these goals during 1969.

Service to Mankind

Communications—The development and use of communications by means of satellites made significant progress in several important areas.

The International Telecommunications Satellite Consortium (Intelsat), managed by the Communications Satellite Corporation, is now providing a large percentage of the total commercial transoceanic communications service across the Atlantic, Pacific, and Indian Oceans. The next generation spacecraft, Intelsat IV, with about eight times the capacity of the current operating spacecraft, are under procurement and should be ready for launch in 1971.

The United States also continued the use of the defense satellite communications system (DSCS) to satisfy unique and vital governmental communications requirements. In this system, 23 operational spacecraft, launched during 1966–68, in near-synchronous orbit are being used by 29 fixed and transportable ground stations. During 1969, development of a new series of high performance geostationary spacecraft to replace the present DSCS system was started. These spacecraft will be equipped with "Earth coverage" antennas and two steerable narrow beam antennas. The narrow beam antennas can focus energy into 2,000-mile diameter circular areas, thereby increasing the channel capacity of the system for selected geographical areas.

The Department of Defense is also proceeding with the development of communications satellites to support tactical operations. The first such satellite, Tacsat I, was launched early in 1969, and working in conjunction with the Lincoln Laboratory experimental satellite, LES–6, provided significant operating experience to Army, Navy, and Air Force mobile terminals.

Navigation—A constellation of four Transit navigation satellites, which were in operation in 1968, have continued to serve surface and subsurface navigators. Since 1967, when the Vice President announced the availability of navigation by satellite to all users, the number of civil users has continued to increase. The strongest interest has been shown by offshore oil survey companies, oceanographic research ships, and ocean liners.

Experimentation has continued on advanced satellite navigation concepts which could meet the needs of air, surface, and subsurface navigators at low cost. Preliminary results have been highly encouraging.

Geodesy—One of the significant accomplishments for the space program has been the precise determination of the size and shape of the Earth's geoid. A national geodetic satellite program was established in 1964, with the objective to establish a primary geometric network of 44 interconnected stations to an accuracy of ± 10 meters extending around the globe. Such a network is of major importance to science, to defense, to global operations requiring precision location, etc. The observations for this objective will be completed in June 1970. Stations with even greater accuracy are being established for specialized purposes, such as antenna locations for the deep space tracking network and test range instrumentation sites.

Meteorology—Space meteorology is the best known space applications program. It directly benefits all mankind. Although the data are primarily for weather forecasters and weather researchers, television viewers everywhere are familiar with synoptic satellite weather pictures.

The U.S. meteorological satellite program was started in April 1960, with Tiros I. It is now a mature system consisting of two types of satellites, an automatic picture transmission (APT) type and an advanced vidicon stored picture readout type. This system meets the requirement for daily observation of global cloud cover conditions. A minimum of one spacecraft of each type is required to maintain the integrity of the system. Only one replacement launch was required in 1969. In 1970, the system will be improved by the addition of the day/night temperature mapping capability of Tiros M.

This year, new sensors were demonstrated in orbit from which the vertical atmospheric temperature distribution down to the surface of the Earth could be derived. Experimental work with geostationary satellites was greatly refined, providing time-lapse films of the development and movement of hurricanes. This technique promises to add significantly to our ability to understand and to forecast destructive storms. Continued progress in meteorology by means of satellite data will result in improved forecasting with attendant economic benefits.

The U.S. weather satellite program has been most successful in developing international cooperation in meteorology.

Earth Resources—In 1969 the experimental Earth resources survey program made progress by using aircraft as sensor research vehicles. The Earth resources technology satellite (ERTS) A and B, based on the use of telemetry for data return, proceeded into a system definition and preliminary design phase. The need for higher resolution calibration of ERTS A and B through the use of photographic sensors is being studied. Earth-oriented, multispectral sensing by both aircraft and spacecraft holds promise of many direct benefits. This was recognized by the President, and international cooperation in this area became a major initiative in his speech to the United Nations in September. The experimental NASA program includes participation by such user agencies as the Departments of Agriculture and Interior. The program is still in an early phase and significant tasks remain for the early 1970's.

National Security

The space programs of the United States are providing benefits to the Nation in the form of enhanced national security. These benefits derive from the applicability of space technology to those military programs that are consistent with our commitments as a signatory to the Outer Space Treaty.

The capabilities of space systems have a direct effect on our national defense posture through such areas as communications, navigation, surveillance, and mapping, and weather forecasting. During the past year, two new Vela satellites were successfully placed in orbit to detect nuclear detonations occurring at any place outward from the surface of the earth. In addition, this program has provided radiation data for manned lunar flights.

The Titan III family of launch vehicles, among other systems, is providing boosters for these military needs as well as a growing number of civil uses. The Titan IIIC launch vehicle research and development program was completed in the past year with two successful flights.

The scientific knowledge and technical expertise of the United States were clearly displayed to an international audience by the successful lunar landings and Mars flybys in 1969, as well as by the long series of preceding missions. Apollo 11 and Apollo 12, whose television pictures were transmitted live around the world by means of communications satellites, were compelling examples of great accomplishment and peaceful purpose. The furtherance of world peace and our image as a strong and peace-minded people were directly served by these historic accomplishments.

Space offers both a medium for the protection of our freedoms and those of our friends, as well as an increasing opportunity to demonstrate our peaceful intent.

Scientific Exploration

The United States has assumed a commanding lead in the science of space. Measurement of the solar wind and interplanetary magnetic field have been correlated with observations of the Sun to yield new understanding of the way in which the Sun's atmosphere extends into space to form the interplanetary medium. Instruments left on the lunar surface by both Apollo 11 and Apollo 12 are already changing our ideas, not only about the Moon, but on how the interplaneary medium interacts with the Moon. The two Apollo landings have produced significant new data that are revealing information on the formation of the solar system and the time scale of its evolution.

The planetary program is structured around three primary goals: The understanding of the origin and evolution of the solar system; an understanding of the origin and evolution of life; and a better understanding of large-scale phenomena by doing comparative studies of Earth and other planets.

The dramatic Mariner 6 and 7 Mars encounters have greatly modified our thinking about the possibility of life on Mars. These vehicles transmitted 200 times more data about Mars than were obtained from Mariner 4. The atmosphere of Mars is far more hostile than had been previously thought. Terrestrial life forms could not survive on the Martian surface; the atmosphere is so thin that lethal ultraviolet radiation actually penetrates to the surface. Indications are that oceans have never existed on Mars and that water vapor is present only in vanishingly small quantities.

Space astronomy has made major advances in 1969. Observations of the Sun and other stars are being made in wavelength regions that are inaccessible to astronomers using Earth-based instruments. For example, ballon- and rocket-borne instruments have discovered that the pulsar in the Crab Nebula emits powerful X-ray pulses. Each pulse contains as much energy as could be produced by collecting the entire electrical output of our present terrestrial civilization for 10 million years, but this pulsar produces such an X-ray pulse 30 times each second. The study of such extraordinary extraterrestrial phenomena will lead to a new understanding of physical processes that may help us to improve life on Earth.

New Capabilities

The vitality of the Nation's aeronautics and space program and its ability to serve the needs of this country is dependent on a strong program to develop new capabilities. This includes improved aeronautical systems, improved space launching systems and improved space vehicles. The thrust of this effort must be to increase safety and performance of aeronautical systems, to bring down the cost of space launch operations and to increase the usefulness of space vehicles. The whole spectrum of technology, including the most advanced, must be used as necessary to achieve these objectives.

During the past year, our national space program demonstrated numerous significant new capabilities. The most outstanding of these was the culmination of a decade of intense effort with the operation of all elements of the Apollo program. This remarkable program not only produced a highly sophisticated and extremely complex system, but also created the technological base and management tools that can readily be applied to the development of new capabilities.

The Apollo capability, in addition to lunar exploration, has provided the cornerstone for the manned follow-on Earth orbital program—Apollo applications. This program involves orbiting a Saturn V upper stage, outfitted on the ground as a manned work shop. This will be a major step forward in our manned Earth-orbital capability. In addition to providing facilities for scientific, technological, medical, and human factor experiments, it will provide valuable precursor data for a future permanent space station.

To achieve economy in space flight, reusability of hardware and commonality of mission equipment are major guidelines in developing future space systems. A space transportation system, proposed as a joint program by the NASA and DOD, is now approaching the project definition phase. Through the principle of hardware reuse, major cost reduction in space operations should be achievable. A permanent space station is also in the early definition phase. The basic element of the space station is a standard module which, by changing instrumentation and internal arrangements, should be usable in an Earth oribital, lunar orbital, or in a planetary flyby mode.

A new satellite infrared spectrometer sensor was used in 1969. The data from this sensor permitted the vertical profile of the atmosphere to be derived in terms of temperature, water vapor, and ozone content. This information will be highly useful in improving weather forecasting over the globe.

The Orbiting Astronomical Observatory (OAO–2), launched December 1968, demonstrated during 1969 the importance of extending astronomical observations into the invisible ultraviolet regions. Major discoveries were made in this region.

The Viking-Mars program, consisting of an orbiting spacecraft and a soft lander will use aerodynamic braking and parachutes in addition to retrorockets in landing the soft lander on the Martian surface. This differs from pure retrorocket techniques of our lunar landings and aerodynamic braking plus parachutes for our Earth reentry systems. Development of this vehicle moved into the hardware contractual phase during 1969.

The advantages of isotope heat sources for space electrical power were increasingly recognized. The SNAP–27 generator was used as the electrical power source for the Apollo 12 experiments left on the Moon by the astronauts and the SNAP–19 was used to power the Nimbus 3 weather satellite.

With the completion of testing of the world's first nuclear rocket engine, the technology development phase of the nuclear rocket was concluded. Based on this technology, development of NERVA (nuclear engine for rocket vehicle application) engine was started. This engine will be a restartable 75,000-pound thrust engine with a specific impulse of 800 to 900 seconds, more than double that of conventional rocket engines.

Advanced development continued on a new liquid rocket engine, featuring both high performance and reusable features for new systems. A new tripropellant system provided record performance for chemically powered engines. Together with work on guidance systems, materials, structural designs, lifting body flight vehicles, and other technology programs, our research and development organizations continued to provide a base for future systems development.

International Cooperation

In 1969 the President highlighted the potential of space as a force for peace. At his request, the Apollo 11 astronauts visited six continents to dramatize their conviction that their successful lunar landing was a triumph for the human spirit everywhere. In September, the President avowed before the General Assembly of the United Nations the determination of the United States to share both the "adventures and the benefits" of space and offered the Earth resources survey program as a manifest of our intentions.

In support of the President's interest in enlarging foreign participation even beyond current levels, NASA informed ministerial and space agency officials abroad of plans for future U.S. space activity, thereby affording foreign interests the earliest opportunity for consideration of increasing their participation in new and important ways. Consultations with officials abroad began, and foreign experts participated in the NASA conference on space shuttle concepts as a first step in acquiring a base of information for use in defining their own nations' potential interests in participation at new and higher levels.

Meanwhile, the established programs of cooperation continued and responded to technical and scientific opportunities and enlarged the basis for support of the President's emphasis on substantive international participation. Among the more significant developments:

NASA concluded an agreement with the Indian space agency for a project in which the ATS–F satellite will be made available for experimental instructional TV broadcasting, directly and by relay, to receivers in 5,000 Indian villages.

Experimental projects with both Brazil and Mexico in remote sensing of earth resources from aircraft helped pave the way for future satellite missions and served increasingly to demonstrate the meaning of these techniques for other developing countries.

NASA launched two spacecraft in joint projects with other countries (Canada and Germany) and one spacecraft on a reimbursable basis (the 10-nation European Space Research Organization). In addition, an agreement was concluded with Italy for reimbursable launchings of NASA satellites from the San Marco platform in the Indian Ocean.

Thirty-nine scientists and their associates from nine foreign countries participated, on the merits of their proposals in the analysis of lunar materials returned to Earth by the crew of Apollo 11.

In 1969 the operational weather satellite program of the United States continued to demonstrate how relatively modest investments in advanced technology can bring incalculable benefits to ourselves and others. U.S. weather satellites provided cloud-cover data which was either distributed through World Meteorological Organization communications channels or transmitted directly from satellites to more than 500 inexpensive ground stations in 54 countries.

Efforts to develop substantive and mutually cooperative programs with the U.S.S.R. are continuing but have met with limited success. The exchange of meteorological data continued via a Washington-Moscow data link. The value of the U.S.S.R. data was overshadowed however, by the quality and availablity of meteorological data from U.S. satellites.

Intelsat, the international communications satellite consortium, further proved its worth as an instrument to advance cooperation between nations during 1969. The venture, managed by the U.S. Communications Satellite Corporation, now includes 70 nations with 36 earth stations in 24 countries relaying live television and telecommunications around the globe. This year the consortium moved to develop permanent agreements to replace the interim founding agreements of 1964. Intelsat satellites supported all Apollo launches and relayed our Moon landings to the largest audience in the history of man ever to witness a single event.

Aeronautics

The levels of aeronautical technology reached during 1969 have subtle and far-reaching significance for most of the world's population. Confronted with achievements of the U.S.S.R. and the British-French consortium in flying their civil supersonic transport prototypes, the President was supported by Congress in his recommendation for our Nation to proceed with the construction of a U.S. supersonic transport prototype which is to be both larger and faster than those now flying.

The U.S. aircraft industry accomplished a major achievement in making the first flights of several large wide-bodied jet transports for civil use early in the year. These flights were followed by a highly successful flight test and certification program.

Both the SST and the wide-bodied jumbo jet aircraft are destined to have as much impact on the traveling habits of the business and private citizen as did the smaller jets when they replaced piston engined transports. The SST and large jets will open new commerical markets for the U.S. businessman, stimulate our economy, and provide cultural contact between nations separated by distances too great for easy direct contact.

Aircraft research and development efforts continued to improve both the quality and quantity of options in aircraft technology available to the designer in aerodynamics, propulsion, structures, safety, air traffic control, and flying qualities. Efforts to reduce the public irritants of noise and chemical pollution during the past year promise relief from these undesirable byproducts of aviation progress.

Aircraft continue to become more important to our national economy. Aircraft are used by the Government for a variety of purposes: Research and national defense, aerial surveying, management of wildlife resources, forest fire patrol, Earth resource surveying, etc. In addition, aircraft of all sizes and performance are used by the business and private sectors as a means of enriching our economic life. For example, besides the obvious transportation function, aircraft are used for commercial fish spotting, pipeline patrol, aerial prospecting, agricultural application, as well as business and pleasure flying thus adding to the aerial activity in this country.

We have witnessed the growth of the airport terminal to preempt the train and bus terminals as the major transportation hubs in our cities, while at the same time, we find ourselves increasingly ensnarled in unmanageable surface traffic. Major efforts were begun in 1969 to improve the quality and effectiveness of surface and air transportation. This activity in aviation has centered about improvements in airport design and in air traffic control to eliminate costly and frustrating delays in the air terminal traffic.

In national defense, the United States took steps to replace its aging fleet of strategic deterrent military aircraft by proceeding with a request for proposals from industry for a new strategic bomber (B–1). To assure the future capability for tactical air superiority and support of our ground forces, engineering development was approved for a new tactical fighter (F–15). The needs for an advanced fleet air-defense aircraft and an improved tactical anti-submarine-warfare (ASW) aircraft have been recognized and engineering development was started for both a carrier-based fighter (F–14) and an ASW aircraft (S–3A). A significant potential for improvement in our combat mobility and air transport capability has been realized with the initial delivery of an operational heavy military air transport (C5A) to the Air Force.

Summary

The achievements in space during 1969, as well as the marked progress in aeronautics, are truly historic events in their own right and the forerunners of a new era of application of our expertise to our national benefit and to the world. A far-sighted program of space activity is being initiated. A vigorous program of aeronautical research and the development of vital aircraft systems for civil and military needs are planned for the coming years. The decade of the 1970's promises concrete returns to the United States in aeronautics and space that will benefit the life of each individual citizen and uplift the spirit of the Nation.

II National Aeronautics and Space Council

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.

The President accepted the resignation of the Council's first Executive Secretary in February 1969, and selected a new Executive Secretary in May 1969. Due to the fact that the newly selected official was an astronaut then assigned to the backup crew of Apollo 11 (the manned lunar landing mission), it was agreed that the appointment would not take effect until the Apollo 11 duties of the Executive-Secretary-designate were completed.

Early in the year as progress in the Apollo program clearly indicated that achievement of the manned lunar landing and safe return to Earth goal was near at hand, the President asked the Vice President to chair a Space Task Group study to recommend the direction the U.S. space program should take in the post-Apollo period. The Secretary of the Air Force, the Administrator of NASA, and the President's science adviser were asked to assist, as was the Director of the Bureau of the Budget.

During the period of this study, the Space Task Group functioned in lieu of the National Aeronautics and Space Council. The NASC staff provided staff support for the Vice President, as Chairman and member. The last meeting of the Space Task Group, in September, for approval of the report was joined by the newly appointed Executive Secretary of the Council. This meeting marked the transition from the ad hoc Space Task Group to resumption of normal Council activity. The Space Task Group report included amongst its findings a recommendation that the National Aeronautics and Space Council be utilized as a mechanism for continuing reassessment of the character and pace of the space program.

Council meetings during the year were concerned with interagency approval of the Space Task Group report, the presentation of the report to the President, and the revitalization of the Council staff and Council functions in both space and aeronautics as proposed by the new Executive Secretary.

As the year closed, the Council staff had been enlarged to include specialists in space science, space nuclear systems, and aeronautics; several having been furnished on detail from Council member departments and agencies to assist in the reviving of the staff effort. Under the direction of the Executive Secretary, an intensive effort was underway to define national policy issues in both aeronautics and space for early Council action.

III National Aeronautics and Space Administration

Introduction

The National Aeronautics and Space Administration concluded another year of successful accomplishments in space achievements and aeronautical research.

This year saw the climax of over 8 years of intensive effort by NASA to achieve the goal established by President Kennedy in 1961 "of landing a man on the Moon and returning him safely to Earth" within this decade. Apollo 11 Astronauts Neil Armstrong and Edwin Aldrin, aboard the Lunar Module *Eagle,* landed at Tranquility Base on the Moon at 4:17 p.m. e.d.t., July 20, 1969, to become the first man on the lunar surface. Six hours and thirty-nine minutes later, Astronaut Armstrong stepped from the ladder of the Lunar Module (LM) onto the Moon with the remark, "That's one small step for a man, one giant leap for mankind."

Apollo 11 was one of four successful manned Apollo flights during the year. Others were Apollo 9, during which a manned LM was first tested in space; Apollo 10, in which an LM carried two astronauts to within 47,000 feet of the lunar surface; and Apollo 12, the second Moon landing mission, which was piloted by the astronauts to a precise landing on the lunar surface on November 19, 1969. In subsequent Apollo launches, the astronauts will stay longer on the lunar surface and carry on more extensive investigations.

In addition to planning for future Apollo missions, NASA continued the development of the Apollo applications Saturn V workshop for an Earth orbital mission, defining a permanent space station module, and studies for the configuration of a reusable space shuttle.

Also this year, NASA continued its many spacecraft programs for both scientific investigations and space applications. To explore Mars, Mariner spacecraft were flown past the planet's equatorial region and southern hemisphere. Other Mariner class spacecraft were being developed this year to orbit Mars during 1971 to map about 70 percent of its area and to investigate its atmosphere and surface, and later, to land in a search for organic compounds and living organisms.

The NASA planetary program is structured around three goals. No. 1 is understanding the origin and evolution of the solar system. The second one is to understand the origin and evolution of life, and the third is to get a better understanding of Earth by doing comparative studies on the other planets.

Two Orbiting Solar Observatories (OSO's), an Orbiting Geophysical Observatory (OGO), and an interplanetary monitoring platform (IMP), were launched to study Earth's outer magnetic field, solar ultraviolet and X-ray radiations, in the regions surrounding the Moon, the Sun, and the Earth. In addition, NASA launched a Biosatellite carrying a highly instrumented monkey into Earth orbit to conduct a complex experiment in biological science. This flight had to be terminated early due to the monkey's early deterioration. The monkey died shortly after recovery from the ocean. The cause of death has been attributed to cardiovascular failure.

Cooperating with the requirements of the Environmental Science Services Administration (ESSA), NASA placed sophisticated meteorological satellites into orbit, and also orbited highly advanced commercial communications satellites for the Communications Satellite Corp. (Comsat). In addition, it carried on cooperative studies and experiments with the Departments of the Interior, Agriculture, Commerce, and Navy to investigate the uses of space-acquired data for surveys of the natural resources of the world. Of great practical significance to international transportation is the continuing evolvement of satellite navigation and air traffic control technology. These efforts by NASA are being carried out in cooperation with DOD and the FAA.

NASA's advanced research and technology efforts continued investigations related to present and future aeronautical and space requirements. Research scientists and engineers obtained results having application to the improvement of aircraft technology, to the behavioral and biomedical aspects of aeronautical and space flight, and to spacecraft engineering for programs beyond the current Apollo flights.

Through research activities, NASA showed how the noise caused by jet aircraft approaching airports can be substantially reduced by 10 to 15 decibels. The concepts studies include a means of acoustically insulating the turbo-fan nacelles. Additionally, studies have shown that Doppler laser techniques for measuring atmospheric and incremental winds caused by passing aircraft (trailing vortices) can have beneficial application to the design and operation of airports and safer control of aircraft in the landing process.

Research pilots completed 28 flights in the HL–10 lifting body research vehicle showing that it has good flying qualities over the entire altitude and speed ranges flown. Data from this study will apply to advanced high speed aeronautical vehicles as well as to the design of future space shuttles. Other research and development flights and studies have been conducted in a wide range of aeronautical areas of interest.

Participating with the Navy and the Department of the Interior, NASA helped conduct project Tektite I—a study of marine, biomedical, and behavioral sciences. In this project, four marine scientists spent 60 days in a nitrogen-oxygen environment 42 feet below the surface of the Caribbean Sea.

Manned Space Flight

The successful Apollo 11 lunar landing mission in July highlighted the progress of the manned space flight program of NASA. It also dramatically demonstrated a national capability for future manned space exploration.

In addition to the historic Apollo 11 mission, there were three other manned space flights in calendar year 1969: Apollo 9 and Apollo 10 which paved the way for Apollo 11, and the second lunar landing flight Apollo 12, which followed in November, with pinpoint accuracy in both the landing on the Moon and on return to Earth in the Central Pacific.

Three Apollo launches are scheduled for 1970. Work on Apollo 13, 14, and 15 is in process in the factories, at the test facilities, and at the NASA centers, carrying forward the momentum attained in the program by the four Apollo flights this year.

In Apollo Applications the program was restructured to provide for a dual-launched dry workshop mission of 28-days' duration and two manned revisit missions of 56 days. This dry launch concept, using the Saturn V vehicle, now replaces the so-called wet concept, which would have used the expended S–IVB stage for conversion in space to a workshop, and would have been launched, using the Saturn IB vehicle. The dry workshop will be completely outfitted on the ground.

The space station and space shuttle programs both progressed significantly during the year, each entering the phase B or definition study phase.

The Apollo 10 mission demonstrated performance of the complete Apollo system in the lunar environment; it was a full dress rehearsal for the lunar landing mission. The Apollo 10 lunar module descended to about 47,000 feet above the lunar surface, and the crew reported excellent visual perception of the proposed landing areas. All mission objectives were successfully achieved.

The Apollo 11 mission achieved the objective of the manned lunar landing program. It accomplished all of its objectives. The international reaction was almost overwhelming.

With the Apollo 12 mission, the Apollo program was transitioned from the lunar landing phase to the lunar exploration phase. A key feature of this transition was a reduction in launch rate from 2-month launch intervals to 4-month intervals to increase emphasis on lunar science and to reduce costs.

Apollo Program

During 1969 the accelerated pace of the Apollo program was maintained through the Apollo 11 lunar landing mission in July. Prior to this, two manned missions were conducted in March and May to provide the operational experience and confidence needed to proceed with the lunar landing mission.

The Apollo 9 mission was the first Saturn V/Apollo spacecraft flight in full lunar mission configuration. This Earth orbital mission permitted an evaluation of the complete Apollo system and was the first manned demonstration of the LM system's performance.

The Apollo 10 mission demonstrated performance of the complete Apollo system in the lunar environment; it was a full dress rehearsal for the lunar landing mission. The Apollo 10 LM descended to about 47,000 feet above the lunar surface, and the crew reported excellent visual perception of the proposed landing areas. All mission objectives were successfully achieved.

Following the Apollo 11 mission, the Apollo program moved from the lunar landing phase to the lunar exploration phase with the flight of Apollo 12. The launch rate was reduced from 2-month-launch intervals to 4-month intervals to lower costs and increase emphasis on lunar science. The capability for a precise "pinpoint" landing of the LM on a preselected lunar site and the increase in lunar extravehicular activity both demonstrated on Apollo 12 enhanced the future outlook for scientific exploration of the Moon.

Apollo 9—This second manned Saturn V/Apollo vehicle was successfully launched on March 3, 1969, following a 3-day delay because all three astronauts had a mild virus respiratory illness. The major objective of this 10-day, Earth orbital mission was to evaluate the performance of the complete Apollo system, including lunar orbit rendezvous mission activities. This objective was achieved with outstanding success. The LM, flown for the first time with men aboard, operated with a precision matching that of the previously validated

CSM. The performance of the LM thus completed the certification of all major hardware required prior to attempting a lunar landing. Simulations of the lunar mission were executed flawlessly and splashdown occurred in the Atlantic on March 13.

All launch vehicle systems performed satisfactorily throughout their expected lifetime with the exception of inability to dump propellants following the third S–IVB burn. All spacecraft systems functioned satisfactorily through the mission. No major anomalies occurred. Those minor discrepancies which did occur were primarily procedural and either were corrected in flight with no mission impact, or involved instrumentation errors which could be checked by other means. Temperatures and consumables usage rates remained generally within normal limits throughout the mission.

The flexibility of Apollo mission planning was demonstrated by changing the splashdown site during the mission. Splashdown was originally planned for an area southwest of Bermuda on revolution 151. Because of predicted marginal wind and sea conditions, NASA chose an alternate recovery area approximately 600 miles east of Cuba, defering splashdown to revolution 152.

Other significant Apollo 9 achievements included the fourth Saturn V on-time launch; the largest payload ever placed in orbit; the first demonstration of the second restart of the S–IVB while in orbit; the first CSM-active dock; the first LM-active rendezvous and dock; the first in-flight depressurization and hatch opening in LM and CM; and the first Apollo space walk.

Apollo 10—Following the Apollo 9 mission, it was decided to fly Apollo 10 as a lunar orbit mission in order to evaluate technical areas still under consideration from the Apollo 8 mission. These were the precision of the lunar orbit timeline and naviagtion while in lunar orbit.

The Apollo 10 space vehicle was launched successfully on May 18 from the Kennedy Space Center. This lunar orbit mission, lasting 8 days, was a nearly perfect dress rehearsal which simulated the lunar landing mission except for the landing itself and the lunar surface activities. This was the first mission in which the complete Apollo spacecraft was operated around the moon, and the LM, on its second manned flight, descended to within 47,000 feet of the lunar surface. Splashdown occurred in the mid-Pacific on May 26.

All launch vehicle and spacecraft systems performed satisfactorily during the mission and all primary mission objectives were achieved. A number of minor discerpancies occurred, but they were readily corrected or compensated for. Temperatures and consumables usage rates remained generally within normal limits throughout the mission.

The LM demonstrated its operating capabilities in cislunar space and validated both the ascent propulsion system (APS) and the descent propulsion system (DPS) in the Moon's environment. These were vital to the lunar landing mission. In two circuits of the Moon the landing radar received a thorough checkout. Previously, the landing radar underwent numerous tests in Earth environment. On this mission, however, the lunar surface reflectivity characteristics were checked with the landing radar. (The descent to within 47,000 feet of the lunar surface provided a low level evaluation of lunar visibility.) These tests provided valuable data to be used in mission planning and crew training for the Apollo 11 lunar landing mission.

Apollo 11—The objective of the Apollo 11 mission was to make a manned lunar landing and return. Supporting the major objective were numerous engineering goals which were achieved. The scientific goals, necessarily subordinate to the engineering aspects on this first landing mission, were also attained.

The mission began on July 16 from the Kennedy Space Center. The Saturn V booster performed perfectly, inserting the third stage and spacecraft into a 100-mile circular orbit. The third stage injected the spacecraft into a translunar trajectory 1½ revolutions later.

After a 3-day flight, the spacecraft arrived at the Moon only 4½ minutes ahead of schedule. After circling the Moon for a day, the LM was separated from the CSM. It landed on the Moon in the planned landing area at 23° east longitude. After a 21½-hour stay, which included a 1-hour 31-minute period of activity on the lunar surface, the astronauts launched the LM's ascent stage from the Moon's surface and rendezvoused with the CM. The astronauts returned to earth aboard the CM and landed in the Pacific Ocean 2½ days later—just 41 seconds earlier than had been planned long before the mission began.

The engineering aspects of this first landing mission were paramount and all systems functioned satisfactorily. Minor subsystem problems developed with out-of-tolerance temperatures or pressures, but these were either reevaluated as acceptable or resolved by operational procedures. The crew was never in danger as a result of any of the few subsystem problems.

During the final approach phase of the descent to the Moon, the manual attitude control was used in order to avoid large boulders and guided the LM to a landing point approximately 1,000 feet farther down-range, at Tranquility Base.

The crew adapted quickly to the one-sixth (Earth) gravity and the extravehicular activity (EVA) was accomplished about 3½ hours earlier than originally planned.

The astronauts unveiled the plaque mounted on the strut behind the LM ladder and also erected an American flag on the lunar surface. Both crewmen indicated that their mobility and agility throughout the EVA significantly exceed all expectations. Also, metabolic rates were much lower than premission estimates.

Lunar Exploration

The crew collected a total of 54 pounds of lunar material including two lunar core samples and a considerable amount of discretely selected specimens. A considerable force was required to drive the core tubes an estimated 6 to 8 inches inches into the lunar surface. The crew also emplaced three scientific instruments during their stay on the lunar surface.

Throughtout the EVA, TV was useful in providing continuous observation for time correlation of crew activity with telemetered data and voice comments and in providing live documentation of this historically significant achievement.

Summary of Primary Scientific Results—The primary scientific results of Apollo 11, which will be revised following further analysis and receipt of additional data, include the following: Analysis of the rock and soil samples has thus far uncovered no evidence of life in any form. Preliminary physical chemical, mineralogical, and biological analysis is continuing. Since no additional hazard or possibility of Earth contamination was detected, samples were released to scientists for detailed analysis.

Analysis of the samples indicates that the minimum age of the surface materials of that part of the Sea of Tranquility is 3.1 billion years (plus or minus 200 million years). Additional work has indicated that the Moon may be older. If so, this would place the formation of this material early in the history of the solar system, generally estimated to be about 4½ billion years old. Some experimenters are suggesting that this result supports the theory that the Moon was formed at the same time as the Earth, from the same whirling gas cloud. If this is so, the Moon may provide a means of learning the conditions of the Earth at the time of its formation.

Other tentative findings from the material analyzed to date are (1) changes in the Moon's surface in the area of the Apollo 11 landing are very slow; (2) the density of the Moon is about the same throughout, with heavy elements more prominent than would be the case on Earth; and (3) no evidence was found of water.

The passive seismometer, an extremely sensitive instrument, recorded numerous events that are being studied. Analysis was being pointed toward the development of criteria by which events of natural origin can be distinguished from man-induced events. The experimenters have suggested the possibility that the data received might be explained by a very heterogeneous structure of the Moon. If this were so, it would be a major discovery in planetary science.

Laser beam returns from the retro reflector (mirror) have been received by telescopes at the McDonald Observatory in Texas and the Lick Observatory in California. These reflections have resulted in more precise measurements of the distance between the Earth and the Moon. The Lick Observatory measurement on August 1 was to an accuracy of 150 feet. The McDonald Observatory measurement on August 19 was to an accuracy of 12 feet, measuring the distance as 232,271.406 miles. The best previous measurement of the Earth-Moon distance, done in the Soviet Union, also by laser beam reflection, was to an accuracy of a few thousand feet. Further measurements in the near future are expected to refine the figure still further and to permit related experiments of considerable significance.

The solar wind composition experiment involved exposing a strip of aluminum foil to the lunar environment and returning it to Earth for analysis. A small piece of the foil has been released to the principal investigator.

The scientific results to date neither prove nor disprove any of the major candidate theories regarding the origin and history of the Moon. Some results appear to favor one theory; some another. The analysis of Apollo 11 results to date is quite preliminary; much work remains. The astronauts commented that they were frustrated in having to leave so quickly with such a wide variety of interesting phenomena to examine and photograph at that single site.

It should be emphasized that the landing site in the Sea of Tranquility was selected for considerations of safety on the first landing. Most of the Moon's surface is much more rugged and probably older. There are some opinions that samples from other sites will be as old as the 4½ billion years of the solar system itself.

Apollo 12—The second lunar landing mission was successfully launched on schedule at the Kennedy Space Center on November 14, 1969. All launch vehicle stages performed satisfactorily, inserting the third stage and spacecraft combination into an Earth parking orbit. Approximately 36 seconds after liftoff, the fuel cells in the CSM went off the line, the spacecraft main electrical circuits were lost, the inertial measurement unit platform tumbled and numerous caution and warning indications were noted by the crew. Through prompt action by the crew, power was reinstated within approximately 1 minute. After orbital insertion, the platform was realined and special checks were made in the CSM and LM. The tentative conclusion is that an electrical overload was caused by an electrical discharge from the clouds through the space vehicle to the ground.

A second firing of the S–IVB stage injected the spacecraft into a translunar trajectory. Separation of the CSM, turn around and docking with the LM, were performed without difficulty. All previous missions to the Moon had maintained a free return trajectory; that is, one which, in the event of problems, would return the spacecraft to Earth after circling the Moon with no need to fire the main engines. In Apollo 12, however, a midcourse correction was made to put the spacecraft into a hybrid of non-free-return trajectory. Use of a hybrid trajectory for this mission permitted a daylight launch and translunar injection over the Pacific Ocean conserved fuel and resulted in an approach to the landing site when the Sun was at the desired elevation for best visibility.

The spacecraft went into lunar orbit on November 17. Certain techniques, developed for Apollo 12 to improve landing accuracy, proved effective and the LM landed about 600 feet from Surveyor III. The Apollo 12 mission was planned as a lunar landing mission to develop techniques for a point landing capability; perform selenological inspection, survey and sampling in a mare area; deploy and activate an Apollo lunar surface experiments package (ALSEP); develop man's capability to work in lunar environment; and obtain photographs of candidate exploration sites.

The point landing capability was clearly demonstrated. After a period of rest and preparation, two astronauts left the LM and began to carry out the scientific objectives of the mission. Television transmission was lost shortly after the camera was removed from the bracket in the modularized equipment stowage assembly (MESA) and despite repeated efforts, was not regained.

After taking a contingency sample and deploying the S-band erectable antenna, the solar wind composition experiment and an American flag, the two astronauts deployed the ALSEP about 600 feet from the LM. The ALSEP contains its own energy source—a radioisotope thermoelectric generator which supplies nuclear power for the six experiments in the array. The ALSEP experiments included a passive seismometer to measure seismic activity of the Moon; a magnetometer to measure the magnetic field of the Moon; a solar wind spectrometer to measure the strength, velocity, and directions of the electrons and protons from the Sun; a suprathermal ion detector to measure the characteristics of positive ions near the lunar surface; a cold cathode ion gage to determine the density of any lunar ambient atmosphere; and a detector to measure the amount of dust accretion on the ALSEP to provide a measure of the degradation of thermal surfaces. The array will remain on the surface and is expected to transmit scientific and engineering data to Earth for at least a year. The astronauts reentered the Lunar Module, concluding a first extra vehicular activity (EVA) of 4 hours 1 minute.

The second EVA began November 19 and lasted for 3 hours and 49 minutes. The astronauts went to the ALSEP deployment site, to several craters, to the Surveyor III, and back. They walked between 1,500 and 2,000 feet from the LM, a total distance of about 6,000 feet. During this EVA, the crew took photographs, gathered samples, and retrieved parts from the Surveyor for later analysis on Earth.

Following the walk, the astronauts retrieved the solar wind composition experiment, stowed all the collected samples, parts and equipment in the LM, and repressurized the cabin. Lunar liftoff occurred without incident November 20, concluding a total lunar stay time of 31 hours, 31 minutes. The astronauts encountered no difficulty during rendezvous and docking with the CSM. After the two astronauts transferred back to the CM, the ascent stage was jettisoned and deliberately impacted on the Moon to provide a signal for the seismometer. Scientists were surprised at the length of time (55 minutes) that vibrations continued to be recorded by the instrument after impact.

The CSM continued in orbit to achieve the final objective of the mission—obtaining photos of candidate future landing sites, Fra Mauro, Descartes, and Lalande.

The maneuvers for return to Earth were all nominal and the spacecraft splashed down in the Pacific at 3:58 p.m., e.s.t., on November 24.

Forthcoming Launches—Additional Apollo missions will be flown to different localities on the lunar surface where experiments and sampling will be carried out in the immediate vicinity of the landing site. On these missions, Apollo 13, 14 and 15, the remaining three Apollo lunar surface experiments packages (ALSEP's) will be deployed on the lunar surface.

Utilization of CSM capability will allow comprehensive orbital surveys with instrumentation now under development. At the conclusion of these missions sufficient new knowledge should be in hand to chart the future course of space activities on the Moon.

371-775 O - 70 - 2

Apollo Applications—The Apollo applications program (AAP), which will make maximum use of Apollo-developed capabilities in Earth orbit is a necessary precursor program to a future permanent space station module in Earth orbit. Through studies of habitability and men's reactions to extended periods in space flight the full potential of man's capability to perform useful work and conduct scientific and technological tasks for the benefit of man on Earth can be realized.

During the early part of 1969, NASA was concentrating on the development of the Saturn I workshop, making use of the so-called wet concept. That is, the S–IVB stage would be used as a part of the launch vehicle until it reached orbit. Once there and empty of fuel, it would become a workshop. Subsequently, a three-man CSM would dock with the workshop. Later launches would add the airlock module (AM), the multiple docking adapter (MDA), and the Apollo telescope mount (ATM).

Studies made in the first half of the year, however, led NASA to adopt the so-called dry-launch concept. This concept permits NASA to completely outfit the workshop on the ground, then launch it into orbit, using the Saturn V vehicle.

Work progressed during the year on defining the workshop configuration; on mission planning; and on design and development of the modified CSM, the AM, the MDA, the ATM, the workshop, itself, and the flight experiments.

One experiment, welding in zero g falls in the category of manufacturing in space. The potential for space processing and manufacturing has received considerable attention in the past year. Several hundred members of industry, universities and government attended a symposium on this subject at the Marshall Space Flight Center at Huntsville, Ala., on October 21 and 22, 1969. Over 30 papers were presented ranging from isotope production to the growth of crystals in the space environment.

The dry workshop provides for more flexibility in ground and space operation.

The dry concept offers two significant advantages: It simplifies the total space vehicle by integrating the systems into a total payload package, outfitted and checked out on the ground; and it assures increased reliability because of the simplification.

Advanced Manned Missions

Studies of potential advanced manned missions reached several crucial decision points during 1969, with planning for space and aeronautical activities to be conducted following Apollo being stimulated by the President's Space Task Group. The resulting NASA program plans are intended to achieve a balance among all options available.

This program is a part of the NASA integrated plan for manned space flight. The major manned space flight features of this plan are development of a lunar orbit station, then a lunar surface station, following the exploration of the Moon with Apollo-type equipment; development of a major facility in Earth orbit, a space station that could evolve into a space base supplied by a reusable space shuttle; and, finally, development of a system for a manned mission to Mars. In the integrated plan these space ventures would be pursued through development of space hardware designed for multi-use, for long life, and for reuse to achieve maximum return for the investment.

Simultaneously with the evolution of the integrated plan, NASA began efforts to implement it in order to assure a smooth transition from the lunar landing program into the more advanced activities. Planning for the space station and space shuttle programs will conform to the phased project planning system developed for management of new NASA programs.

NASA set up special task forces for these new programs and enlisted contractors to help define the space station and the space shuttle. In the latter part of this year, NASA was in the process of identifying the studies and technology required to initiate the other major elements of the integrated plan. An orderly approach, to be backed with supporting technology effort, has been tentatively fixed for the next 5 years. This approach should make certain that all elements of the integrated plan are well devised and initiated at the proper time to accomplish overall objectives.

Space Station—The space station is a key element in the total integrated space flight system. It can be the laboratory in Earth orbit for scientific and technological experiments. It can be the supply depot and assembly point for future deep space missions and it can be the heart of significant applications activity that will enhance the life of man here on Earth. Communications, air and sea traffic control, Earth environmental survey and analysis and medical, biological and physical experiments are some of the prospects for a future permanent space station.

Such a space station in addition to providing for practical, beneficial applications of space to the civil economy should also serve as a base for research to increase man's knowledge of his surroundings and provide a thrust to space technology and operations for use in future exploration of the solar system.

NASA concentrated its space station activities on defining the uses and intrinsic nature of a manned Earth Orbital Research Facility to meet the near-term goals of the Nation's space program.

Toward these ends, certain space station general characteristics were defined. The concept selected for study is a 12-man station, to become operational in the mid-1970's, capable of modular growth to accommodate about 50 men in later years. It should have a useful life of at least 10 years, with adequate maintenance and resupply. As envisioned, such a space station would be a centralized facility, placed in space, to conduct research and development in many disciplines. It would also serve as an orbital operations and maintenance center for unmanned satellites.

Having better defined the nature of the desired space station, NASA, in April, issued a request for proposal to interested contractors. Proposals were received in early June. NASA appointed a Source Evaluation Board to evaluate these proposals and report its findings. In late July, two contractors were selected to conduct the studies.

The major purpose of these contractors' efforts is to conduct what NASA calls the "definition phase" of the effort: to evaluate the preferred concepts for the space station program. Such evaluations would include the core station modules, the experiments and experiment module, the logistics system, operations, and facilities. It would also include development of technical and management data. From such data, NASA can select a recommended single program concept for possible design effort (phase C).

In addition, in-house and other contracted activities in the area of experimental payload modules, logistics vehicle, and supporting systems are involved in the total program definition effort.

Responsibility for overall space station program management and integration was delineated and a former astronaut was selected to be Field Director of the program.

Space Shuttle—A series of preliminary design studies of logistics systems was started in February as part of the advanced manned mission program. These studies served as the focal point for a task group established by NASA in April. Subsequently, more definitive characteristics and requirements for the space shuttle were determined. These results narrowed the number of alternatives and focused attention on developing preliminary design concepts which more nearly met the desired system characteristics.

NASA and DOD conducted a joint study to assess the practicality of a low-cost space transportation system to meet the needs of both agencies. From this effort a joint summary report which was submitted to the Space Task Group reached the conclusion that it was both practical and desirable to develop a common system that could meet the needs of both agencies. Additionally, the report defined the general characteristics desired in such a system.

Several basic missions bearing on the future of space exploration were identified. The space shuttle should provide for space station/space base logistic support, placement and retrieval of satellites, delivery of propulsive stages and payloads for high energy missions, delivery of propellants, satellite servicing and maintenance, short duration orbital missions, and possible space rescue and the retrieval of space debris.

Desired system characteristics for the space shuttle were examined, and certain ones were selected as design criteria for developing a space shuttle.

Of the several classes of space shuttle studied, the fully reusable class appears to be the most economical prospect. The Space Shuttle Task Group recommended that concepts within this class be examined in the phase B "definition" study, to be conducted in 1970.

Planetary Exploration

Mariner—The Mariner VI spacecraft, launched on February 24, encountered Mars on July 31 to transmit valuable scientific data on the planet's equatorial region. Mariner VII (its twin) was launched March 27 and flew by Mars August 5 to supply data on the planet's southern hemispherical region. Both carried out their missions as planned, even though there were several malfunctions that were successfully corrected in transit.

These vehicles obtained over 200 times more data about Mars than obtained with Pioneer 4. The scientific return from these vehicles represents a major achievement in planetary exploration. It was learned that the probability that microbial life exists on Mars is much less than had been previously supposed. It now appears unlikely that Mars has ever had an ocean. The amount of water vapor detected in the atmosphere is too little to permit the growth of any known terrestrial species. And finally, it had been determined that lethal ultraviolet radiation reaches the surface of Mars; its atmosphere is too thin to protect it.

Exciting new features of Mars were discovered. For example, the chaotic and the featureless terrains, which constitute dramatic evidence of presently unknown surface phenomena. The true power of the Mariner class vehicle for planetary exploration was demonstrated by these missions.

These spacecraft provided over 2,000 measurements on the chemical composition of the upper atmosphere and more than 400 measurements on the composition of the lower atmosphere and surface. Also, over 100,000 distant and 800 close-up temperature measurements were made of the surface and atmosphere. In addition, TV cameras took 198 high-quality pictures of the surface. Atmospheric pressures near the planet's surface were found to be between 1/250th and 1/125th of that of the Earth's sea level pressure, and evening atmospheric temperatures near the surface ranged from 28° F. in the equatorial region to −80° F. in the polar region.

Carbon dioxide, carbon monoxide, and atomic hydrogen, oxygen, and carbon were detected in the upper atmosphere, but nitrogen and ozone were not. Pictures of the edge of the planet showed at atmospheric haze almost 6 miles thick at an altitude of about 9 miles. Solid carbon dioxide at high altitudes off the bright limb and solid silica or silicate material in the lower atmosphere were observed. The surface temperature was found to be relatively moderate—during the day between −63° F. and +77° F. and at night between −63° F. and —153° F. Southern polar cap temperature was determined to be about −193° F.—a temperature at which solid carbon dioxide will not evaporate under Martian conditions.

Numerous craters up to 300 miles in diameter were seen on the planet's surface. The sharp demarcation of the light and dark areas, noted from Earth, seemed more diffused and splotchy when observed in higher resolution. The polar cap region, also heavily cratered, appeared to be covered by a thin layer of ice, which might be carbon dioxide with a small mixture of water. There were three types of terrain—cratered, featureless, and chaotic. The featureless terrain (without geographic marking at 900 feet) was observed in the Hellas region just north of the southern polar cap.

The northwest region of Aurorae Sinus, near the equator, was one of unusual chaotic topography indicative of terrestrial slump regions but much larger in area. Cratered regions, quite different from the Moon's, were observed throughout the areas photographed except in the area Hellas.

Since spacecraft design was completed, the major spacecraft effort progressed to the hardware fabrication and test planning phase. Functional design of mission operations was also completed, and moved forward to development and performance demonstration of the required computer programs.

Viking—NASA also plans (through its Viking project) to send two instrumented spacecraft to Mars for 90 days in 1973.

In February, 38 outstanding scientists—including three Nobel laureates—were asked to help plan the entry and lander portion of the missions. They were assisting in determining the scientific objectives for the spacecraft and in developing instruments to assure the maximum return of data.

Also, in 1969, a contract was signed for building the lander. The Viking Orbiter teams were formed at the Jet Propulsion Laboratory; NASA and the Air Force agreed on the use of Titan-Centaur as the launch vehicle; and NASA and the Atomic Energy Commission agreed on using radioisotope thermal generators as a source of electric power for the lander.

Pioneer—In addition, it was decided in February to fly the Pioneer F and G (XI and XII) spacecraft beyond Mars for exploring the interplanetary medium, the Asteroid Belt, and the environment and atmosphere of Jupiter. The spacecraft contractor and experiments were selected for launches in 1972 and 1973.

The fifth and last in the early Pioneer series (Pioneer E or X) was launched on August 27. However, about 8 minutes after liftoff the vehicle was destroyed when the Delta boosters failed. Pioneers VI through IX—launched into solar orbits, 1965–68—were still transmitting data on the interplanetary medium, solar activity, and their influences in Earth's environment.

Advanced Studies and Technology—Updating NASA's long-range plans for planetary exploration and laying the groundwork for missions to the planets in the near future, various studies were conducted. It was concluded that two three-planet "grand tours"—one to Jupiter, Saturn, and Pluto in 1977 and another to Jupiter, Uranus, and Neptune in 1979—would take advantage of the unique relative positions of these outer planets, not occurring again for 179 years; and a Venus-Mercury mission in 1973, to benefit from a "gravity assist" by Venus, would afford scientists an economical first exploration of Mercury.

Also established was the feasibility of a relatively low-cost Delta class mission to Venus in 1975 with multiple probes to explore the Venusian atmosphere; rendezvous missions for several comets with ordinary ballistic flight using chemical propulsion; and a Jupiter orbiter mission employing the basic spacecraft developed for the "grand tours."

These outer planet missions require major technological advances in such areas as telecommunications, data handling, and storage, guidance and control, onboard computing, failure diagnosis and self-repair, and environmental effects analysis. Through its planetary advanced technical development program, NASA was preparing to meet these stringent requirements.

The long life, more reliable, smaller, and lighter electronic and mechanical components, which are expected to be developed, will have widespread nonaerospace applications.

Planetary Astronomy—Two telescopes (funded by NASA) will be used in lunar and planetary studies. One of these—a 107-inch instrument at the McDonold Observatory of the University of Texas—obtained high resolution spectra of the planets and employed a laser beam to measure the distance between the observatory and the Moon. The other, an 88-inch telescope, was recently installed atop a 14,000-foot mountain peak for astronomers of the University of Hawaii.

Space Science and Applications

Orbiting Observatories—Three satellites of the Observatory type were launched during 1969: OSO–V, January 22; OSO–VI, August 9; and OGO–VI, June 5.

OSO–V—in a nearly circular orbit at a height of 350 miles, above most of the Earth's atmosphere—is made up of a rotating wheel to spin-stabilize the spacecraft and a "sail" section pointing steadily at the Sun. The "sail" carries an X-ray spectroheliograph designed and built in Great Britain; a Naval Research Laboratory ultraviolet spectroheliograph to map the solar disk; and an X-ray grazing angle spectrograph from Goddard Space Flight Center to study radiations from 1 to 400 angstroms. On the rotating wheel are experiments to monitor solar hydrogen, deuterium, and gamma rays, X-rays, and ultraviolet radiation, and to observe the dim zodiacal light.

OSO–VI, shaped like OSO–V, is designed to better scan the solar disk from a similar orbit. Its stabilized "sail" can point with an accuracy of better than 1 minute of arc at any of 16,384 points in a grid over the solar disk, and carries an ultraviolet spectrometer-spectroheliometer and X-ray spectrometers. On the "wheel" are a British experiment to study important solar helium spectral lines, an Italian experiment in solar X-rays and gamma-ray astronomy, and three American experiments in solar X-rays, zodiacal light, and the neutron flux.

Flown aboard OGO–VI (in low Earth orbit, 250 to 675 miles) are 25 experiments to investigate geophysical and solar-terrestrial phenomena helping scientists to better understand the relationship of the Earth as a planet of the Sun. These experiments ranged from investigations of the density and composition of Earth's upper atmosphere to studies of solar radiations reaching the Earth.

The performance of Orbiting Astronomical Observatory II (OAO–II), launched in December 1968, marked a substantial advance in astronomy when it demonstrated that astronomical observations must be extended from the visible to the invisible ultraviolet region of the spectrum to understand stellar phenomena. Traveling at an altitude of about 480 miles, the satellite carries two experiments. One of these, from the University of Wisconsin, uses five ultraviolet photometers and two spectrometers to obtain detailed photometric measurements of stars and nebulae, and the other, from the Smithsonian Astrophysical Observatory, uses four telescopes with TV imaging photometers to map the sky in the ultraviolet.

Explorer and International Satellites—Also launched in physics and astronomy programs were an IMP or Explorer XLI on June 21 and three cooperative international satellites. Explorer XLI, in its highly elliptical orbit extending to 110,000 miles from the Earth, carries 12 experiments for studying particles and fields in the near interplanetary space reaching about half way to the lunar orbit. In addition to transmitting scientific data, it supplied information needed to assure astronaut safety.

Radio Explorer I (RAE–I)—orbited July 4, 1968—continued to map the distribution of ionized hydrogen in the Milky Way of Earth's galaxy.

ISIS–I, the largest of the three international satellites was launched on January 29. A cooperative Canadian-American spacecraft, it was built in Canada, and orbited and tracked by NASA. In a near polar orbit, from 300 to 2,800 miles, its 10 experiments (four designed in the United States) study ionospheric physics by observing the upper ionosphere and atmosphere. The satellite continues investigations of the upper ionosphere begun by Canadian-American spacecraft in the Alouette I and II series of 1962 and 1965.

Also launched by NASA was the European Space Research Organization (ESRO) satellite Borealis on August 9. Borealis carries eight experiments from three of the 10 ESRO countries to study the polar ionosphere and the polar aurora borealis. In addition, the first cooperative satellite with West Germany, AZUR, was orbited by NASA on November 6. From a near polar elliptical orbit at moderate altitudes up to 1,600 miles, this satellite's seven experiments developed in German laboratories measure magnetic fields, protons, electrons, and a band of ultraviolet radiation between 3,000 and 3,900 angstroms.

Sounding Rockets and Balloons—During 1969 approximately 85 sounding rockets were launched to altitudes between 100 and 1,000 miles for studies in space physics and astronomy. These launches were conducted from sites in the United States, Canada, Brazil, and India. Also, about 60 high-altitude balloons were launched for outer space observations to altitudes as high as 150,000 feet, rising above 95 percent of the atmosphere of the Earth. These balloons carry heavier equipment than either satellites or sounding rockets.

Biosatellites—A primate was orbited for 8½ days aboard Biosatellite III June 28 through July 7 and recovered, marking what could well be the most complex experiment in the history of biological science.

The most important result of the flight (about 200 miles above the Earth, was the direct measurement of an increase in central venous blood pressure which the investigators have ascribed to weightlessness, caused by blood pooling in the central part of the body—shown by implanted catheters in and near the heart. Resultant increase in perspiration and urine output led to a dangerous drain in the monkey's fluid content leading to failure to maintain adequate blood pressure. The animal had to be recovered earlier than planned, since it was losing alertness, had stopped drinking and eating, and showed decreased brain temperature and venous pressure. It died 12 hours after recovery due to cardiovascular failure.

During the flight the primate lost about 20 percent of body weight mainly through water loss, had disrupted sleep patterns, a disturbed relationship between the eyes and organs of balance, and a loss of skeletal calcium.

Although these results cannot be directly extrapolated to man, the physiologic alterations, except for severity and progression, tend to validate some of the observations made in manned space flight. Since the cardiovascular control mechanisms of man and monkey are thought to be similar, they also suggest questions to be studied in future flight and ground-based experiments on both animal and man.

Communications Satellites—Three of the Intelsat III series of commercial communications satellites were launched in 1969—in February, May, and July. The July mission was unsuccessful when a launch vehicle failed. Two more Intelsat III's will be orbited next year, if needed by Comsat. These all have 1,200 two-way voice channels and can operate for 5 years.

NASA launches the Intelsat satellites (on a reimbursable basis) for Comsat on behalf of the 70 countries of the International Telecommunications Satellite Consortium (Intelsat) which owns them.

Intelsat IV procurement for an advanced spacecraft to provide between 3,000 and 10,000 telephone circuits to function for 7 years was in progress. An agreement was signed with Comsat to launch these satellites with Atlas-Centaur launch vehicles beginning in 1971.

NASA also served as consultant to Comsat, provided facilities services, and advised the Federal Communications Commission on several technical inquiries regarding the Intelsat spacecraft. Launching and associated services, including specific consultations and facilities services, were provided on a reimbursable basis.

Applications Technology Satellites—Applications Technology Satellites I and III (ATS–I and ATS–III orbited in 1966 and 1967) continued to provide experimental services. ATS–V launched this August failed to stabilize as planned. Even though some of its experiments were useless, a large number of them were able to achieve a high percentage of the expected results through modified data recovery techniques.

In September NASA and the Indian Government agreed to cooperate in an experimental program using ATS–F for instructional telecasts for agricultural training and family planning throughout that country.

Navigation-Traffic Control Satellites—In addition, NASA continued to use the ATS–III Omega position location experiment, in cooperation with the Department of Defense and the Federal Aviation Administration, to pinpoint the locations of ships and aircraft. NASA also entered into a cooperative study arrangement with them to investigate a preoperational UHF satellite system for the North Atlantic, and discussed testing this system in cooperation with the European Scientific Research Organization.

Geodetic Satellites—GEOS–II (Explorer XXXVI launched in January 1968) continued to supply some data and support Air Force camera teams in geodetic observations. The satellite also helped to calibrate laser tracking equipment for NASA and the Smithsonian Astrophysical Observatory. Operation of GEOS–II will not be continued beyond 1969.

Meteorological Satellites—Nimbus II, launched in May 1966, responded to commands until its control system failed in January 1969. Nimbus III (replacing Nimbus B destroyed at launch in May 1968) was orbited on April 14, 1969. The satellite has provided the world's first quantitative measurements of the structure of the atmosphere—supplying data from which the vertical profile of the temperature, water vapor, and ozone content could be deduced.

As the year ended Tiros M, the operational prototype for the next generation of operational weather satellites, was being readied for launch in early 1970. It will replace the global stored data satellite and the local direct-readout satellite of the first generation Tiros operational satellite system, and transmit global and local cloud cover data day and night.

NASA launched ESSA IX, a Tiros operational weather satellite, for the Department of Commerce in February. This spacecraft replaced ESSA VII—which had experienced camera and recorder failures—in providing global recorded cloud cover data. ESSA VIII, launched late in 1968, continued to transmit local readout cloud cover data. Other satellites of this system (ESSA II, V, VI, and VII) also continued to provide limited cloud cover coverage.

Meteorological Sounding Rockets—NASA launched 63 research sounding rockets of the Nike-Cajun class at altitudes between 20 and 60 miles, to obtain quantitative measurements of the Earth's atmosphere and develop methods of obtaining new and improved meteorological data. NASA also continued to develop improved, less expensive techniques to obtain routine meterological data for aerospace operations and research by launching 126 Dart or Arcasonde rockets.

Earth Resources Survey Program—Studies and experiments to investigate uses of space-acquired data to survey the Earth's natural resources were being continued by NASA at an increasing pace in a cooperative program with the Departments of the Interior, Agriculture, Commerce, and Navy.

Twenty-three aerial missions were flown over ground test sites to provide geoscientists with substantial Earth resources information. Aircraft operating at low, medium and high altitudes flew these missions carrying multispectral cameras, infrared imagers, microwave radiometers and radar to provide sensory data for evaluating developmental sensors and for developing scientific observational and interpretive techniques. Besides these test site missions over the United States cooperative aircraft overflight missions were conducted in Mexico and Brazil.

In addition, contracts were awarded two companies for definition and preliminary design studies of Earth Resources Technology Satellites (ERTS–A and ERTS–B). Spacecraft procurement and payloads were scheduled to meet launches in 1972 and 1973. These missions are expected to provide information needed for further devolpment of the applications of Earth resources survey data, test the operation of specialized sensors in space, and try out ground data management systems. They will help pave the way for an operational Earth resources survey system.

Further—cooperating with the Departments of Agriculture, the Interior, and Navy—NASA continued to support numerous detailed investigations to develop practical applications of space-acquired data in agriculture, forestry, geology, geography, hydrology, and oceanography. These investigations are based on the sensory data supplied by the aerial overfllights of the test sites, and from space photography such as the Apollo 9 multispectral photography experiment. This Apollo mission experiment demonstrated the potential of simultaneous correlated spacecraft and aircraft coverage for compiling an inventory of Earth's natural resources.

A conceptual study of two film recovery Earth Resources Satellites (ERTS–C and –D) was completed. The study clearly indicates the desirability of flying such missions while the ERTS–A and –B satellites are in orbit and acquiring data.

Light and Medium Launch Vehicles—During 1969 Scout launched the ESRO 1B satellite and the West German GRS–A1 cooperative international spacecraft.

Thor-Delta vehicles orbited OSO V, ISIS I, Intelsat III (F–3), ESSA IX, Intelsat III (F-4), Explorer XLI, Biosatellite III, OSO VI, Skynet I and Intelsat III (F–6). The launch vehicle failed to launch Intelsat III (F–5) and Pioneer E.

Thorad-Agena launched Nimbus III—a replacement for the Nimbus lost last year when the vehicle malfunctioned—and OGO VI, the last in the series.

Atlas-Centaur was used to launch two Mariner spacecraft to fly by Mars. The vehicle also orbited Applications Technology Satellite E.

Advanced Research and Technology

Basic and Applied Research

Fluid Dynamics—A significant advance in gas dynamic laser research was made this year with the development of an all chemical laser. It is the first for which continuous operation is achieved solely by the simple act of mixing commercially available bottled gases together. Laser energy is supplied entirely by the energy release of the chemical reaction that results spontaneously when the requisite bottled gases are mixed together. The advantages of this chemical laser are compactness, simplicity, and the fact that no electrical power source is required for excitation.

In sonic boom research, progress was made in predicting pressure waves from aircraft maneuvering through a nonuniform atmosphere. Theories were extended to include the effects of unsteady winds and atmospheric turbulence. Research was also underway to determine the pressure magnitudes in a "super boom" and also to determine the effects of three-dimensional flow fields near the aircraft on the prediction of sonic boom signatures near the ground. Of great importance were theoretical studies of the lower bounds for overpressure and shock pressure rise which indicate that substantial boom reductions are feasible. Theoretical concepts to achieve these lower bounds of sonic boom were evaluated in the NASA wind tunnels.

Research was initiated on the fluid dynamics of the interaction and dispersion of atmospheric pollution from airborne and ground sources in urban areas. Preliminary data from smoke flow experiments on an urban development model in a wind tunnel showed the concentrations and flow motions near buildings on streets perpendicular or parallel to the directions of winds. On streets perpendicular to the wind direction, there appears to be low ventilation into the adjacent streets. Research will continue to obtain quantitative data for a variety of atmospheric and pollution source conditions.

Recent improvements in instrumentation technology were the basis for the development of a skin-friction balance for direct measurements of the skin friction of aircraft structures for mach numbers up to 7. This new research tool reduced the uncertainty in the skin-friction results obtained by previous empirical methods from about 50 percent to a level of about 10 percent at mach 7. For a typical hypersonic transport designed to fly near mach 6, an uncertainty in skin friction of 25 percent is estimated to be equivalent to an uncertainty in payload of 25 passengers.

Applied Mathematics—In an effort to acquire more knowledge about exact solutions of nonlinear stochastic differential equations, NASA investigated a class of stochastic optimal control problems with minimum time, minimum expected fuel consumption, and least upper bound fuel consumption as performance criteria. The mathematical results were encouraging and should be applicable to calculations relating to the control of space vehicles by low thrust engines.

Electrophysics—A technique for continuously tuning a laser over many wavelengths is an important step in developing a laser for use in electronic communication systems. Although the intensity of the radiation at each of the various colors was very low, the Electronics Research Center researchers obtained a smoothly varying range of colors (wavelengths) from a single wavelength source of radiation by sending a highly intense beam of red light from a pulsed ruby laser through a small beaker containing ordinary water. Some of the red light was converted into light of other colors, and a continuous distribution of colors, ranging from violet to green, was observed, each color emerging at a different angle. Research is being continued in an effort to understand the color distribution and to develop the effect for practical use.

Materials—Silicon, which is the most important material for solid state electronics, depends upon the kind and the amount of impurities that can be introduced into its crystal structure for its electronic properties. Materials scientists at NASA's Langley Research Center were able to control the introduction of magnesium and beryllium impurity atoms into high purity silicon, and are continuing research on the manner in which magnesium and beryllium modify the electronic structure of silicon. Data from this research should increase power and current levels in circuits using these materials.

In other materials studies, a new nickel-base allow strengthened with tungsten, aluminum, and zirconium was developed; it may be useful at temperatures up to about 2050° F. Dispersion strengthened alloys were also extensively studied and ways were found to strengthen these allows and make them easier to produce.

In surface studies, new techniques (ion implantation) and new compounds (rare Earth fluorides) were evolved. The innovations will extend the life and temperature capability of dry film lubricants. Also, a new way to study the nature of a compound absorbed on metallic and semiconducting surfaces were found. The method, which utilizes field electron emission techniques, gives information on the electronic structure of absorbed molecules.

Aeronautics

Aircraft Aerodynamics—Progress in aerodynamic research increased knowledge of the basic principles involved in overcoming the limiting effects of shock waves generated as the local air flows over subsonic jet aircraft become supersonic. In wind tunnel tests, various improvements resulting from a better understanding of these principles were combined into advanced aircraft configurations capable of cruising very near the speed of sound (660 m.p.h.)—an increase of about 20 percent—without prohibitive penalties in range or payload. The reshaped wings and bodies evolved in the laboratory research will be flight tested on a supersonic airplane being modified by NASA. Research also indicated that this supercritical technology may be applicable to supersonic aircraft configurations without serious loss of supersonic capabilities. Thus, it may prove advantageous for supersonic cruise aircraft, such as the SST, to fly overland at speeds considerably faster than those of present subsonic jet transport aircraft but not fast enough to generate intolerable sonic booms on the ground.

Aircraft Operating Problems—Field tests proved that the laser Doppler technique can be used for remote measurement of atmospheric winds and incremental winds caused by the vortex wake of aircraft. One immediate use of the technique will be in an aircraft vortex wake research program, which seeks increased knowledge of the extent and persistence of dangerous winds contained in the wake of heavy transport aircraft. Such knowledge should be useful in the design and operation of airports, and control of air traffic in relatively crowded situations. The technique would also be valuable in research on clear air turbulence and wind shears.

Aircraft Flight Dynamics—An investigation was carried out to determine the cause of an apparent directional divergence problem experienced in flight by a twin-engine swept-wing aircraft. The problem, which occurred at high angles of attack and produced inadvertent poststall gyrations and spins, was found to be part of one cycle of a highly unstable Dutch roll oscillation brought about by simultaneous loss of both static directional stability and effective dihedral. The study indicated that the problem could be alleviated by incorporating wing leading-edge droop; this method was tested and verified by flight tests.

Aircraft Noise Alleviation—Research to determine methods of acoustically insulating turbofan nacelles to reduce engine fan-compressor noise showed that reductions of 10 to 15 decibels are feasible.

The quiet engine program advanced with the letting of a contract to develop and demonstrate the technology for a subsonic aircraft engine with maximum quieting of internal noise sources through basic changes in engine design.

Supersonic Aircraft—NASA wind tunnel tests of the low speed landing and takeoff characteristics of a highly efficient supersonic cruise transport configuration led to design improvements representing a significant advance in supersonic transport technology that may be applicable to current and second generation supersonic transports.

NASA–USAF YF–12 Flight Research Program—With the conclusion of the XB–70 and X–15 programs, a joint NASA-USAF supersonic research program was instituted in June to continue aeronautical research and development using YF–12 aircraft capable of sustained mach 3 flight. Phase I of the program is oriented primarily toward Air Force interest in a further definition of the tactical performance and support requirements of an advanced interceptor. Phase II is concerned primarily with NASA research objectives such as investigations of propulsion systems, airframe-propulsion system interactions, stability and control predictions of an aerothermoelastic airplane, structural deformation and flight loads, elastic mode control, and aerodynamic characteristics. Two YF–12 aircraft were being put in a flight-ready status and instrumented for the flight research.

V/STOL Aircraft

The V/STOL transition research wind tunnel at the Langley Research Center is readied to begin operation in March 1970. It is the only Government wind tunnel designed specifically for tests of V/STOL aircraft models. Specially designed slotted and removeable walls in the 15-by-21-foot test section will make it possible to obtain accurate aerodynamic data on high-lift STOL and VTOL models at very low speeds.

A large number of concepts for V/STOL aircraft have been investigated in past years. One V/STOL concept under present consideration for transport applications features a tilt rotor as the primary lift and thrust mechanism. A study of this design was begun in order to verify experimentally predicted characteristics of low disc loading of tilt rotors and to determine the effects of aeroelasticity, mach number, and Reynolds number on tilt-rotor performance. Initial tests were completed in the NASA 40-by-80-foot tunnel, the Army 7-by-10-foot tunnel, and the French Onera 26-foot tunnel, at speeds up to 500 knots. Additional tests of the dynamic characteristics of these rotors are scheduled.

An extensive flight research program continued the study of the operational problems of VTOL aircraft in the low-speed descent and landing phase of flight, particularly under critical instrument-flight conditions. Vehicles tested employed vectored-jet-lift, lift-fan, tilt-wing, and rotor concepts. The program seeks to determine the levels of control power and automatic stabilization required to minimize the time, fuel consumption, pilot workload, and airspace for landing the vehicle under instrument flight conditions. The program also includes the consideration of the use of pilot-displays to assist the pilot in making the approach to landing.

Chemical Propulsion

Liquid Propulsion Systems—Work in this area included the design of propulsion modules to investigate the problems of flight-weight propulsion system using two space storable, high energy propellant combinations, OF_2-diborane and flox-methane. Spacecraft thermal control and performance and weight were emphasized. Long firings with diborane produced a chamber durability problem arising from an apparent chemical attack on the carbon lining of ablative chambers. The solution to the problem involves the use of vaporized diborane as a regenerative coolant in a metal chamber.

Progress was made in developing a chemical process to manufacture oxygen difluoride at less than half the current market price.

Research on the flox-methane space storable propellant combination advanced with the completion of tests on a 5,000-pound thrust regeneratively cooled thrust chamber at 500 p.s.i.a. chamber pressure under simulated altitude conditions. Test performance and heat transfer data were used to prepare the detail design of a flight-weight pump fed flox-methane engine, capable of delivering a specific impulse of 400 seconds or more and of throttling over a 10/1 thrust range.

Experimental engineering tests of the 100-inch-diameter truncated plug nozzle thrust chamber under simulated altitude conditions were completed. These and similar sea level tests demonstrated the altitude compensation characteristics of this thrust chamber configuration. They also showed that this type of engine concept can provide ideal engine performance for booster stages operating in the Earth's atmosphere and for upper stages operating at altitudes.

In tests of the catalytic ignition of gaseous oxygen and gaseous hydrogen—a candidate propellant combination for auxiliary propulsion systems—ignition of 20-pound-thrust engines was obtained with propellant temperatures as low as −250°F. at chamber pressures of 10 and 100 p.s.i.a. Reliable ignition was also obtained with as much as 25 percent helium in the propellants. This combination would have application in space shuttles, space stations, and propulsion stages using oxygen-hydrogen as the main propellants.

A new high in delivered specific impulse for chemical rockets was attained in an altitude facility firing of a tripropellant (fluorine-lithium-hydrogen) thrust chamber: 508 seconds. This firing used a two-stage combustion cycle that avoids the extremely high temperatures normally associated with this propellant combination. A companion engine design study, using the two-stage cycle, indicated that a 15,000-pound-thrust pump-fed engine would weigh approximately 250 pounds and deliver a specific impulse of 515 seconds. A study program was started to compare the value of this engine system with a fluorine-hydrogen system over a range of spacecraft missions and launch vehicles.

Large Solid Motor—The effort in this area was expanded to include work on low-cost rocket case insulation, ablative nozzle materials, propellant process variables, a simplified motor steering system, and handling heavy motors.

Solid Spacecraft Propulsion Systems—Significant technology advances in solid fuel propulsion systems included the successful testing of two of the three concepts and readying of the third for test.

A full size hybrid motor prototype, weighing 3,200 pounds, was successfully fired in October. The energy level of the slightly modified propellant mix was equivalent to 380 seconds specific impulse under space conditions. In the firing, which had two burning phases—15 seconds and 50 seconds—separated by several days, all components performed satisfactorily.

A low acceleration motor was designed and tested. This design calls for loading the motor case completely full of propellant, with no central bore, and "end-burning" it to maximize the burning time. Three such motors were successfully tested, two weighing 60 pounds, the third 800 pounds. The latter burned for 2 minutes, three times the duration normally associated with this motor size. Further work to increase burning time and reduce hardware weight, should enable this motor to reach the remarkable efficiency level of being 93 percent propellant.

The third spacecraft propulsion system—a high energy restartable motor—is of a more conventional configuration, but includes a composition delivering 10 percent more energy than current solid systems and a stop and restart capability. A motor weighing over 3,000 pounds was manufactured and prepared for testing early in 1970. At any time during burning, the motor can be extinguished by injection of a small amount of water into the chamber. A built-in second igniter can reignite it, and a second quench supply used to finally stop burning. For missions not requiring stop and restart, the quench system can be removed and an increase in performance attained.

Solid Propulsion Technology—Several significant achievements were made in this area. An electron paramagnetic resonance (EPR) method for monitoring the rate of atomic bond rupture in plastic type materials was demonstrated. This very sensitive technique, which may provide information not readily obtainable by more conventional methods, can be applied to study environmental effects (stress crazing, cracking, damage from impact and shock loading) on polymers, including rubber and propellants. Another achievement is the use of the scanning electron microscope in combustion research. Using this device, it is possible to study in detail never before possible the deflagration behavior of ammonium perchlorate, aluminum and beryllium metal particles, and composite propellant itself. The ability to make such studies is an important advance in theoretical modeling and in the practical control of combustion processes. Finally, the Langley Research Center made significant progress in work on the decomposition mechanisms of ammonium perchlorate—a principal solid propellant ingredient. It found a means for stabilizing undesirable decompositions of this material. Such stabilization is an asset in solid propellant motors which must withstand the severe heat sterilization environment.

Biotechnology and Human Research

Human Research—Emphasis on vestibular research was increased during the year because of the apparent occurrence of a type of motion sickness in several of the Apollo astronauts shortly after launch. Studies are being continued in an effort to solve this problem, but no reliable protection from it has yet been found. Studies were underway in the National Academy of Sciences to define the effects on biorhythms of rapid transportation across time zones, cardiovascular research and bacterial and viral implications of space flight.

Bioinstrumentation—Transcutaneous optical techniques were being developed to measure major blood gas constituents during long duration manned space flights. The Electronics Research Center (ERC) tested an electro-optical instrument which measures the blood oxygen level by using red and infrared radiation reflected from the back surface of the eye when it is illuminated through the pupil. The instrument can be applied to other blood gases and, with minor modification, to other body sites such as the earlobe and finger. Clinical instrumentation of this type should be useful in anesthesiology and in mass medical screening centers.

The Flight Research Center (FRC) developed a modified Wright spirometer (a small device for measuring respiratory gas flow volume which must be read and recorded manually) in which a spoked wheel interrupts a light beam between a low power light source and a photosensor. The resulting digital electrical output can be automatically recorded and computer analyzed, permitting correction of the data for any nonlinearity at low flow rates. Such instruments should be increasingly useful to laboratories and hospitals which monitor active patients.

Aircraft Noise and Sonic Boom—NASA continued to gather data on the psychological and physiological effects of noise parameters on people. Acoustical and sociometric surveys which involved interviews with over 4,000 people while related noise measurements were being taken were made in Boston, New York, and Miami to determine community reactions to airport noise. The data was being studied and related to similar information collected last year for other cities.

Spacecraft Water Reclamation—A reverse osmosis water reclamation unit using glass membranes was developed. The glass membrane material eliminates problems of clogging and deterioration affecting units using organic membrane materials. Also, the glass can be subjected to heat sterilization and is chemically inert and resistant to corrosion. Tests of the unit at the Ames Research Center (ARC) showed over 97 percent rejection of organics, salts, and phenol. The Office of Saline Water continued to work with NASA on this approach to water conversion because it offers several advantages: low cost production of contaminant-free water, ease of service, complete and rapid system sterilization in the event of bacterial contamination of the water supply.

Emergency Life Support System—A prototype emergency life support system was being developed for the Manned Spacecraft Center (MSC). The lightweight system includes a breathing vest, a gas-operated pump for air and coolant circulation, and a 1-pound sublimator unit for cooling. Total weight of the system, excluding the liquid cooling garment, is 30 pounds; it fits in a container approximately 7 by 17 by 19 inches.

Metal Fabric Space Suits—A constant volume hybrid space suit made of a metal fabric with nonflammable elastomer backing was being developed for the MSC. The one-layer fabric, combining the qualities of abrasion resistance, pressure restraint, and gas impermeability, should be much more durable under operational conditions than the multiple layer suits now in use.

Aircraft Oxygen System—NASA developed a closed-loop breathing oxygen system for aircraft and tested it in a Navy aircraft. This system supplies oxygen from the electrolysis of water and removes carbon dioxide from exhaled gases through an electrochemical cell. The newly developed unit requires only stored water and electrical power, and NASA plans to study application of the technique to long duration manned flights. The military services also planned to support further development of the system as a possible replacement for present on-board liquid/gas stored oxygen systems.

Habitability—MSC surveyed the preferences of the astronauts and Air Force test pilots for off-duty activities during long duration space flights. Preferred items were physical exercise equipment, news and sports events, communications, and availability of snacks; however, the astronauts indicated that they did not believe there would be much free time available. MSC also developed equipment using flexible boots and small magnets dispersed in the sole, to facilitate astronaut mobility inside a space station in orbit. And the Langley Research Center was designing lunar shelters to improve habitability by facilitating passage through hatches and by arranging internal furnishings.

Behavioral Research—Tektite I, a joint Navy, NASA, Department of the Interior marine sciences, biomedical, and behavioral research study, was completed. Four marine scientists spent 60 days in a nitrogen-oxygen environment at a depth of 42 feet in the Caribbean Sea, collecting information on group interactions, psychomotor performance, habitability, and on microbiological and physiological data of interest to NASA.

Space Vehicle Systems

Aerothermodynamics—The NASA HL–10 lifting-body research vehicle completed 18 flights this year for a total of 30. It was flown near its maximum speed and altitude capability, reaching Mach 1.6 and an altitude of 80,000 feet. The flight test data indicated that the HL–10 has good flying qualities over the entire speed and altitude ranges flown. Future flights were scheduled to obtain additional aerodynamic data and to evaluate powered landings. The X–24A Air Force lifting-body made its first flight on April 17, and has now completed seven flights.

Flight and wind tunnel tests of parachutes designed to land unmanned spacecraft on Mars concentrated on ways of obtaining more stable operation at higher

Mach numbers. Progress was also made in research on inflatable devices attached to the aft end of planetary entry spacecraft to provide greater deceleration of the vehicle. Wind tunnel tests with 5-foot-diameter models demonstrated that the inflatable device will operate satisfactorily in the low density atmosphere of Mars.

Research also continued on vehicle shapes and heat protection systems for planetary atmospheric probes. Advances were made in designing and fabricating a spacecraft that can be used to determine planetary atmospheric composition from instrument measurements and vehicle motions during entry.

Structures—A NASA-sponsored computer program for structural analysis—Nastran—was completed and delivered to the Agency. Nastran gives NASA the capability for analyzing far more complex structures than was previously possible, and it will solve a greater variety of structural problems. Because it can be employed on several different types of computers, it will transmit structural data between the NASA centers and their contractors. In addition, its modular design makes it easy to incorporate improvements in structural analysis resulting from research programs. This ability gives the program a longer and more useful life and an increasingly broader capability.

Space Environmental Protection and Control—Research on charged particle radiation shielding led to an improved ability to calculate the effectiveness of shields against high energy protons. Codes previously applicable to particles up to 400 MeV were extended to energies as high as 3 GeV. They will be useful in shielding calculations for the supersonic transport program, high energy particle accelerators, and for space vehicles.

The Pegasus III meteoroid detection satellite reentered the Earth's atmosphere on August 4, after a 4-year lifetime, with all subsystems operating properly. A Scout-launched meteoroid technology satellite was approved; it will incorporate improved pressure cell sensors to obtain anchor-point data on the effectiveness of double-wall structures in preventing meteoroid penetrations. Another pressure cell meteoroid sensor experiment and an optical meteoroid experiment were approved for flight on the Pioneer F/G mission to assess the meteoroid hazard between the Earth and Jupiter, especially in the region of the asteroid belt. Continued research on devices for laboratory simulation of meteoroids resulted in acceleration of a 2-gram simulated meteor to 42,000 feet per second.

A triangular radiator, based on the selective stagnation concept developed for the Apollo CSM environmental control heat rejection system, was constructed; a simplified version, incorporating a glycol coolant, was found to have a sufficiently wide heat load range for use on a lunar landing vehicle. It was studied as a possible replacement for the present expendable water cooling system used on manned lunar landing vehicles.

A computer program was developed which permits greater accuracy in estimating incident radiation on orbiting spacecraft surfaces. It was used in the thermal design of spacecraft at the Goddard Space Flight Center.

To improve calibration of solar simulators, both 1969 Mariners were equipped with radiometers to measure solar intensity during solar vacuum testing and in flight. As a result, the solar constant was measured in space for the first time; the intensity of solar radiation at the Earth's mean distance from the Sun was found to be 135.3 ± 1 percent milliwatts per square centimeter. Small variations in solar intensity recorded during the flight to Mars simultaneously on both vehicles are believed to be caused by certain variations in solar ultraviolet energy.

Aerospace Design—Eleven space vehicle design criteria documents were completed and disseminated to the aerospace community. They covered information on environments important in design, and criteria and preferred practices for use in the design of vehicle structures and guidance and control systems.

Electronics and Control

Predicting Flight Test Performance—The ARC improved present procedures and developed new methods for mathematically modeling the airframe, the vehicle control system, and the pilot dynamics from flight test records. The ability to form such mathematical models is an important part of flight test analysis. Ames' scientists used modern control theory and digital computers to analyze flight test data, derive the pilot's response, the multidimensional motions, and instrumentation inaccuracies, and to construct mathematical models which are applicable to untried flight conditions or new vehicles. As a result, they were able to make more accurate predictions of vehicle and pilot performance before flight. The same methods appear to be applicable to such fields as biology, economics, and chemical processes, where it is also important to identify and analyze the dynamics of systems under study.

Saturn V Manual Guidance and Control—A backup manual guidance and control systems for the Saturn V launch vehicle developed by the Ames Research Center, and verification work by the Marshall Space Flight Center and the MSC led to the incorporation of such a system on Saturn V launch vehicles, beginning with Apollo 10. This system gives astronauts the capability of injecting into Earth orbit for some failures of the launch vehicle automatic guidance and control system. Without this capability the launch and mission would have to be aborted.

Scanning Electron Mirror Microscope—The operational model of the scanning electron mirror microscope developed by the ERC for nondestructive study and examination of semiconductor devices was completed. This instrument is particularly useful on integrated circuits that do not have multilevel flat surfaces. The Air Force used the prototype model of this instrument to screen several hundred transistors as a test of its capabilities, and is now purchasing an operational model.

Integrated Circuit Production—The ERC devised an improved technique for wafer separation, a step in integrated circuit production, which results in nearly 100-percent yields. In this technique, a scribed wafer is placed between a domed surface and a flexible cover and pressure is applied to the cover to force the wafer into the shape of the dome. As a consequence the individual chips are separated and forced away from their neighbors, eliminating contact between chips and minimizing damage during the separation process. In the older method, 10 to 25 percent of the chips in a single wafer could be lost due to cracks and scratches caused by the scribing and breaking step in the process. Since each chip represents a large fraction of the total cost of a packaged device, the improved technique is important for economy in large-scale production.

Cost Effective Computer Programing Techniques—ERC scientists developed a technique for more cost-effective programing of small, high speed computers commonly used in laboratory research. This "time shared disc operating system" enables the computer system to participate in program development by continuous interaction with the user to assess and validate each coded instruction as it is generated. Remote input and display devices allow several researchers to develop independent programs simultaneously using the computer in a time shared mode. Three organizations other than NASA have adopted the technique for research application, and several computer manufacturers are considering commercial marketing in conjunction with standard product lines.

Structural Stress Measurement—The Langley Research Center (LRC) developed an electro-mechanical fatigue gage which measures and records the accumulated number of times various strain levels are exceeded by aircraft wing structures in flight. Small and relatively inexpensive, the device incorporates a unique mechanical motion-magnification principle by which the motion along the strain sensitive axis is magnified 30 times, thus eliminating complex power supply and electronic amplification circuits. The gage should also be useful in predicting the service life of large structures such as bridges.

Zero Power Remote Switch—The ARC developed advanced solid state switches using silicon transistors and silicon controlled rectifier circuits. They consume practically no power in the off position and thus conserve battery power. Actuated by an external electromagnetic pulse, such switches are used in ARC's multichannel telemetry circuits and in the ultrasonic micrometer which telemeters the dimensions of the beating heart to an external recorder. As a result the operable lifetime of the circuits is approaching 2 to 3 years—the shelf life of the batteries.

High Altitude Altimeter—The Ames vibrating diaphragm pressure transducer system was improved and modified from its original laboratory version into a rugged, lightweight package suitable for airborne and space applications. The principle was incorporated in prototype atmospheric entry probes which will be used to measure planetary atmosphere profiles, it will also be used as a high altitude aircraft altimeter at the Flight Research Center. In tests, a system resolution equivalent to 10 feet at 100,000 feet altitude was achieved.

Beach Erosion Instrumentation—LRC developed a water current meter which uses a strain gage balance similar to those used in wind tunnel instrumentation in combination with a small water-force sensing perforated sphere. From measurements with this instrument, water movement was correlated with sand transport. The Virginia Institute of Marine Science plans to use arrays of such instruments to study methods for the control of beach erosion.

Pilot Warning Indicator—Development of a relatively simple and inexpensive pilot warning collision threat indicator (PWI) progressed sufficiently to permit testing of the microwave model in actual aeroplane flights. The tests demonstrated the soundness and validity of the principle. Work continued to optimize operating frequencies, size, and weight, and to reduce the cost, so that the system will be acceptable to the general aviation aircraft industry.

Work also progressed on development of a PWI based on optical principles. Two somewhat different models were built for the ERC for testing in 1970.

Telescope Active Optics Technology—The technique of controlling small deformations of the optical surface of large mirrors and of space telescopes was successfully demonstrated with a 30-inch-diameter thin mirror. Surface irregularities due to thermal, gravitational, or other effects are detected by a laser "figure sensor" in front of the mirror. Error signals, proportional to the deformations, are developed and sent through a servo control system to a suitable number of actuators attached to the back of the mirror. The actuators push or pull on the mirror, counteracting the surface deforming forces, thereby restoring the mirror surface to its undistorted condition. Work continued at ERC to refine the techniques and technology and to build space qualified components of the complete active optics system. These techniques are important to future NASA space astronomy programs, which will use large-diameter mirrors.

Optical Communication Lunar Experiment—The technology developed by Goddard Space Flight Center for the pulsed ruby laser, used to track orbiting satellites, was successfully applied to measuring the distance from Earth to the optical reflector left on the moon by Apollo 11 astronauts. Short pulse lasers, coincidence detection circuits for noise discrimination, and very fast photo-detectors and timing circuits were used, and accuracy achieved was about 4 meters. Work will continue to reduce the errors to less than 1 decimeter. This technology will make it possible to measure the distance from the Earth to the Moon, and the lunar path around the Earth with greater precision than formerly possible.

New Infrared Detector—Marshall Space Flight Center developed a new highly sensitive infrared detector, operating in the 9,000-angstrom region whose quantum efficiency is some two orders of magnitude greater than that obtainable previously. This same detector also works in the visible region with very high efficiency. Made of gallium-arsenide with a cesium oxide surface, the detector will have wide application in astronomical research in optical communication receivers.

Space Power and Electric Propulsion

Thermionic Conversion—Major progress was made in several areas of the reactor powered thermionic conversion program. Long-term test data were obtained on uranium carbide and uranium oxide fuels at thermionic operating conditions (temperatures, power densities, etc.). Very long-term stability of emitter-collector surfaces and satisfactory performance of other converter components were demonstrated in 23,000 hours of out-of-pile testing of an unfueled thermionic converter. The converter, which operated at 1700° C, had a high performance "preferred (crystal) oriented" tungsten emitter which remained metallurgically stable throughout the test and as a result produced a constant electrical power output. Also, analytical and electrical analog studies indicated that fast neutron spectrum in-core thermionic reactor systems can be controlled by conventional means. Finally, significant data were obtained in various experimental programs concerning uranium oxide fission gas venting methods; performance of "preferred oriented" Rhenium emitters; fuel emitter metallurgical compatibility at high temperatures; and the electrical properties of "cracked" insulators in the presence of cesium vapor.

Thermoelectric Conversion—In April, two SNAP-19 radioisotope thermoelectric generators (RTG's) were successfully launched aboard a Nimbus satellite and are operating. The SNAP-27, another RTG, is used as the power supply for the Apollo lunar surface experiment package (ALSEP) placed on the Moon in the Apollo 12 mission. RTG's based on the SNAP-19 design were under development for the Pioneer F and G Jupiter missions and the Viking Mars lander mission during the 1970's.

Electrochemical Power—OAO-II, launched December 7, 1968, carried a new battery charged-controller developed for the Goddard Space Flight Center. The three batteries have the conventional temperature-compensated, voltage-limited charge control. However, the specific voltage cutoff is determined by ground control based on the third electrode signal. Experience during 1969 showed that having this control electrode aboard has permitted the voltage to be reduced by 0.4 volt for the first 8 months and by 0.2 volt thereafter. The lower overcharge resulted in less gassing and less overheating of cells, and consequent longer cell life. The electrochemical onboard power of OAO-II has been free of problems. The improved battery characteristics make it probable that third electrodes will be used on subsequent spacecraft and will also be used directly for controlling the battery chargers.

Solar Cells—NASA continued to make progress in extending the usefulness of solar cell power systems to the higher power levels needed for future space vehicles. Improvements made on lightweight rollout solar cell arrays moved toward the goal of 30 watts per pound for planetary spacecraft applications. Important experimental data were obtained on a lithium diffused silicon solar cell that promises to be more radiation resistant that the conventional N on P boron diffused solar cell, and theoretical understanding of the lithium cell was increased.

Nuclear Electric Power Systems—All the major components of the 35 KWe SNAP-8 mercury Rankine power conversion system reached a demonstrated life of 10,000 hours, and life testing is continuing. A breadboarded power conversion was operated for 7,200 hours without major component change or repair, giving important data on long-term component interactions in actual system operation. System transient investigations prerequisite to preparation for tests using a reactor were completed in a second breadboarded power conversion system.

In the advanced alkali metal Rankine program, testing of a three stage turbine representative of a 300-KWe unit resumed, testing of a full-scale boiler feed pump started, and fabrication of single tube 2100° F. experimental boiler for thermal performance testing was completed.

Testing of a 2–10-KWe Brayton turbogenerator system using electrical heaters to simulate the planned nuclear isotope heat source was started at the Lewis Research Center. Separate hot endurance testing of a second combined turbine-alternator-compressor rotating unit for this system reached 1,000 hours.

A discussion of progress and uses of other nuclear systems, including the SNAP–27 device used in the Apollo 12 lunar experiments, may be found in the Atomic Energy Commission chapter of this report.

Electric Engine Systems—Research on solar array powered electric propulsion continued to advance. The ground systems technology program completed a demonstration of remote control of the necessary elements of power handling, thruster throttling, and attitude control. The results of this study were used to assemble the equipment required for evaluation of a more advanced system closely approximating that required for a mission spacecraft. A second element of this effort is the planned space electric rocket test (SERT–II) orbital flight intended to verify long-term ion thruster performance in the space environment. Technical difficulties in the power handling subsystem resulted in the rescheduling of this launch to 1970.

In another auxiliary propulsion effort, a major milestone was achieved with the successful conclusion of an 8,000-hour test of high temperature resistojets, which are prime candidates for use in drag cancellation and attitude control of manned space stations. These engines were also operated on life support system byproducts.

Nuclear Propulsion

The nuclear rocket program, a joint NASA/AEC effort, is aimed at providing a significant increase in propulsion capability for future space activities. The principal objectives are to acquire the basic technology for nuclear propulsion systems and to develop a 75,000-pound-thrust engine called NERVA (nuclear engine for rocket vehicle application) based on this technology. The program also includes a variety of supporting and advanced research and technology activities to assure continuing improvement of nuclear rocket performance and to provide the base of information for developing a nuclear stage.

The United States has been conducting this program for 10 years. During 1969, the effort was successfully concluded when researchers completed tests on a ground-experimental nuclear rocket engine in the desert at Jackass Flats, Nev. Based on this technology, development of the NERVA engine was initiated.

Technology Phase—The technology which has been developed and is now being put to use in the design of NERVA has provided many reasons for being optimistic about the future of this new form of propulsion. For example, since 1964, when the first nuclear rocket reactor was operated at 1,000 megawatts, 12 consecutive reactors and engines have been tested for a cumulative test time of more than 14 hours. During more than 4 hours of this time the test articles operated at high power. These tests, when viewed with all of the previous research and laboratory tests and analyses, have substantiated the belief that a high level of performance and reliability can be achieved from this new form of propulsion.

Power tests on the XE engine involving the flow of propellant (liquid hydrogen) began on March 20, and ended on August 28. During this period, 28 successful engine startups were completed under simulated conditions. The engine was operated for a cumulative test time of approximately 2.8 hours at various thrust levels, including 3.5 minutes at full thrust (approximately 55,000 pounds).

The XE engine tests explored a variety of engine operating methods, including automatic startups through the use of bootstrap (self-powered) techniques which do not require external sources of energy, multiple restarts, and throttling, and demonstrated once again the high degree of stability of the nuclear rocket engine. The program also validated the design and operation of the engine test stand No. 1 for testing the nuclear rocket engines.

Nuclear Engine Development—The results of the technology program provided a sound basis for proceeding with the development of a nuclear propulsion system capable of rapid startup, adequate shielding, high power density, long reactor lifetime, self-energized start (bootstrap), throttleability, and high performance.

The first generation nuclear rocket engine, NERVA, on which work is now underway, is being designed to provide approximately twice the specific impulse of chemical rockets (75,000 pounds of thrust, with a specific impulse of 825 seconds). As an integral part of a new capability for space transportation, the NERVA engine should be able to move large payloads from low Earth orbit to geosynchronous orbit or to lunar orbit in support of extended lunar exploration. It should also offer major advantages for transporting heavy payloads into deep space in a reusable mode consistent with the NASA integrated plan. The increased propulsion energy it makes available can be used for any of a variety of purposes in such missions. It can be used to increase payloads, to reduce trip times for certain missions, and to provide greater reliability for the successful completion of the mission.

During 1969, NERVA engine development work was concentrated on a thorough systems analysis of flight-engine design requirements and on studies to determine the best way of designing the engine to meet these requirements. The next step is to complete the design of the reusable flight rated engine and enter into the component testing phase.

Test Facilities—NASA and the AEC began preliminary planning and analyses to define the facility requirements for NERVA engine/stage development tests at NRDS. The existing test cell "C" will be used for all NERVA reactor tests. The NERVA engine will be qualified in engine test stand No. 1 (ETS–1). The design of ETS–1 modifications to accommodate the 75,000-pound thrust NERVA engine is underway.

The two agencies also conducted a preliminary engineering study for the design and construction of the new engine/stage test stand. This stand, to be called E/STS–2, will be used to qualify the nuclear stage, incorporating NERVA, for flight operations.

Nuclear Stage Technology—The technology required for a nuclear-rocket stage is largely the same as that for a cryogenic chemical-rocket stage. Consequently, stage work sponsored by the nuclear rocket program is focused on problems unique to nuclear propulsion or nuclear-rocket missions. They deal primarily with liquid hydrogen storage.

During 1969, the two agencies began examining various nuclear stage concepts to assure a basic configuration suitable for a variety of missions, including unmanned planetary probes and orbital ferry service. Emphasis of this study will be on the ferry missions, in which solutions to long-term liquid hydrogen storage requirements bear crucially on mission success.

One possible approach to improve liquid hydrogen storage in space is to reliquefy the propellant boil-off and reinsert it into the tank. A hydrogen reliquefier, capable of reliquefying about 3 pounds per hour of hydrogen vapor was built and is soon to begin undergoing laboratory testing.

Tracking and Data Acquisition

The NASA tracking and data acquisition networks handled a substantial workedload supporting 64 missions, 24 of which were launched during the year. The accurate communications support provided the flights of Apollo 9 through 12 enabled hundreds of millions of persons to follow these flights and to witness man's first step on the Moon's surface during Apollo 11. Support was also given the highly successful Mariner 6 and 7 missions to Mars, the four Pioneer missions, and OSO, ATS, and Biosatellite flights.

Manned Space Flight Network—The network began the year's flight activity with the launch of Apollo 9 (March 3). This was the first time the network had to support two manned spacecraft simultaneously—the LM and the CSM. The maneuvers performed by the two Apollo 9 spacecraft involved the most complex support requirements up to that time. In addition to performing many more routine tracking and data acquisition functions, the network also monitored astronaut extravehicular activities. The network next supported the Apollo 10 mission (May 18–26). This was a manned lunar mission development flight to evaluate the performance of the LM in the cislunar and lunar environment. As the LM and CSM spacecraft undocked in lunar orbit, the network stations began simultaneous support of the two manned vehicles. Precision tracking and high quality voice communications received and relayed by the global network stations permitted the flight controllers at Houston and the astronauts to work together to assure safe descent of the LM to within 10 miles of the lunar surface and the return rendezvous with the CSM. In addition to providing precise tracking and telemetry coverage during the journey from the Earth and the Moon and at lunar distance, the network received 19 color television transmissions, including dramatic color views of the Moon.

On July 16, the network began the actual in-flight support of the historic Apollo 11 mission—a flawless performance by the network facilities and operating personnel. Voice communications were perhaps the best ever, enabling people all over the world to share the sounds, and often, sights, of man's first journey to the Moon.

Following the Apollo 11 flight, the Apollo schedule was revised to a lower launch rate, and significant changes in the network configuration were possible for the Apollo 12 mission. Only one of the National Range tracking ships was required for Apollo 12 (five were originally required), the requirements for Apollo aircraft were reduced from eight to four, and the number of land stations was also somewhat less.

Deep Space Network—The deep space network continued its support of the four ongoing Pioneer missions—6, 7, 8, and 9. In addition, the network supported the highly successful Mariner 6 and 7 missions, lanuched February 25 and March 27, respectively. From liftoff through their flyby encounter of the planet Mars, the twin spacecraft were monitored and controlled by the network. The continuous command and control capability of the network enabled the Mariner 6 and 7 spacecraft to come within 150 and 190 miles, respectively, of their targeted points after traveling nearly 190 million miles—an accuracy of 1 part in 1 million. Limited support continues for the two spacecraft as they continue their journey beyond Mars.

The network stations have received nearly one-half billion bits of scientific data from the Mariner spacecraft. The ability to acquire such a vast amount of data—16,200 bits per second for the Mariner 1969 spacecraft, or almost 2,000 times the rate capability of Mariner 4 and 5—was the result of significant improvements in the spacecraft and ground support network. The deep space network was used for two experiments which reqiured no special instrumentation aboard the spacecraft. One was an occultation experiment which provided atmospheric pressure measurements of Mars through the analysis of changes in the spacecraft radio signal as the spacecraft disappeared behind the planet relative to the Earth. The second experiment dealt with celestial mechanics, and, by analyzing the tracking data, it has been possible to determine that the mass of Mars is about one-tenth the mass of Earth.

Satellite Network—This network continued its support of an average daily workload of about 40 satellites related to NASA's scientific and applications programs as well as to space projects conducted by other Government agencies and private industry.

In addition to the planned support of the above missions, the network was called upon to provide unique support for the OSO–6 and emergency support for the ATS–5. OSO–6, launched August 9, includes an experiment capable of scanning small areas of the sun's surface. Normal operation calls for the spacecraft to scan the entire solar surface. If an area of the sun's surface is experiencing unusual activity, however, the spacecraft is commanded, via the satellite network, to scan the selected sector, allowing experimenters to examine the phenomenon in greater detail. This near-real-time command capability of the network increased significantly the scientific data return from this experiment and made it possible to formulate a model of solar flare phenomenon.

ATS–5, shortly after its August 12, 1969, launch, required emergency support from the network. Due to a malfunction in the onboard stabilization system, the spacecraft had to be placed into its synchronous orbit at a point where normal coverage from the Earth could not be obtained. To overcome this lack of geographical coverage, the station at Johannesburg, South Africa, made use of the ATS–3 spacecraft to support the ATS–5. Flight controllers at the Goddard Space Flight Center sent the necessary commands to the Rosman, N.C., station which relayed them via ATS–3 to Johannesburg and then to ATS–5. The rapid response by the network allowed insertion of ATS–5 into synchronous orbit during its first apogee after launch.

In June, the final Biosatellite flight in the present series was completed. As a result, it was possible to deactivate the station at Lima, Peru, in August, and to relocate the majority of the equipment to other stations. Similarly, the launch of ATS–5 allowed NASA to close the transportable station at Toowoomba, Australia. The station will be operated by the Australian Government for experimentation in conjunction with the ATS–1 spacecraft.

University Programs

NASA's university programs include all project-oriented research supported by the various program offices and NASA centers, and the sustaining university program. They are supervised by the Office of University Affairs. The programs, emphasize quality research which is useful to NASA and to the colleges and universities as a source of strength.

In 1969, NASA funded about 1,400 projects at some 230 universities, with an expenditure of approximately $115 million. NASA made a special effort to alleviate the recurring funding crises of research projects by providing some forward funding at reduced levels for approximately half of the continuing research projects at the universities.

International Affairs

Significant achievements in NASA's international activities included an agreement with India for an experiment involving use of a NASA satellite to broadcast instructional television programs; an agreement with Germany or Project Helios; the foreign distribution of lunar material; action in support of the President's statement to the United Nations on the Earth Resources program; and the successful launching of three foreign satellites. In addition, a tracking support agreement was extended Spain and a renewal of an Australian agreement was under way.

The purpose of the satellite television experiment with India is to demonstrate the potential value of space technology to the establishment of mass communications systems in developing countries and to evaluate the impact of the experiment on managerial, economic, technological and other aspects of national development in India. The experiment will be the first to provide television broadcasting from a satellite into small receivers without the intervention of ground relay stations. NASA will make the ATS–F satellite

371-775 O - 70 - 3

available to India for 1 year. The satellite is scheduled to be placed in synchronous orbit over the Equator in 1972 and to be available to India while additional experiments are conducted by U.S. and other experimenters. India will have sole responsibility for television programing (to be directed primarily to family planning, agricultural improvement, and national integration). It will also provide and maintain the ground hardware segment of the experiment, including the village receivers. Any continuing service after the first year of the experiment will be the responsibility of India.

Project Helios is a cooperative endeavor with the German Ministry for Scientific Research to place two solar probes (1974–75) closer to the Sun than any other spacecraft yet scheduled. The objective is to acquire new understanding of fundamental solar processes and of Sun-Earth relationships. An agreement was also reached with Germany on Project Aeros, in which NASA will launch a German-developed satellite in 1972 for aeronomy measurements.

Lunar surface material returned by the Apollo 11 astronauts was distributed in 1969 to 39 principal investigators from nine countries—Australia, Belgium, Canada, Finland, Germany, Japan, South Africa, Switzerland, and the United Kingdom. Major fields of investigation are mineralogy and petrology, chemical and isotope analysis, physical properties, and biochemical and organic analysis. Switzerland contributed one of the scientific experiments carried out during the Apollo 11 mission, a sheet of aluminum foil deployed on the lunar surface to measure the composition of the solar wind.

The three foreign satellite launchings in 1969 were the Canadian ISIS–I, launched in January as the third of a series of cooperative satellites to conduct ionospheric measurements; the ESRO–IB, launched in October for the ESRO on a reimbursable basis; and the German Azur, launched in November in a German/United States cooperative project to conduct radiation belt measurements. Agreements for new projects were reached with the United Kingdom, Italy, the Netherlands, and Canada. The United Kingdom agreement concerns the U.K. No. 4 satellite, to be launched in 1971 on a NASA Scout vehicle to conduct ionospheric particle and radio noise measurements; and an experiment to fly on the Nimbus E spacecraft in 1972. The agreement with Italy provides for the San Marco C satellite to be launched in 1970 on a NASA/Scout vehicle from the Italian San Marco Range in the Indian Ocean; it also provides for use of the San Marco Range for launching the NASA spacecraft into equatorial orbit. With the Netherlands, the agreement enables two scientists to participate as guest obsrvers in the OAO program. And the arrangement with Canada calls for a reimbursement launching of a Canadian domestic communications satellite. The last is an agreement in principle and is the first such arrangement for the U.S. launching of a foreign civilian communications satellite.

In an address to the United Nations General Assembly on September 18, President Nixon drew attention to the potential benefits of Earth resources survey techniques. He stated that as the program proceeds and fulfills its promise, the United States would take action to share the projected benefits. In support of the President's pledge, NASA has already joined Brazil and Mexico in cooperative remote sensing aircraft and provided advice to India on the establishment of a similar program. NASA support the international biological program with Earth resources aircraft data and expanded its international graduate fellowship program to include Earth resources disciplines. It brought the attention of U.N. member states to the Sixth International Symposium on Environment held at the University of Michigan in October. Finally, NASA participated in a number of Earth resources symposia abroad and collaborated with India in developing a recommendation to establish a space applications liaison office in the U.N. Secretariat.

Additional international cooperative projects included the launching of one Italian, two British, and two French experiments on NASA spacecraft. Sounding rocket projects with Australia, Brazil, Canada, India, Japan, Norway, Pakistan, Spain, Sweden, and the United Kingdom were continued. Canadian and French experiments were included on the Convair 990 flights to study aurorae in northern latitudes. Also continued were the aeronautical research projects with Canada, France, Germany, and the United Kingdom.

On June 25, the agreement with Spain for the NASA Madrid Tracking Station was extended until 1984; and negotiations with Australia were underway to extend arrangements until 1980. These extensions will assure adequate tenure for the 210-foot-diameter antennas to be established in each country for the support of planetary explorations.

Following reassessment of requirements for tracking station support for both the manned flight and scientific satellite programs, NASA deactivated the Lima Stadan station, arranged for a phase-out of the Newfoundland Stadan station, and placed the manned flight stations at Antigua and Grand Bahamas Island on a standby status. Following fulfillment of U.S. requirements, the Cooby Creek Applications Technology Satellite ground station was made available to the Australians on a temporary basis for use with Australian-initiated experiments. It was further determined, in coordination with the Canadian National Research Council, that U.S. sounding rocket launchings and related scientific research at the Churchill Research Range under the intergovernmental agreement of June 11, 1965, will be phased out by June 30, 1970.

In addition to the support by regular NASA tracking stations in Australia, that country supported Apollo lunar flights with its 210-foot antenna at Parkes.

Industry Affairs

This area embraces a number of different industrially related activities of NASA. In each of these, NASA sought to improve management practices in the interests of efficiency and economy.

Inventions and Contributions—The Inventions and Contributions Board reviewed and recommended action on more than 140 petitions for patent waiver received from NASA contractors during the year. The Board also recommended the granting of monetary awards amounting to aproximately $100,000 for scientific and technical contributions made by NASA and NASA contractor employees. A study of the activities of patent waiver grantees showed a continued increase in the number of inventions which were fully commercialized by NASA contractors after a waiver of patent rights.

Research Grants—Measures taken during the year to enhance the effectiveness of NASA's research grant program with educational institutions and nonprofit organizations included the preparation of a Grant Negotiator's Guide which is being field tested; the presentation of a 3-day training course in grant negotiation, award, and administration to a large number of NASA and other Government agency personnel; and the development of a Research Grant Handbook containing all NASA regulations in this field. It will be ready for distribution early next year.

Government Property Management—For better management of industrial property, NASA expanded its Government property controls to require the contractor to provide industrial plant equipment costing less than $1,000; to maintain and administer a program for utilizing Government property in accordance with sound industrial practice; and to state in writing his financial inability or unwillingness to acquire facilities necessary for the performance of a NASA contract. In addition, the rental rates for commercial use of Government property were raised.

Procurement Processing—NASA continued its efforts to compress the length of time required to put a major procurement under contract once the decision to proceed has been made. In a study to ascertain the time required to process contractual actions requiring headquarters approval, the overall time for each of the major milestones in the cycle was analyzed, and all the elements contributing to the milestones involving headquarters' participation were intensively examined. The study results were reviewed by a senior management committee, which recommended ways of streamlining the decisionmaking process. Another phase of the study covering milestone steps performed at field locations was in progress.

Cost Reduction Program—Cost reduction savings achieved during the year amounted to $345 million an increase of $5 million over 1968, although the available funds for both years were approximately the same. NASA and its major contractors successfully accelerated their efforts to improve performance and substantially reduce costs. The NASA internal cost reduction program yielded savings of $170 million, and the NASA contractor cost reduction program, in which 32 of NASA's principal contractors voluntarily participate, yielded savings of $175 million, or $25 million more than last year. Cumulative savings since 1964 now exceed $2 billion.

Labor Relations—The number of man-days lost due to strikes on all NASA contracts decreased from 10,009 in 1968 to 4,427 in 1969. Man-days lost due to strikes at Kennedy Space Center were also reduced—from 3,200 in 1968 to 337 in 1969.

Most of the days lost were attributable to strikes during negotiations of labor agreements. Lengthy area strikes by the carpenters' unions in the Boston area and pipefitters and operating engineers in the Southern California area resulted in 1,860 man-days lost at Electronics Research Center, and 1,177 at JPL or approximately three-fourths of the total time lost on all contracts. The remaining time lost was distributed among strikes at centers which were short and involved a minimum of lost time. The Labor Relations Office worked with Center management in anticipation of labor disputes to take measures which would minimize their impact. As a result, labor problems did not interfere with program schedules.

Reliability and Quality Assurance—NASA revised its quality assurance and basic reliability requirements for aeronautical and space system contracts to reflect recent experience and to be consistent with phased project planning. At the field centers reliability and quality assurance activities were evaluated with particular attention to hardware effectiveness and problems revealed in flight operations. Also, improvements were made in disseminating and using reliability and quality experience data.

Technology Utilization

In its technology utilization program, NASA continued to evaluate aerospace-generated technology reported by research and development contractors and inhouse laboratories; prepared and distributed special publications on technological advances of commercial interest; and identified new technology of potential benefit to the public; and established new capability to transfer aerospace technology to public sector areas such as environmental quality.

New Technology Publications—The amount of published materials on NASA-developed technology available to the nonaerospace community steadily increased. Technology Utilization Offices at each NASA installation were primarily responsible for identifying and documenting the new technology resulting from NASA's research and development programs. Almost 1,000 NASA *Tech Briefs* were published in 1969 to announce innovations with possible nonaerospace uses. Also, technology utilization compilations, reports, and surveys included publications on air pollution monitoring instrumentation; bioinstrumentation; clean room technology; and induction heating.

Regional Dissemination Centers—To help increase the transfer of space technology for nonaerospace applications, the information bases of the regional dissemination centers sponsored by NASA's Office of Technology Utilization were broadened through an expanded chemical abstracts service, and more data in engineering, electronics, and plastics.

These centers also were marketing computer software available from the Computer Software Management and Information Center (Cosmic) program of the University of Georgia, and cooperating with other Federal agencies such as the Small Business Administration and the Office of State Technical Services, Department of Commerce.

Technology and Biomedical Applications Teams—NASA-sponsored technology applications teams, were established at the IIT Research Institute, Chicago, Ill., and the Stanford Research Institute, Menlo Park, Calif. The teams worked with the Federal, State, or local government agencies to match problems in air and water pollution, law enforcement, weather modification, and mine safety with potential solutions based on aerospace technology.

Biomedical application teams continued to identify and define significant biomedical problems which can benefit from application of aerospace-related technology. Stress was placed on problems which represent major obstacles to clinical and medical research programs of national scope and importance. Relationships were established with the National Cancer Institute (National Institutes of Health) and the National Health Services Research and Development Center (Health Services and Mental Health Administration). One example of the results of the application of aerospace technology to such problems is a flexible, implantable electrode which may ultimately provide relief for persons suffering from cardiac impairment with attendant *angina pectoris* pain.

Cosmic—The Cosmic continued to provide service to nonaerospace users.

The Cosmic inventory nearly doubled, now containing some 700 computer software packages of documented programs.

Two steps were taken to increase public awareness of the services available through Cosmic. NASA-sponsored regional dissemination centers now make available this computer software along with their other scientific and technical information services. The computer programs are also now announced in a new publication, *Computer Program Abstracts,* available through the Government Printing Office.

Relationship With Other Government Agencies

NASA's Office of Department of Defense and Interagency Affairs is responsible for coordinating the relationships with other Federal agencies engaged in aerospace activities.

During this year, the Aeronautics and Astronautics Coordinating Board, the principal formal organization for coordinating national space and aeronautics activities between NASA and DOD, considered the following subjects: NASA-DOD plans for meeting the need of the President's Space Task Group, means of applying more NASA effort in the research and development of military aircraft, the need for and means of establishing new aeronautical research facilities, and NASA-DOD plans for the development of a space transportation system.

As part of a continuing review of NASA-DOD interfaces in space and aeronautics, NASA assisted the Army and Navy in identifying needed design improvements in military aircraft; a joint NASA-Air Force research program was initiated using Air Force YF–12 aircraft; and fifty technical areas were identified for exchange briefings and further coordination with the Army.

Collaboration between NASA and the military services continued in the detailing of military personnel to NASA for 2- to 3-year tours. Of particular interest was the detailing to NASA of some of the specialists freed by the cancellation of the DOD Manned Orbiting Laboratory program.

NASA and DOD continued their joint research on ways and means of achieving economies in manpower and other resources in common endeavors. Specifically, the two agencies considered the exchange of additional common services at the Air Force Eastern Test Range, and the consolidation of activities involved in the checkout and launching of common launch vehicles. This office also coordinated NASA's report to the Space Task Group, which was appointed by the President in February 1969 to recommend space objectives and budget options for the post-Apollo period. The NASA report and the Task Group report to the President were both released to the public on September 17, and subsequently widely distributed to individuals and agencies within and outside the Government.

In addition, this office handled the negotiation and consummation of agreements between NASA and other Federal agencies. Those processed and approved covered such activities as the loan of DOD operational and research aircraft to NASA, DOD support of NASA at Vandenberg Air Force Base, DOD support of NASA contract administration, DOD support of NASA tracking stations, NASA support of the national search and rescue program, and NASA support of the General Services Administration's air pollution control program.

In the area of communications satellites, NASA assisted the Department of Commerce and Alaska in identifying possible uses of communications satellites to meet that State's telecommunication requirements, and NASA assisted a White House working group in developing guidelines for use by the Federal Communications Commission in connection with the U.S. domestic communications satellite program. In addition, NASA consulted with such organizations as the Office of Education, the National Library of Medicine, the Division for the Blind and Physically Handicapped, and the Corporation for Public Broadcasting, regarding the possible applications of communications satellite technology in meeting their specific requirements. It also continued close working relations with the Office of Telecommunications Management and the Federal Communications Commission.

The NASA Safety Program

NASA substantially formalized and strengthened its system for identifying and controlling hazards and for evaluating residual risks in its space hardware systems, facilities, and aircraft operations. New concepts in safety were implemented and the principle effort underway at year's end was to measure the effectiveness of both the concepts and their implementation.

Safety Management Approach—The overall NASA safety requirements were published in a NASA Safety Manual. Additionally, the safety section of the NASA procurement regulation was revised to strengthen the safety requirements being placed on contractors as part of specific facility or space hardware system procurement. It also requires the contractor to preplan the safety effort through submittal of a safety plan. Other subtier safety requirements were being documented and published at the institutional, field installation, and functional levels.

A regular schedule of field installation, program and contractor safety reviews was developed and implemented. Staff safety personnel are evaluting the safety and safety-related activities to determine what safety levels have been attained, and the adequacy of the individual safety efforts. The results of these evalutions, together with recommendations for corrective action, are forwarded to the appropriate management area for resolution. All NASA field installations and hardware programs were reviewed so that there is now a finite baseline from which improvement can be measured during future reviews.

System Safety—Product or system safety technology was formulated and was being documented. The concepts and methods selected for implementation are flexible so that the technology will be fully applicable to the wide range of the NASA aerospace hardware systems and their missions. Strong emphasis was being placed on implementing systems safety in new hardware development programs where the greatest effectiveness can be attained. Equal emphasis was placed on the mature systems, both manned and automated, to formalize the existing safety and safety-related activities into an effective risk evaluation program.

A special training course in system safety technology was coordinated with the University of Southern California, to be offered to NASA personnel during early 1970.

Industrial Safety—NASA evaluated the industrial accident prevention efforts at all centers, measuring them against the new safety manual requirements. In general, the reviews indicated satisfactory performance in personnel safety. The elements considered necessary for a sound agency program are management interests, contract compliance with safety requirements, system safety, personnel protection, attention to public safety, safety certificates and training, hazards research, accident investigation, and fire protection.

Improvements are being made in NASA's ability to protect Government losses to a degree paralleling the importance of NASA missions. This requires that areas of weakness be identified and decisions made as to where money should be assigned to attain the desired standards. In this connection, a higher level of effort in the fire prevention and suppression is considered necessary. Steps are being taken to assure that such effort is exerted.

Aviation Safety—NASA progressed significantly in the area of aviation safety. A committee comprised of

NASA personnel with strong aircraft operations experience was established and is functioning. This committee is developing a standard aircraft operations handbook to provide a uniform set of safe operating procedures for all NASA pilots. Arrangements were completed with the Flight Safety Foundation for evaluation of flight operations in specific areas and for recommendations as to how these activities may be improved and made safer.

General Activities—Safety standards for all NASA personnel were documented, and final editing is in process for early publication.

In November, NASA conducted a Safety Conference to bring together all the NASA people directly involved in performing safety activities for a frank exchange of ideas, experience, and the latest techniques in accident prevention, hazard identification, and risk evaluation.

IV Department of Defense

Introduction

Action in support of the President's Space Task Group (STG) highlighted DOD activity in aeronautics and space during 1969. Other significant events included: (1) The successful launching of Tacsat I on a Titan IIIC booster into geostationary orbit; (2) the launching of the fifth pair of Vela nuclear detection satellites; and (3) continued support of Apollo missions.

Space Development Activities

Space Task Group—During the year many individuals within the DOD participated in the preparation of the final report to the President by STG. Through this major effort our understanding of future military space programs and related technology has been significantly enhanced.

The final report should be a valuable reference document in future DOD planning by providing pertinent information on space activities and their relationship to national defense objectives.

It is important to recognize that the report represents program options and mission opportunities and does not represent programmatic decisions. In view of severe constraints on military spending, each new system must compete with other alternatives on a case-by-case basis. Decisions to initiate new space programs will be carefully structured in the context of the threat, economic constraints, and the national priorities placed on defense. In particular the DOD will embark on new military space programs only when they can clearly show that particular mission functions can be achieved in a more cost-effective way than by using more conventional methods.

Manned Orbiting Laboratory—At the direction of the Secretary of Defense, and with the concurrence of the President, Manned Orbiting Laboratory (MOL) program was canceled on June 10, 1969. Among the factors which contributed to this decision were the immediate need to significantly reduce the DOD budget, and the continuing large annual investments which would have been necessary to sustain program progress.

In order to assure that maximum use was derived from the MOL program development effort, technology and hardware, the Secretary of the Air Force appointed an ad hoc committee to review MOL residuals and to make recommendations for disposal of the inventory. The ad hoc committee findings, arrived at after a very intensive and careful technical survey, resulted in recommendations, approved by the Secretary of the Air Force, for the use of substantial elements of MOL hardware and technology by other high priority activities.

For example, (1) MOL astronaut pressure suits and support equipment, waste management and oxygen sensor technology, and Gemini aerospace ground equipment have been transferred to NASA; (2) computer assisted ground equipment including the associated computers and software is being transferred to the Air Force Western Test Range; (3) computer integrated test equipment has been transferred to the Air Force Office of Scientific Research to be used in a National Science Foundation program being conducted at a large state university; (4) significant items of hardware, technology and support equipment acquired during the Titan IIIM development program have been transferred to the on going Titan IIIB, C and D booster programs; (5) the MOL simulator has been transferred to NASA for use in the manned space program; (6) 15 sets of automatic data processing equipment of differing types, capacities and applications have been reported for disposition in accordance with the Armed Services Procurement Regulations.

Of the 14 MOL astronaut trainees, eight have been assigned to NASA, seven as flight crew candidates of whom three have been entered into graduate schools for work at the masters and doctorate levels. One has been assigned to the National Aeronautics and Space Council and the remaining five have been returned to high priority flight duties.

These and other carefully considered actions to transfer MOL technology and hardware to laboratories, NASA and designated Government agencies will result in the useful application of a significant portion of the investment in MOL to important ongoing and continuing Government work.

Titan III Space Booster—The flight test phase of the Titan IIIC research and development program was culminated during this past year with successful flight of the remaining two R&D boosters. The first launch in February orbited a Tactical Communications Satellite while the second launch carried a Vela satellite and three Office of Aerospace Research experimental payloads.

The development of the Titan IIIM booster was terminated when the program was canceled in June.

The Titan IIIC production program continued on schedule in order to provide boosters for initial launch in 1970.

Agreements between the Air Force and NASA were formalized in September and govern NASA use of Titan III space boosters in support of certain of their scientific missions in the future.

DOD Satellite Communications—The DOD program for satellite communications is divided into two broad categories, the long-distance point-to-point system and the tactical system.

Long-Distance Point-to-Point System.—The mission of this system is to satisfy needs for secure communications. Efforts to fulfill this mission consist of the Defense Satellite Communications System (DSCS), Syncom, and international cooperative efforts.

DSCS: The initial defense satellite communications project (IDSCP) which has provided the DOD and other government agencies with an initial operational satellite communications capability is now referred to as phase I of the defense satellite communications program. Phase II of the program is now being implemented and will provide for increased capabilities through evolutionary growth of the system. Phase I of the program has continued its planned progress with the space subsystem now having a total of 23 operational satellites. These satellites have low power, are spin stabilized and are located in near synchronous orbit. The Earth subsystem of the phase I system has had similar progress. The worldwide array of Earth terminals totals 29 fixed and transportable stations. Shipboard terminals once included in the system have been withdrawn for modification and improvement.

The operational use of the phase I system continues to satisfy many unique and vital communication requirements. One of the services which the system is now providing is the rapid transmission of photographic images from South Vietnam to the United States. The system can transmit high resolution photographs at the rate of 6 minutes for each frame, utilizing two satellites and four terminals. In addition to its normal use, the DSCS this year constituted a major national asset in meeting unprecedented communications demands. Satellite communications for President Nixon during his trip to Asia were supplied by the DSCS.

A satellite communications terminal flown to Alaska successfully relayed live television coverage of the Apollo 11 mission via satellite. This was the first time Alaskans viewed events occuring outside their State on live television.

During 1969, planning has proceeded for the development and acquistion of the phase II of the DSCS. Contracts have been awarded for development and production of the new satellites. Under current phase II concepts, several new satellites will be placed in synchronous equatorial orbits by early 1971. These satellites are to be equipped with "Earth coverage" antennas which direct most of the radiated power toward the Earth so as to cover fairly uniformly that portion of the earth visible to the satellite. In addition, two steerable narrow beam antennas will be provided which are capable of concentrating the satellite's power on an area of the Earth's surface 1,000 to 2,000 miles in diameter. The new satellites 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 area. The phase II Earth subsystem will utilize to the maximum extent the terminals acquired during phase I by modifying them to phase II specifications. Additional new terminals are to be developed and procured for operation with the phase II satellites. With the new satellites and increased number of Earth terminals, the phase II system will greatly increase the number of satellite channels available to the defense communications systems and will provide greater communication capabilities into and within theaters of operations.

Syncom: Use of the Syncom satellites, developed and orbited by NASA originally for R&D purposes, has provided DOD Earth terminals with an interim means for handling operational traffic in the Pacific area. However, as the greater capabilities of the DSCS have become increasingly available, use of the Syncom satellites by DOD has been terminated.

International cooperative efforts: Under the provisions of the September 1966 Memorandum of Understanding with the United Kingdom, tests were conducted in which simultaneous operation of two United States and two United Kingdom Earth terminals demonstrated the feasibility of joint but independent use of one satellite. In addition, exploratory talks with the United Kingdom have continued to discuss the characteristics of the phase II system of the DSCP and the possible operational use of the phase II system by the United Kingdom. Launch of the first United Kingdom Skynet satellite, produced in the United States, is scheduled for early 1970.

Cooperative effort with NATO for the establishment of NATO's preliminary satellite communications system continued. Use of phase I satellites was provided to NATO for tests of two earth terminals purchased from a U.S. firm by NATO. Launch of the first NATO satellite, similar to the United Kingdom Skynet satellite, is scheduled for early 1970. NATO has contracted for earth terminals to complete their system. One of the NATO terminals will be installed in the United States at Norfolk, Va.

Tactical Satellite Communication Program.—The purpose of this joint service program is to investigate and demonstrate the use of spaceborne communication repeaters to satisfy selected communication needs of our mobile forces.

The space segment of the program consists of Lincoln Laboratory experimental satellite (LES) Nos. 5 and 6 which were launched in July 1967 and September 1968 and Tacsat I launched in February 1969. Although valuable early experiments were conducted utilizing LES–5, currently the test program employs primarily the LES–6 and Tacsat I satellites. The terminal equipments used by the four services with the above satellites are installed in jeeps, trucks, aircraft, ships and team packs.

Tacsat I was successfully launched on an Air Force Titan IIIC booster February 9, 1969 and was placed into a geostationary equatorial orbit at 108° west longitude. The 1,600-pound highly complex spacecraft can operate in both the UHF and SHF frequency bands and has been used for advanced technical tests conducted by the four services.

The Navy effort has been devoted to extensive testing of Tacsatcom terminals, both shipborne and airborne. The development of operational procedures and doctrine and the testing of multiple-access techniques have been emphasized. The Navy is exploring various modes of operational application for this system with a view that satellite communications will enhance open sea communications reliability.

The Army is conducting extensive testing of ground terminals—team pack, jeep, shelter and van installations—under varied environmental conditions and in simulated tactical situations. These tests have proven the technical feasibility of the Tacsatcom concept. The operational phase of the Army Tacsatcom program, if approved, will include a family of tactical ground terminals ranging from a one-man portable unit for long range patrols to a 2½-ton truck mounted terminal to provide communications service for use by ground forces within a theater of operations.

Spaceborne Nuclear Detection—Two new Vela satellites were successfully launched into circular orbit at 18 Earth radii in May of 1969. The new Vela satellites were the fifth pair in a series that began in 1963 and included launches in 1964, 1965, and 1967.

The Vela research and development program is a joint responsibility of DOD and AEC. Its purpose is to develop a satellite capability to detect nuclear detonations from the surface of the Earth out to deep space.

Vela spacecraft carry sensors to monitor the radiation characteristics of nuclear detonations, such as gamma radiation, optical fireball radiation, and radio-frequency electromagnetic signals. In addition, to obtain fundamental measurements of the radiation background in space, other particle and radiation sensors are provided. The Bela satellite data has been very useful to NASA, particularly during Apollo flights, and has provided timely data to ESSA and to DOD.

Geodetic Satellites—DOD geodetic satellite activities during 1969 continued toward the goal of defining more precisely the Earth size, shape, and gravity field, in addition to providing geodetic positions for features on the Earth's surface. Satellites observed included Geos–II, Pageos, Navy Navigation Satellites, Secor and others. This is the last full year of observations for the original geodetic satellite program. Continued DOD efforts in the geodetic satellite area will be directed toward meeting special requirements using primarily the doppler system.

The Army Corps of Engineers is nearing completion of the Secor equatorial belt, providing a global control net around the equatorial area including several sites which will provide geodetic positions for range tracking instrumentation. During 1969 the Secor system advanced into the Pacific. The network should be completed early in 1970 when the last link, Hawaii to mainland United States, is accomplished. The Secor system will be phased out at that time. An Army tactical satellite system investigation was initiated to study the potential of using special ground station equipment for field artillery support.

The Pageos primary geometric network constitutes the primary DOD input for the National Geodetic Satellite program. It is managed by the Army and is being accomplished by the Army and the Coast and Geodetic Survey. The observation portion of the program is entering the last phase and should be completed in the summer of 1970. The data reduction has been extended an additional year beyond the original completion date because of fund reductions.

The Navy Doppler Network (Tranet) observed the four Transit satellites in 1969 primarily for the purpose of improving the model of the Earth's gravity field and positioning various global sites. The positions of 12 sites were determined during this year. The doppler system will be continued as the primary geodetic satellite system for DOD applications. A lightweight package, Geoceiver, has been developed and is being procured to increase the flexibility of operation.

The Air Force operated PC–1000 cameras in South America and at two stations in the Pageos primary network. The South American densification supports mapping and charting efforts in that area. PC–1000 cameras are located in the Pacific to provide additional observations necessary to complete the Pageos network in this area.

Navy Navigation Satellite System—The Transit system was declared fully operational to the fleet in October 1968. The same four satellites that were used during most of 1968 continued operating during this year.

Following the Vice President's announcement of the Transit system for civil use in 1967, commercial firms have developed shipboard receivers for sale to interested parties. Particular interest has been demonstrated by offshore oil survey companies.

Space Ground Support

DOD National Ranges

Department of Defense space activities are principally supported by five National Ranges: Air Force Eastern Test Range (AFETR), Air Force Western Test Range (AFWTR), Air Force Satellite Control Facility, Navy Pacific Missile Range and Army White Sands Missile Range. Each range is available to any government user who may require its support. At Navy Pacific Missile Range and Army White Sands Missile Range, space activity amounts to approximately 4 percent of the total range effort.

Air Force Eastern Test Range (AFETR)—During the past year the AFETR has continued to emphasize the development and improvement of its mobile data gathering fleet. These are the aircraft and ships which are strategically located throughout the world to gather data for ballistic and space programs when land based instrumentation is not adequate or available.

Four C–135B aircraft became operational early in the year. These aircraft, in conjunction with the eight Apollo range instrumented aircraft, support the NASA and DOD aircraft requirements at the national ranges. One ship, which provided only telemetry support, was deactivated in light of the newly acquired aircraft capabilities.

Air Force Western Test Range (AFWTR)—During 1969, the AFWTR made several changes in range support capability. An 80-foot antenna autotrack telemetry system was put into operation at Pillar Point Air Force Station, Calif., increasing AFWTR's capacity to receive P- and S-band telemetry signals. A new optics site equipped with two mobile optical trackers was activated at Santa Ynez Peak, Calif. This site, when used with optics at Anderson Peak, Calif., and image enhancing processes, provides excellent coverage of launch events. The Vandenberg Automatic Data Equipment Facility went into full operation and provides real time telemetry data processing through a computer based data acquisition and reduction system. The AFWTR range instrumentation ship fleet has been reduced by three, the USNS *Range Tracker* and the USNS *Mercury* have been deactivated and will be returned to the National Defense Reserve Fleet and the USNS *Redstone* has been transferred to the AFETR. The AFWTR has instituted a comprehensive radar calibration program encompassing the calibration of all VAFB radars and formed an interrange instrumentation accuracy improvement group. AFWTR operates the new Joint Pacific Area Scheduling Office which is responsible for coordination of all range test operations involving joint use of Pacific area range instrumentation.

Satellite Control Facility (SCF)—During 1969, the new Satellite Test Center building at Sunnyvale, Calif., was completed. The MOL program cancellation made available three mission control complex (MCC) modules out of a total of 14 for assignment to other programs and technical activities. The space ground link subsystem (SGLS) installation has been completed at all remote tracking stations (RTS) except the Indian Ocean station. This installation is expected to be completed in July 1970. The new Guam station has become operational. Study and analysis effort is a continuing task to insure that the SCF is responsive to the workload and technological needs of the using programs.

Aeronautics Development Activities

C–5A Heavy Logistics Transport Aircraft—The flight test program began in June 1968. The first seven airplanes currently in the program had accumulated 1,320 hours of flying time as of early November 1969. The results to date indicate that the C–5A has good flight and ground handling qualities and that there is high probability that the airplane will meet all range, payload, takeoff and landing performance requirements. Current predictions also indicate that the contractural requirements for reliability and maintainability will be met.

To date, the C–5A has achieved a maximum gross weight takeoff of 798,200 pounds, a maximum speed of 0.89 mach, a maximum altitude of 40,200 feet, a flight duration of over 9 hours, and a short landing, ground roll distance of less than 1,500 feet. These are all significant results of the flight test program and indicative that the aircraft performance is remarkably good. Although the C–5A has not required a major "breakthrough" in technology, the design and manufacture of this aircraft of unprecedented size and capabilities has presented some challenging problems, the successful solution of which represents an impressive achievement.

The first operational C–5A is scheduled for delivery to the Air Force in December 1969.

F–111 Aircraft—The F–111 aircraft program is composed of various models which include four tactical versions, F–111A, F–111D, F–111E and F–111F; one bomber model, FB–111; and one version proposed for reconnaissance, RF–111. Also, one model, the F–111C, is designed for use by the Australian Air Force.

The F–111A program has been in the process of transitioning from a development status to an operational status during the past year. Approximately 165 aircraft have been delivered to the Tactical Air Command. The category I and category II tests efforts are continuing at Fort Worth, Eglin AFB, and Edwards AFB. The bulk of this continuing work is in the areas of weapons release, static and fatigue testing and full-flight envelope clearance.

Since the development and testing of the airframe and the airplane's general subsystems have been largely accomplished in the F–111A program, development of later U.S. mdoels of the F–111 has concentrated largely on the avionics system.

The F–111D model which incorporates the advanced Mark II avionics package is in production with two aircraft scheduled for delivery prior to 1 January 1970. When production is completed, there will be 96 of the F–111D aircraft. Because of the cost of the F–111D/Mk–II system, a less expensive and less advanced avionics version is being designed into the 219 F–111F which will follow the F–111D aircraft. These F–111F aircraft will have also an improved propulsion system, utilizing the new higher thrust TF–30–P–100 engines.

The airframe fatigue test program has revealed the need for several modifications to the wing carrythrough structure. These modifications are being installed on the production line and in a retrofit program.

Delivery of the first F–111C aircraft to the Australians took place in September 1968. Subsequent deliveries to the Australians have been delayed pending additional tests currently underway.

On September 28, 1969, the first FB–111 was delivered to Carswell AFB, Tex., for use in the Combat Crew Training Wing. This organization is scheduled to receive eight more aircraft before January 1, 1970.

Tactical Air Command expanded its F–111 activities to include the buildup of a second tactical fighter wing, located at Cannon AFB, N. Mex. Meanwhile, an extensive combat crew training effort is in progress at Nellis AFB, Nev., utilizing the experience gained during last year's deployment to Southeast Asia.

F–14 Carrier Based Tactical Fighter—Engineering development of the F–14, a new advanced carrier based tactical fighter was initiated on February 3, 1969. The F–14A will be a new airframe utilizing the TF30–P412 engine and the AWG–9 missile control system. The AWG–9 missile control system will control Phoenix, Sparrow, and Sidewinder missiles and 20-mm. guns. In addition to its Fleet Air Defense capability, the F–14A will be superior to the F–4 in other fighter roles. The F–14A will also have a significant air-to-ground capability to augment attack aircraft once air supremacy has been achieved.

Contractor proposals for an advanced technology engine, with increased thrust and reduced weight, are being evaluated. It is planned to initiate engineering development in early 1970. The advanced technology engines will be incorporated in a modification of the F–14; i.e., the F–14B to improve air superiority characteristics. The F–14B will be capable of countering the predicted threats in the late 1970's and early 1980's.

F–15 Tactical Fighter—To counter advanced enemy fighter aircraft, the Air Force has begun the development of a new air superiority fighter, the F–15. The F–15 concept was finalized during 1968; in September of that year, the request for proposal was issued to all interested major airframe companies. By December 1968, three aircraft companies were in competition for the final development and production contract. These companies submitted their design and cost proposals during July and August 1969. The Air Force has evaluated these proposals and will soon award the contract for F–15 development and production. Supporting development programs on engines, radar, and weapons were also started in 1968. These subsystem developments will insure that all components of the weapon system will have the performance necessary in an advanced fighter.

The F–15 concept calls for a fixed wing, two engine, single seat fighter having a superior performance over a broad range of altitudes and speeds. It will have high thrust-to-weight and low-wing loading and will carry a balanced mix of armament to optimize the aircraft for aerial combat. The aircraft is being designed to provide sufficient maneuverability and performance for air-to-air combat to exceed the capabilities of predicted enemy fighter designs in the 1975–85 period. It will replace the F–4 in the air superiority role.

A–7 Development—The Navy A–7A and A–7B carrier based light attack aircraft have proven their versatility, flexibility and increased ordnance carrying capability in combat. Nineteen squadrons have been deployed through October 1969. The A–7D/E Air Force/Navy joint development program is progressing on schedule and aircraft incorporating the improved navigation/weapons delivery system entered Air Force category II and Navy Board of Inspection and Survey (BIS) testing during 1969. Increased accuracy and tactical flexibility has been demonstrated by the improved weapon delivery system in the A–7D/E. All Air Force A–7D's and Navy A–7E's #68 and subsequent are powered by the TF–41 turbo-fan which improves performance significantly over earlier versions. The first A–7E operational fleet aircraft was delivered in June 1969 and the first A–7D aircraft was delivered to Tactical Air Command in September 1969.

Carrier-Based ASW Aircraft—The S–3A, formerly designated VS(X), received approval for engineering development in July 1969. The S–3A will be powered by two TF–34 high bypass turbofan engines. It will have a crew of four. Through the use of advanced ASW sensors and a digital computer, the S–3A will provide significant improvement over the S–2 Tracker in searching large areas of the ocean, detecting modern nuclear submarines and in localizing and destroying these submarines. The S–3A will operate in the 400 knot speed range at altitudes over 30,000 feet enroute to operating areas and still be able to operate economically at the lower altitudes required during certain phases of antisubmarine operations. The TF–34 engine which has been under development since early 1968 completed "first run" in May 1969 and has subsequently been tested at full power.

E–2C Development—The E–2C development will provide the vital airborne early warning system necessary for effective fleet operations and will provide airborne command and control compatible with Navy and Marine Tactical Data Systems. The E–2C has a proven airframe (E–2A) and carries an updated electronics system which provides greatly improved operational capability, system reliability, and effectiveness in its operation. The development is proceeding on schedule.

EA–6B Development—The EA–6B development will provide an effective tactical airborne electronic jamming system necessary to jam enemy radars. It will support carrier and advanced base strike aircraft. The EA–6B system will use the basic A–6 airframe (modified for a four man crew) which has proven to be a dependable and efficient platform in aircraft carrier operations. The development is proceeding on schedule.

Helicopter Research—The Army has continued its research to improve rotorcraft capabilities. Studies are continuing on telescoping rotors and stopped-stowed rotors to improve performance. During 1969, a compound helicopter achieved a speed of 274 knots, an unofficial world speed record for rotorcraft. Integration of helicopter and airplane controls is being investigated to assure precise control of the aircraft at all speeds.

The Army has also been actively investigating noise generation and suppression. A quiet helicopter program initiated in 1968 continued to show encouraging results.

In 1969, as a result of a previous conference on helicopter and V/STOL aircraft generated noises, the Army implemented an aeronautical noise program. Investigations were undertaken by industry, universities and in-house laboratories to include: basic elements of rotor noise generation and propagation; design tradeoff studies; studies of noise sources; noise level detectability criteria; and rotor blade vortex interaction.

The program is being closely coordinated with the military services, NASA, and DOT. The achievement of program goals will enhance the military tactical reconnaissance capability and should provide useful data for solving civil helicopter noise problems.

AH–56A (Cheyenne).—The AH–56A, the first helicopter developed as an integrated aerial weapons system, continued in the development phase. The Army and NASA are jointly monitoring this development. Flight tests, conducted on the prototype aircraft, identified significant technical problems that resulted in termination of the production contract. However, the Army has a continuing need for the capability offered by this type of aircraft. Future production decisions will be based on demonstrated performance and cost effectiveness.

AV–6B Harrier.—The U.S. Marine Corps will receive 12 AV–6B Harrier V/STOL aircraft, starting in 1970, for use in the close air support role. The Harrier is a single-seat, single fan jet transonic aircraft, manufactured in the United Kingdom. It is the operational version of the P–1127 Kestrel, which was funded, developed, and evaluated by the United

States, United Kingdom, and the Federal Republic of Germany. The Royal Air Force has equipped an operating squadron with the Harrier, and the Marine Corps and Air Force are actively participating in the British operational employment to take full advantage of their experience when the Harrier is delivered to the United States.

CX–84.—The Canadian Government is procuring three CX–84 tilt-wing V/STOL aircraft for military operational suitability testing in calendar year 1971. It is expected that this testing will provide valuable experience in the use of V/STOL aircraft. The U.S. Army is monitoring the program and contributing limited equipment and technology to the program in return for test information.

X–22.—The X–22 ducted propeller aircraft completed the triservice V/STOL evaluation in April 1969. This aircraft is the only V/STOL aircraft having capabilities and characteristics enabling it to investigate a range of flying qualities. A research program is now planned, using the X–22 configured as a variable stability aircraft as a flying testbed, to determine the effects of various control parameters on the flying qualities. It is anticipated that this will be a joint program with USN, USAF, NASA, and FAA participating.

Light Intratheater Transport—The Air Force is proposing a V/STOL light intratheater transport (LIT) for the late 1970's to replace the aging C–7's/C–123's and augment the C–130E's in the Tactical Airlift Force. The LIT will provide increased capability and flexibility to be responsive to the Army and other users throughout the entire spectrum of tactical airlift mission. The LIT will also have an adequate cargo compartment size and payload carrying capacity to efficiently distribute cargo offloaded from the C–5, C–141, or C–130 aircraft.

A concept formulation package/technical development plan (CFP/TDP) has been prepared for the Office of the Secretary of Defense for fiscal year 1971 funding consideration. The LIT development plan outlines a step-by-step approach which requires technology to be demonstrated before total funding is committed.

During 1969, a large diameter propeller verification and demonstration program was initiated. In addition, technology efforts were started in the areas of flight control and advanced structural materials.

Advanced Manned Strategic Aircraft (B–1)—During 1969, the Air Force continued preliminary design studies and advanced development of critical propulsion and avionics components for the B–1 advanced manned strategic aircraft (AMSA). These efforts have further amplified and validated the design and characteristics of an advanced strategic bomber. Based upon the extensive study effort that has been done on the B–1 AMSA, the decision has been made to initiate full-scale engineering development in fiscal 1970. The Air Force has structured an orderly development program that will lead to a first flight approximately 42 months after contract award. Although a production decision has not been made at this time, the current program could provide for an operational force of advanced strategic bombers in the latter half of 1970's.

Bare Base Program—The Air Force demonstrated a new mobility capability in October 1969 by implementing a 2-week test deployment of a tactical F–4D squadron and complete associated base support elements to a "bare base." This concept is centered on the ability to move a complete operational unit into a location where only runways and water exists. All other facilities and equipment required for sustained operations were airlifted into the base along with all supplies and ordnance required for the first five days of operations. Tactical operations were conducted at a surge sortie rate for the full period of the demonstration, and the demonstration was concluded with the air redeployment of all equipment and personnel. This concept permits maximum flexibility and mobility of tactical aviation and frees it from dependence on continuously maintained fully equipped bases. Quantity production of the new base operating support equipment is anticipated to start in fiscal year 1971.

Supporting Research and Technology

Over-the-Horizon Radar—Over-the-horizon (OTH) radar technology, sponsored by DOD under R&D programs, has demonstrated capabilities to detect aircraft and missiles at ranges of several thousand miles. This capability is a tenfold range improvement over radars developed during the decade following World War II. In this technology, great importance is attached to selecting the appropriate frequency of transmission and in utilizing ionospheric refraction of the radar energy to detect targets below the line-of-sight horizon. Laboratory and field evaluations are continuing to determine the desirability and feasibility of applying this technique to improve our ability to detect and track aircraft as well as to enhance our tactical early warning capability against missiles.

VTOL Engine Development—This Air Force program includes the United States part of the Joint United States-United Kingdom lift engine program. This cooperative R&D effort was initiated in 1965 to develop a lift engine for the United States-Federal Republic of Germany V/STOL aircraft program.

When the aircraft system effort was terminated in 1968, the United States and United Kingdom agreed to continue the propulsion portion as a demonstrator engine to extract technological benefits from these advanced light weight engine concepts.

The contractors have completed their design and hardware fabrication. The program is now in the demonstrator engine testing phase, scheduled for completion in 1970.

The engine, designated the XJ–99, incorporates advanced design concepts, lightweight materials and high temperature components. As a result, it represents a significant advancement in turbine engine technology.

Wind Tunnel Testing of V/STOL Aircraft—In 1969 the Army supported research to evaluate wind tunnel wall effects and recirculation effects on V/STOL model testing. The magnitudes of these parameters have been established and it is now possible to properly design a wind tunnel for V/STOL testing to meet model requirements or to build a model to suit a given wind tunnel. A specific result of this program permits predicting the ratio between the size of the wind tunnel and the V/STOL aircraft model. This research has had a significant impact on the testing of V/STOL aircraft in government, industry, and foreign facilities, and in particular, on the design of new tunnels and tests. Reruns of older tests and data comparisons have shown some of the old data is actually invalid.

Spacecraft Technology and Advanced Reentry Tests—The Air Force's current efforts in developing technology for maneuverable reentry spacecraft consists of the piloted low-speed tests (pilot) programs and the space transportation system (STS) studies. Pilot was instituted and is a follow-on effort to prime to provide aerodynamic and stability and control data from mach 2.0 to horizontal landing. The prime program provided flight data from reentry conditions to approximately mach 2. Five glide flights of the pilot vehicle (X–24A) from 40,000 feet have been successfully completed. Flow separation and stability characteristics of the X–24A vehicle are being determined in preparation for the power phase of the program which is scheduled to begin in January 1970. The STS studies are a preliminary design effort to evaluate the capability of various system concepts to meet Air Force mission requirements (payload, cross range, etc.) for reusable, recoverable launch vehicles. Follow-on studies and technology work in this area will depend on the results of the space shuttle being investigated by both the Air Force and NASA.

Advanced Liquid Rocket Technology—The Air Force advanced liquid rocket technology program has been established to develop and demonstrate critical propulsion technology needed for future space vehicle systems which will be operational in the time period beyond 1975.

In 1969, development of the XLR–129 high performance reusable rocket engine is continuing with emphasis placed on demonstrator engine component development and test. This project will provide essential technology in support of a future reusable National space launch vehicle development program. Its specific task objectives ares continuously coordinated with NASA as well as DOD program needs, through the joint advanced chemical rocket engine (ACRE) working group.

Upper Atmosphere Investigation—The Ballistics Research Laboratory (BRL) participated in several experiments in aeronomy. Cooperative firing of five Nike-Javelin rockets was conducted in Alaska in March 1969 producing barium clouds. Electron density in the cloud and the absorption of radio waves passing through the cloud were successfully measured.

Seven Nike-Javelin rockets were instrumented by BRL as part of a cooperative experiment on polar cap absorption (PCA). During the experiment measurements were made of electron density, radio wave absorption at six frequencies, and the energy and rate of emission of energetic electrons, protons, alpha particles, and gamma rays.

Under contract with a civilian university, 10 ARCAS rockets were instrumented to measure ion currents during PCA events at Fort Churchill, Canada.

Space Object Identification—During 1969 ARPA continued to develop ground-based optical techniques to identify physical characteristics of objects in Earth orbit. These techniques include measurements of radiation in the visible and infrared region of the spectrum and the use of lasers to measure their range with extreme accuracy. This program is carried out at the ARPA Maui Optical Station, on Mount Haleakala in Maui. At the request of the NASA this facility also supported the lunar laser ranging experiment conducted during Apollo 11.

Solar Radiation Monitoring Satellite Program—The Navy's Solrad IX, launched on March 5, 1968, has continued solar radiation monitoring, broadening our base of knowledge of the physics of the Sun and the mechanism of emission of solar particle, ultraviolet and X-ray radiation. This knowledge is required if we are to develop techniques for predicting solar-induced disturbances affecting operation of ionosphere-dependent systems and space systems.

Telemetered data is received at the NRL Tracking and Data Acquisition Facility at Blossom Point, Md., where it is relayed by dataphone to the Solrad Data Operations Center at the Naval Research Laboratory. Real-time analog and stored digital telemetry data are converted to flux values by manual and ADP methods. Daily pass-by-pass and flare profile messages are transmitted via the U.S. Air Force operated solar observing and forecasting network (SOFNET) for use by the ESSA Space Disturbance Forecast Center at Boulder, Colo., and the U.S. Air Force Solar Forecast Center at the NORAD Cheyenne Mountain Complex, Colo.

Predictions of periods of solar activity, which are likely to cause ionospheric disturbances, are transmitted to the Naval Communications Command for use in the formulation of Navy alerts to all communicators.

Although analysis of Solrad data has made possible the development of criteria for prediction of solar activity, the reliability of prediction suffers from real time limitations of solar observation (6 percent) imposed by satellite low orbit configuration. This deficiency will be overcome in the future by launching a three-satellite constellation in a 20 earth radii circular orbit which will readout to a single ground station. This system, still in the planning stage, will provide real time and continuous monitoring.

Advanced Turbine Engine Gas Generator—The advanced turbine engine gas generator (ATEGG) program is an Air Force advanced development program. Large turbine engine components (compressors, combustors and turbines) are developed and integrated into demonstrator engines which receive sufficient testing to give confidence that the advanced concepts can be applied into a specific engineering development program when the need arises. This program is needed because component operations in isolated rig tests are not completely representative of that component's operation when integrated into a high performance engine and used in widely varying operational conditions.

During the past year, the four contractors participating in this program have demonstrated significant advances in thrust to weight ratios, high operating temperatures, pressures ratios and over all efficiency.

Advanced Propulsion Subsystem Integration—The advanced propulsion subsystem integration (APSI) program is an Air Force advanced development program, designed for the purpose of assuring that the engine and airframe are optimally matched for maximum performance.

The matching starts with the forebody engine inlet and inlet interaction. In turn, all of the compoents through the engine and airframe back through the exhaust nozzle are analyzed. Through this program, we are also working to improve the capability to correlate data between wind tunnel model testing and actual flight testing. As an example of the contribution of this program, valuable data on airframe-inlet integration and inlet-engine interaction was provided to each engine and airframe contractor involved in the F–15 program.

This program also includes engine component development to adapt the advanced turbine engine gas generator (ATEGG) cores to specific flight requirements.

Airborne Warning and Control System—In the airborne warning and control system (AWACS) program, the Air Force has completed an overland radar technology program demonstrating that the radar technique to be used is feasible. Presently, the Air Force is completing a long lead radar component program and expects to select the contractor for the program in early 1970. The initial phase of the engineering development program is a flight test program of a prototype brass-board radar testbed through a limited operational test.

The AWACS will provide an airborne air surveillance capability and command, control and communication functions in a military version of a subsonic commercial jet. The distinguishing technical feature of this weapon system is the capability of its radar to detect and track aircraft operating at high and low altitudes over both land and water. The AWAC aircraft provides command and control for the interceptor force as well as sustaining air operations such as counter-air, interdiction, close air support, rescue, airlift, etc. The flexibility of the AWAC System permits it employment at any level of military action with the capability to serve as an Airborne Command Post, Tactical Air Control Center, Airborne Direct Air Support Center, and Airborne Control and Reporting Center.

Survivable Flight Control System Development Program—On July 7, 1969, the Air Force Flight Dynamics Laboratory contracted for a survivable flight control system (SFCS) development program. This 3-year effort is designed to develop and demonstrate in-flight technology that will significantly reduce flight control system vulnerability to combat damage.

The SFCS concept is based on the principle of separated redundant control elements and combines the heretofore separate technologies of fly-by-wire controls and integrated hydraulic servo-actuator packages to achieve a significant increase in flight control system survivability. The fly-by-wire approach decreases vulnerability of the control linkage from the pilot's control stick to the surface actuators through redundant separate electrical channels. The integrated servo-actuator package reduces the vulnerability of the hydraulic lines which supply power to the actuators through the application of redundancy, dispersion and hardening techniques.

The use of a proven fly-by-wire control system would make possible system performance improvements, reduced system cost, improved reliability and weight reductions.

Advanced Composite Materials Application—The technology of applying composite materials to aircraft structures is progressing from replacement of selected skin panels to conceptual design of major components such as wings and stabilizers, using composites for the skin and load bearing substructures. Enough confidence and experience has been gained in the application of boron plastic composites to tail skins and selected panels that boron/epoxy has been declared production capable as a material for new systems. The F–14 will have a boron/epoxy horizontal stabilizer skin with a 25 percent weight savings over a conventional titanium skin. The F–15 will also have various panels and skin portions composed of boron/epoxy composite material.

A second composite material, graphite/epoxy has been developed to the stage, as a material, where it is beginning to be applied to selected aircraft skin components. Higher temperature capable composites such as boron/aluminum and boron/titanium are being applied to jet engine components with predicted weight savings of up to 15 percent.

The largest composite structure attempted to date, an F–100 wing with a boron/epoxy skin, is being assembled for ground tests in 1970 and flight test in early 1971. As larger and more complex structures are fabricated from composites, the capability to reduce the weight of future aircraft by amounts varying from 3 to 50 percent is systematically being demonstrated.

Space Experiments Support Program—The Air Force space experiments support program (SESP) provides spaceflights for DOD Research and Development experiments and certain operational spacecraft as multiple payloads on single boosters. In 1969 SESP supported the launch of an Atlas F which orbited three Air Force spacecraft containing thirteen DOD experiments. The orbital transfer rocket of one spacecraft went into a separate orbit carrying a Navy experiment. An Army geodetic survey spacecraft rode into orbit as a secondary payload on the NASA launch of a weather satellite. A Navy payload of a cylinder and cone, used in space object identification and calibration, was orbited as a secondary payload aboard a classified DOD launch. Three Air Force spacecraft rode as a secondary payload aboard the launch of a Titan IIIC for the Vela program.

Seek Storm—The Air Force has established Project Seek Storm to provide a significant improvement in Air Force capability to support the U.S. hurricane effort. This project concentrates on developing an improved radar which will make it possible to see through the areas of precipitation which surround hurricanes and thus identify areas of turbulence and intense rainstorms from a much longer range. This, in turn, will give forecasters more precise storm intensity and location information which will lead to better storm path and damage potential predictions. Development will be initiated in fiscal year 1970, and it is expected that installation in storm reconnaissance aircraft will be made in fiscal year 1972 or 1973.

Cooperation With Other Government Agencies

DOD has continued its close coordination and cooperation with other Government activities particularly NASA. Included below are examples of the manner and types of this coordination.

National Aeronautics and Space Council—There is a continuing liaison, coordination and exchange of information with this organization of which the Secretary of Defense is a member. The Council staff is periodically briefed on all aspects of DOD aeronautics and space activity. There are presently six Air Force officers detailed as members of the Council staff.

Aeronautics and Astronautics Coordinating Board—The Aeronautics and Astronautics Coordinating Board continued to effectively play a necessary role in facilitating the planning, coordination, and information exchange in areas of common interest to DOD and NASA. Four meetings were held in 1969. Increased emphasis was placed this year on the aeronautics area. Large aeronautical ground test facilities necessary for future national aeronautical research and development activity were clearly identified and prioritized as a first step leading toward possible facility acquisition. Emphasis was also placed on an assessment of current aeronautical research and aircraft developments. The studies initiated last year in a number of areas such as manned spacecraft recovery, networks, launch vehicles, range support operations, and other common areas of DOD–NASA activity were completed. While few near term cost savings were identified, the studies were beneficial in showing the way so long term savings and promoting better working relationships and understanding between agencies.

Joint Army-NASA Aeronautical Research—The Army Aeronautical Research Laboratory was established April 1, 1965, as a result of an Army-NASA agreement to augment low-speed aeronautical research. This agreement permits the Army to use NASA facilities in the low-speed subsonic areas and provides the Army with an internal aeronautical research capability. The Army's primary interests are in rotary wing and other vertical and short takeoff and landing aircraft. The integration of Army personnel into the NASA low-speed programs permits efficient use of talent and facilities to perform research of mutual interest. The laboratory is located at Moffett Field, Calif.

DOD Support of NASA—During fiscal year 1969 DOD support of NASA totaled more than $235 million. There were 246 military personnel assigned to NASA (164 Air Force, 23 Navy, 56 Army, 3 Marine Corps). Below are listed examples of support furnished.

Apollo Program—Commensurate with the national objective to place a man on the Moon by 1970, DOD continued to provide assets for the support of the Apollo program. The major portion of this support was allocated to the recovery operation. The primary responsibilities of the recovery force were to insure the rapid location and retrieval of the CM and crew and to provide on-scene assistance to the astronauts. Associated responsibilities involved the collection, retrieval, and return of data and hardware; transportation of the astronauts from the recovery area; and, in the case of the lunar landing missions (Apollo 11 and 12), insuring that lunar samples were delivered within a specified time and biological decontamination procedures were carried out.

Medical Projects—The Naval Aerospace Medical Institute, Pensacola, Fla., conducted space-related medical tasks which included study of the biological effects of varying magnetic fields, preflight aspects of long duration weightless flights with primates, hazards of proton radiation, techniques of in-flight electrocardiography, and effects of gravitational forces, inertial forces, and extended weightlessness upon man with particular emphasis on his vestibular systems.

The Naval Medical Research Institute, Bethesda, Md., carried out tasks including study of microcalorimetry as a method for life detection, biochemistry of stress in aviators under combat stress, and the effects of varied barometric pressures on human infectious disease resistance.

Aerospace Feeding Systems—The U.S. Army Natick Laboratories continued development of new and improved aerospace food products for NASA. Five new thermal processed wet meat products were introduced into Apollo flights as the first eat-with-a-spoon foods. Menus for Apollo 8 and 9 flights were planned according to the astronauts' individual selections from available flight qualified foods. In addition, five new dehydrated formulations developed for the long range patrol ration were adopted as eat-with-a-spoon items for space flight use and were carried on Apollo flights 10 and 11.

Test Range Support—The U.S. Air Force test ranges continued to provide major support to the Apollo program. Support areas included recovery, communications, range safety and operation of the Apollo ships and instrumented aircraft. Other support to manned and unmanned NASA missions included data acquisition, transmission, processing and reduction; industrial support; launch-complex control and support operations; and facilities engineering at the Air Force Eastern and Western Test Ranges.

V Atomic Energy Commission

Introduction

During 1969, development of nuclear power for space applications included continuation of work on system technology that will be required in future missions as well as on several operational systems for current national space program missions. Highlight events include the following:

Nuclear Power—A SNAP–27 isotopic generator is serving as the sole electrical power source for the Apollo lunar surface experiments package (ALSEP) deployed on the lunar surface by an Apollo 12 astronaut.

Two SNAP–19 radioisotope thermoelectric generators were launched aboard the Nimbus III weather satellite in April, and have been supplying continuous electrical power to the spacecraft since launch.

Work has begun to meet the National Aeronautics and Space Administration request for AEC development of isotopic generators for the Pioneer F and G Jupiter flyby probe missions to be launched in 1972 and 1973 and the Viking Mars lander missions to be launched in 1973.

Design and development of a 30-watt-power system for a Navy navigational satellite continued throughout the year.

Study efforts were initiated for the development of a multi-hundred watt modular power system for use on a variety of projected missions in the mid to late 1970's, particularly the outer planetary Grand Tour and related precursor missions.

The zirconium hydride reactor-thermoelectric conversion system was identified as a principal candidate for the prime power system on the proposed manned space station planned to be launched in 1976–77.

Ground testing of a flight-configured zirconium hydride reactor (S8DR) achieved full power operation early in the year. Several months of endurance testing have been accomplished. While the reactor operation has been satisfactory, evidence of fuel cracking has been observed.

Nuclear Rockets—The technology phase of the NERVA technology program was completed with the completion of the ground-experimental engine test program.

The NERVA engine design and development efforts were underway, directed toward development of a reusable 75,000-pound-thrust engine.

Space Electric Power

Space Radioisotope Power Systems

SNAP–19 and SNAP–27—The SNAP–19 and SNAP–27 generator programs were successfully concluded during 1969 with the launch in April of two SNAP–19 generators on the Nimbus B weather satellite and with the deployment on the lunar surface of a SNAP–27 generator as part of the experiment package left on the Moon by the Apollo 12 astronauts. Both generators are fueled with plutonium-238.

The SNAP–19 provides supplemental power to the Nimbus B weather satellite while the SNAP–27 is the power system for the ALSEP which collects and transmits scientific measurements and data back to Earth. The ALSEP experiment package is designed to operate for a period of up to 1 year. The SNAP–27 permits data to be transmitted during the lunar night as well as during the lunar day.

Pioneer and Viking—An adaptation of the SNAP–19 generators utilizing an improved heat source and thermoelectrics is under development for the NASA Pioneer and Viking programs. Launches are scheduled in 1972 and 1973.

SNAP–29 Isotopic Generator—Because of budgetary priorities, the development of the SNAP–29 short-lived generator was terminated in 1969. An electrically heated generator test was conducted with available hardware but was only partially successful.

Transit Generator—A comprehensive design tradeoff study was completed for selection of the generator approach for the Navy's improved transit navigational satellite. With a design goal of 5 years of operation, a single 30-watt plutonium-238 fueled generator using lightweight thermoelectric panels and a refractory metal capsule was selected as the reference design. The Transit generator will supply total system power for the spacecraft.

Multihundred Watt Generator Module—A contractor was selected and work started on the first phase of a program to develop a lightweight, long-life, plutonium-fueled, radioisotope thermoelectric long-life power system producing several hundred watts of power for use on future space missions. A primary aim of the program is to design, fabricate, test, and deliver an optimized thermoelectric power module with an electrical output of between 100 and 200 watts. This module will be a basic building block for space power systems in the 100- to 1,000-electrical-watt range.

During the year, thermoelectric couples using SiGe were operated at temperatures up to 1,150° C. Efficiencies of 6.6 percent were demonstrated at 2,000° C in a thermoelectric converter, and a nominal 35-watt foil insulated generator was fabricated for testing in 1970.

High Temperature Radioisotope Capsule—Effort continued for development of a high temperature capsule for application with the NASA isotope-Brayton ground systems test scheduled to begin in 1972. The work included analysis and impact, fire, and creep testing. This technology is also applicable to other systems.

Space Reactor Power Systems

Zirconium Hydride Reactor Systems—Testing of the flight-configured ground-prototype uranium-zirconium hydride reactor (S8DR) continued. Startup testing and operational sequences initiated in 1968 were completed early in 1969. The reactor then underwent approximately 3 weeks of operation at 1,000 thermal kilowatts. Following this, it was placed on an intended 10,000-hour test. Test data collected since that time indicate that some fuel element cracking has taken place.

The phenomena that determine fuel element integrity are temperature dependent. Data obtained in this test indicates that part of the core may have been operated at temperatures higher than expected and this could be the cause of the observed cracking.

Operating this reactor at reduced, but useful, temperatures indicated that it would have been possible to continue the test to its planned ten thousand hour life. The decision was made to shut down the reactor after about seven thousand hours of operation because longer operation might make it more difficult to obtain evidence as to the cause of any clad cracking which had taken place.

Effort continued toward development of components and system technology for use in a reference zirconium hydride reactor. This reference reactor, in concert with compact thermoelectric conversion systems, is one of the prime power system options being considered for use on the proposed manned space stations to be launched in the late 1970's.

Development of the converter system continued, and prototype converter modules were placed on test.

Advanced Reactor Concept-Thermionic Reactor—The in-core thermionic reactor program continued to emphasize the development of fuel elements capable of long endurance operation at emitter temperatures around 3,000° F. This reactor will be capable of satisfying the high power requirements of the expanded bases and other missions of the 1980's. The development schedule is oriented towards the demonstration of a power-producing prototype reactor during the mid-1970's. During 1969, the design concept for the first ground based reactor experiment was chosen. This concept, employing the so-called flashlight assembly of diodes, consists of a matrix of tubular fuel elements, each containing a number of small thermionic diodes connected in series, much like batteries in a flashlight. A prototype fuel element was operated in a reactor core for more than 5,000 hours.

Space Isotopic Fuel Development

Polonium-210—With the termination of the SNAP-29 short-lived generator project, work in development and production of polonium fuel was terminated in 1969.

Curium-244—Characterization and property measurements related to development of a curium-244 fuel form were continued throughout the year. Several hundred grams of curium-244 were made available for these development efforts. Compatibility experiments were carried out with refractory metals at temperatures in the neighborhood of 1,500° C. for 10,000 hours, and 2,000° C. for 1,000 hours. This isotope is the only practical long-lived radioisotope for thermionic generator applications. The design and fabrication of a one thermal kilowatt heat source planned for life test operation at thermionic temperatures was completed.

Plutonium-238—As an extension of fuel development activities carried out in previous years on solid solution and molybdenum cermet fuel forms, development was initiated on a solid solution cermet fuel form. This fuel form combines the properties of the solid solution and molybdenum cermet fuel forms. It is being developed as one which is more shock resistant and can operate at higher temperatures than is possible with the existing microspheres fuel form. This fuel form will be used in the Pioneer, Viking, Transit, multihundred watt, and isotope-Brayton applications if it can be characterized in time and its characteristics prove to be as anticipated.

Nuclear Rocket Program

One major objective of the joint NASA-AES nuclear rocket program is to develop a 75,000-pound thrust, long-endurance engine for space vehicle application. This engine, identified as NERVA, will have a specific impulse of about 825 seconds, the capability for multiple restarts and a very high reliability. The NERVA engine incorporated in a reusable nuclear stage can perform a large number of the future missions in the NASA integrated plan. These will include earth orbit to synchronous orbit or lunar orbit, earth orbit plane changes, scientific probe launches to deep space, including ultimately manned planetary trips. Engine development is being accomplished using a base of technology which took more than a decade of extensive analytical and experimental research to acquire.

In addition, the nuclear rocket program goals include a variety of supporting and advanced technology activities which are directed toward the extension of nuclear rocket performance, and activities related to facilities design and construction. For the description of progress in these areas, see chapter III.

Among the most significant accomplishments in the nuclear rocket program during 1969 was the completion of tests on the NERVA ground-experimental engine at the Nuclear Rocket Development Station in Nevada, and the completion of the systems engineering required to proceed with the preliminary and detailed design of the NERVA flight engine.

The ground-experimental engine test program was the last test event to be conducted in the technology phase of the nuclear rocket program. Throughout this phase, the important basic aspects of nuclear rocket operation required to develop a flight engine were investigated. All technology goals have been met. In all, 12 consecutive reactors and engines have now been tested, from which more than 14 hours of power operating experience have been accumulated. Approximately 4 hours of this experience was at high power. With the completion of the ground-experimental engine test program, all NERVA effort is now devoted to the development of the 75,000-pound thrust NERVA flight engine. For the description of the ground-experimental test program, see chapter III.

Progress in NERVA Development—During 1969, the emphasis in the NERVA development program was on systems engineering to establish engine requirements based on the classes of missions inherent in the NASA integrated program plan, design studies to determine the best way of achieving these requirements, the preparation of preliminary engine specifications, and engine definition studies to establish a baseline engine configuration. Work also was initiated on the preliminary design of engine and reactor components, such as the turbopump, the nozzle, materials of construction for various components, controls and control concepts, and engine/stage interface considerations. In the reactor design, investigations included details of the structural design, reflector configuration, reactor control system and the fuel region of the core.

Fuel Element Research—The continuing emphasis on fuel technology has resulted in major improvements in fuel performance during the past year. Fuel element lifetimes of 4 to 5 hours with multicycle operation such as required for the orbital shuttle mission appear possible now with the present fuel material systems. Improvement to 10 hours and 60 cycles appears to be possible by direct extensions of the present technology.

Research on new fuel materials indicates the possibility of longer times at current temperatures or 10-hour cyclic endurance at a specific impulse of at least 900 seconds. This performance capability will greatly reduce the costs and increase the flexibility to perform NASA missions of the kind indicated in the Space Task Group report.

Detection of Space and Atmospheric Nuclear Explosions

The AEC-instrumented Vela satellite program continued in 1969 with the fifth successful launch by the DOD in five attempts of a satellite for the detection of nuclear explosions in space or in the atmosphere.

The launch of Vela V was conducted on schedule from Cape Kennedy on May 23, 1969, using a Titan IIIC booster. The two AEC-instrumented spacecraft were injected into their nominal 65,000-nautical mile radius orbit, with a 180° phase separation, on May 24 and May 26, 1969.

The complement of detectors includes those designed to measure signals generated by atmospheric nuclear explosions, and the X-rays, gamma rays, and neutrons from a high altitude or space nuclear explosion.

The spacecraft on Launches I (1963), II (1964), and III (1965) were spin-stabilized while those on IV (1967) and V were attitude controlled to be continuously pointing toward the earth, which adds materially to the capability of the downward-looking detection instrumentation systems.

In addition to detector systems for nuclear explosions, the spacecraft carry detectors to accumulate data for studying the naturally occurring radiation environments produced by the sun and other sources, and for evaluating the effect of these on the nuclear detector systems. In the performance of this function, these additional instrumentation systems also collect much basic scientific data of importance to furthering an understanding of the solar-terrestrial relationships and other astrophysical phenomena. For example, a strong X-ray source in the southern sky was first observed by Vela V instrumentation, and scientists are now studying this event with great interest.

VI Department of State

Introduction

Worldwide interest in U.S. space activities reached unprecedented levels with the landing upon the moon by American astronauts. In the course of his address before the United Nations General Assembly on September 18, President Nixon stated: "Of all of man's great enterprises, none lends itself more logically or more compellingly to international cooperation than the venture into space." Noting that he feels "it is only right that we should share both the adventures and the benefits of space," the President referred, as an example of U.S. plans, to determination to take actions with regard to Earth resource satellites as this program proceeds and fulfills its promise. In a subsequent speech, the U.S. Representative to the First Committee of the General Assembly outlined the steps that the U.S. is taking to foster international understanding of, and cooperation in, this program.

During 1969 the Department of State, in close consultation with NASA and other U.S. agencies, continued active efforts to encourage the further development of international cooperation in the exploration and use of outer space for peaceful purposes, and to ensure understanding and support abroad of the U.S. national space program. Several new bilateral agreements were concluded during the year. Looking toward future possibilities to extend cooperative arrangements in space science and applications, discussions continued with foreign officials representing individual governments and international organizations such as the European Space Research Organization, and in meetings under United Nations auspices. Further growth took place in the global commercial communication satellite system established by the International Telecommunications Satellite Consortium (Intelsat), and the United States served as host Government for the Plenipotentiary Conference on Definitive Arrangements for Intelsat, which will reconvene in Washington in February 1970.

Activities Within the United Nations—In 1969 the United States participated actively in meetings of the U.N. Committee on the Peaceful Uses of Outer Space and its Working Group on Direct Broadcast Satellites, as well as in meetings of its two Subcommittees.

The Scientific and Technical Subcommittee met in New York in March and made a number of recommendations, cosponsored and supported by the United States, to promote applications of space technology, particularly for the benefit of developing countries and other nonspace powers.

At its June meeting in Geneva, the Legal Subcommittee briefly discussed questions relating to the definition and utilization of outer space, but concentrated primarily on efforts to complete a draft convention on liability for damage caused by objects launched into outer space. Although some progress was made, several difficult issues remained unresolved.

The Direct Broadcast Working Group met first in February to study technical and economic matters and again in july to study social, cultural, legal and other implications of direct television broadcasting from satellites. The Working Group at its first session did not foresee direct broadcasting to unaugmented home receivers before 1985, but direct broadcasting to augmented home receivers was considered technologically possible by 1975 and possibly earlier for community receivers. At its second session, the Working Group concluded that there was substantial potential in the long run for the application of direct broadcasts from satellites in the interest of all mankind. The Working Group stressed the need for international cooperation and further studies.

The Outer Space Committee met in New York in early September to consider the reports and approve the recommendations of its two Subcommittees and the Direct Broadcast Working Group. The Committee agreed to made further efforts to complete the liability convention during the 24th session of the General Assembly, and requested its Chairman to conduct private consultations among the members and to reconvene the Committee in mid-November to consider the results of the consultations. Some progress was registered during the November consultations but the major issues preventing agreement were not resolved.

The General Assembly, in a resolution cosponsored by the United States on international cooperation in the peaceful uses of outer space, endorsed the report of the Outer Space Committee and urged the completion of a liability convention for consideration at the 25th General Assembly.

Following up on the President's speech at its opening session, the General Assembly approved a resolution, also cosponsored by the United States, expressing the desire that Earth resources survey satellite programs be available to produce information for the world community as a whole and encouraging participation to the extent feasible in their development. It invited member states to share experiences in remote Earth resources surveying and data analysis, and requested the Outer Space Committee to study international cooperation in the development and application of Earth resources survey techniques.

New Bilateral Agreements—An agreement was concluded with Japan in July concerning arrangements to permit U.S. industry to provide certain categories of unclassified technology or equipment for the development of specified Japanese launch vehicles and communications and other satellites for peaceful applications. Under the agreement, the Japanese Government provided assurances that the use of the technology and assistance obtained will be for peaceful purposes and compatible with Intelsat arrangements. Further, that the technology and equipment will not be transferred to third countries without the approval of both Governments.

Two agreements were concluded with Italy, confirming arrangements between NASA and the University of Rome's Aerospace Research Center. One, in September, concerned arrangements for a cooperative project to continue satellite measurements of upper atmospheric characteristics, and involves the launch of an Italian scientific satellite from the Italian San Marco Launch Facility. (Two satellites were previously launched under arrangements with Italy in a 1962 agreement.) The other agreement, concluded in June, concerned the conditions under which launching and associated services for NASA experimental scientific satellites will be furnished to NASA at the San Marco Launch Facility.

In June, NASA and the German Federal Ministry for Scientific Research agreed to cooperate in a project for the exploration of interplanetary space. Called Project Helios, it is the most ambitious international space flight project yet undertaken, and involves a pair of solar probes (to be launched in the 1974–75 period) which will carry 10 United States and German scientific experiments closer to the sun than any spacecraft thus far scheduled. NASA and the German Ministry also concluded another agreement in June to conduct a cooperative project to launch in 1972 an integrated aeronomy satellite. Under an earlier cooperative project agreement with the German Ministry, the first German scientific satellite (Azur) was launched by NASA in November.

In September, NASA and India's Department of Atomic Energy concluded a memorandum of understanding concerning cooperation in an experiment in the use of an applications technology satellite (ATS–F) for direct broadcast to rural community receivers in India and limited rediffusion through VHF transmitters of Indian-developed instructional TV program material (relating primarily to agricultural training and family planning). The arrangements envisage utilization of the ATS–F satellite for this experiment for a period of up to 1 year, during 1972–73, while additional experiments are conducted by U.S. and other experimenters.

Tracking Networks—A series of bilateral agreements, relating to the establishment and operation of the facilities abroad that are part of NASA's global tracking network, have been concluded in the past with the countries concerned. An extension of the agreement with Spain, providing for continuation of the tracking and data acquisition station near Madrid for an additional 10 years (until January 1984), was effected by an exchange of notes in June. A 10-year extension of the agreement with Australia is under negotiation. NASA plans to construct a 210-foot-diameter deep space antenna as an addition to its tracking facilities in both Spain and Australia.

Apollo Program—As in the case of previous manned flights, the Department of State and its overseas posts maintained a state of alert throughout the Apollo missions this year, to support NASA and DOD in the event of an emergency recovery requiring such support. Before each such mission, the Department through our embassies also facilitated the positioning of support units at appropriate locations abroad.

The Department and its overseas posts assisted in arrangements for travel abroad by astronauts, particularly the tour by the Apollo 11 crew, and in informing the foreign scientific community of the opportunity to participate in NASA's program for the scientific study of lunar materials returned to earth.

Communications Satellites—The global commercial communication satellite system established by Intelsat added seven members in 1969 increasing its membership to 70 countries. Additional members are expected to join in coming months.

An increased volume and variety of global telecommunication services have been made available to all continents of the world through new and larger capacity satellites added to the global system, and through the steadily increasing establishment of earth stations to work with the satellite system. By January 1970, a total of 36 Earth stations in 24 countries are expected to be in operation; of these, 21 operate through satellites above the Atlantic Ocean, 13 through Pacific satellites, and 11 through the Indian Ocean satellite. Several countries have more than one station in operation.

The global satellite system has not only vastly expanded international telecommunication capacity but also made possible direct country to country communications where such service had not formerly been possible. Developing countries have been the particular benefactors of greater reliability, versatility and lower user costs. Live intercontinental television transmission is also now possible via satellite on a global basis.

In February–March 1969 the United States served as host government for the Plenipotentiary Conference on Definitive Arrangements for the International Telecommunications Satellite Consortium. The Conference recessed in March, having created an international Preparatory Committee to develop draft definitive arrangements. The Committee met in Washington in June, September, and November and has completed a report to the Plenipotentiary Conference which will reconvene in Washington in February 1970.

One outstanding Intelsat achievement during the year of wide international importance was the transmission of live coverage of the Apollo 11 mission which permitted an estimated audience of 500 million persons to witness the first step by man on the surface of the Moon.

Aeronautical Service Satellites—The United States continued to work with the International Civil Aviation Organization (ICAO) in the study of requirements and specifications for a satellite system to provide aeronautical services such as air traffic control, surveillance, and company operational control. The ICAO Panel on the Application of Space Techniques Relating to Aviation (ASTRA) will eventually make recommendations with regard to characteristics of a system to serve international aviation.

Cooperation With Department of Defense—During 1969 the Department of State worked closely with the Department of Defense on those DOD space-related programs which had an international bearing. Some of the major programs were the NATO tactical satellite communications system, the cooperative program with the United Kingdom in developing the Skynet system, and overseas arrangements to support the national geodetic satellite program.

VII United States Information Agency

Introduction

In 1969, the climactic year of space exploration, the U.S. Information Agency focused on the Apollo 11 and 12 missions as it had for no other events.

It has been estimated that over half the world's people saw, heard, or read about man's first Moon landing. USIS was directly involved in this story reaching the world audience. At the Cape Kennedy launch a USIA multilingual staff assisted over 800 foreign correspondents with accreditation, technical information, and local support; the same was provided for the foreign newspaper, radio and television correspondents covering Houston. The Voice of America carried the story in 36 languages to over three-quarters of a billion listeners. In response to an unprecedented demand, special motion picture and television productions, exhibits, models, pins, photomurals, books, pamphlets, and files of wire service and feature copy, documented and amplified the story. For USIA Apollo 11 was the event of the year, although other space events were given full coverage.

Guidelines

USIA used these guidelines for treatment of the Moon landing:

(*a*) The Apollo Moon landing represents mankind on the Moon.

(*b*) Men are going to the Moon because it is in the nature of man to attempt the difficult and challenging; because men are being benefited in practical ways from the effort; because the scientific results are important, and because, as President Nixon has said, those who downgrade space "miss one of the great lessons of history. Any great nation, if it is to remain great, must be in the forefront in exploring the unknown—in discovering the new worlds."

(*c*) Historically, Apollo is a U.S. effort that is built upon the achievements of scientists from many nations.

(*d*) Apollo has a strong international context; its scientific results are available to all, while the astronauts are what the Treaty on Outer Space says they are, "the envoys of mankind in outer space."

(*e*) Apollo holds a promise—legitimately raising man's hopes that eventually he can use technology to resolve some of the long intractable problems that face him here on Earth.

Treatment

Radio—The seemingly unappeasible world appetite for information on Apollo 11 made it possible for the Voice of America as never before in its 27-year-old history to concentrate so completely on a single subject. Taking the flights of Apollo 8 through 12, and the two 1969 Mariners to Mars, the Voice was estimated to have had a total audience of 2 billion listeners. Direct broadcasts on the Moon-landing mission in 36 languages, plus relayed transmissions by more than 3,600 foreign TV and radio stations, are thought to have reached over 615 millions in 66 non-Communist countries. If audiences in the U.S.S.R., China, and other Communist countries are included, VOA's total audience for the Moon landing could be three-quarters of a billion—27 percent of the world's population outside the United States.

Planning and preparing the coverage was an extensive project. Some 5,000 prelaunch tapes and scripts were shipped to posts around the world for placement with foreign media on the mission to come.

Live coverage of all major aspects of the mission was broadcast in worldwide English, and in Portuguese, Spanish, and Russian, while special live broadcasts were made in Arabic, French, Greek, Japanese, Turkish, Chinese, and other languages. All 36 Voice languages used heavy programing on Apollo 11. When the Voice, following the mission, announced photos of the crew were available upon request, over one-half million responses were received.

Press and Publications—Materials sent to newspapers and publications abroad who requested data on the Moon landing were unprecedented in quantity and scope. Prelaunch materials included special packets of byliners, flight plans, flight-path drawings, and interviews with space officials; a special article commissioned from Pearl Buck; and full picture coverage, including, with special permission, a weekly magazine's feature on the astronauts and their families. A heavily illustrated pamphlet in color, the 48-page "Man on the Moon," printed in 16 languages for a total of 422,000 copies, was also in the field before liftoff. A four-page leaflet commissioned from John Dos Passos, "On the Way to a Moon Landing," stressing the human aspects of the flight, was printed in four languages, 212,000 copies. Also printed in advance were 1,958,000 color postcards of the Apollo 11 astronauts.

Wireless File, going to 106 countries, reported all details of the flight, with 200 stories totaling 68,000 words going out July 18–20. During the lunar walks the File was on the air continuously for 12 hours. Fully 39 photos and nine color transparencies of the launch went to all posts immediately, while 38 posts got fast photos of the Washington-based ambassadors of "their" countries watching the launch.

A special postflight leaflet, "Eight Days in July," was printed in 17 languages, over 1 million copies, while 394,400 copies of a 28-page pamphlet, "To the Moon and Beyond," done in 12 languages, were also sent out after the mission. A special album of color photos from the mission was made up for presentation abroad to VIP's below the chief of state level, 700 copies being printed for post needs. The Wireless File covered the 24-nation world tour of the Apollo 11 astronauts—a Voice of America reporter was on their plane—while 150,000 colored lithographs of the astronauts were distributed along the route. ***America Illustrated*** carried a 16-page section on Apollo 11 in its November issue, the November issue of ***Topic*** in eight-page color spread.

Motion Pictures and Television—A large part of the world's population that saw the moon landing, and other space activities through the year, was observing film produced, acquired, or distributed by USIA.

The Agency produced nine films of its own on Apollo, while it distributed other films acquired from NASA, including the 30-minute "America in Space: the First Decade," which went to 115 countries. The Agency used the Pacific communications satellite to transmit its quickly produced "Apollo 11: Man on the Moon," to Tokyo for fast local processing and distribution to Southeast Asian posts. The Agency's principal Apollo 11 production, "One Giant Leap for Mankind," a half hour color film based on NASA film, went to 138 countries. Before liftoff the Agency had in hands of posts for television a half hour interview with an Apollo astronaut on human and technical problems related to the coming mission.

Over a dozen NASA newsclips on Apollo went to over 75 countries monthly through the year. "Science Report," a monthly television review of U.S. science, seen in 82 countries, used a dozen segments on various space subjects. So did "Washington Correspondent," a news and feature program air pouched weekly for telecasting in 57 countries. Dozens of space newsclips were sent out, while posts abroad facilitated the production of many commercial films by supplying requested footage on space.

Information Centers and Exhibits—Well in advance of the mission, the Information Center Service, which services the field with exhibits, books, posters, and special items, began its plans for the Moon landing. A large assortment of three dimensional and audiovisual items were designed and purchased. In the hands of posts well before liftoff were over a million Apollo 11 lapel buttons; 125 Apollo "Kiosk" exhibits (a 6-foot-high, three-sided stand with blinking lights, music, photogelatin transparencies, and five space posters, all on Apollo) ; 1,000 photogelatin color transparencies on lunar flight to fit light boxes; 390 sets of 10 unmounted poster panels on Apollo 11; 280 sets of 32 color photo prints; 10,000 lunar maps; 275 manned lunar landing charts; 840 plastic Saturn 5 rockets; nine full-size Apollo space suits; 103 models of the Apollo spacecraft, and 240 16-inch Moon globes.

The major space exhibit was the showing of the Apollo 8 spacecraft at the Paris Air Show, and other European cities. The Agency provided heavy support for a space exhibit at Amsterdam in October.

By late autumn, the Agency was exhibiting moon rocks in USIS-managed tours of South America, Africa, Asia, and Europe, including at a USIA exhibit, "Education, U.S.A.," in Moscow.

Also distributed were 1,000 copies each of special Apollo 11 editions of weekly magazines; two articles, "We Reach the Moon" and "Apollo on the Moon," as well as the special Moon-landing edition of a metropolitan daily, with over 5,000 copies purchased. Also distributed were sets of 30 to 50 slides on Apollo 8 through 11, of which about 350 sets were presented to schools, universities, and scientific institutions.

VIII Arms Control and Disarmament Agency

Introduction

Outer Space Treaty—The successful voyages to the moon were conducted in strict conformity to the Outer Space Treaty of 1967, which has now been ratified by 54 governments. It is gratifying that these advanced and pioneering explorations had already been preceded by intellectual and legal concern for the peaceful and international nature of space exploration.

The closing off of new environments to the liabilities of an arms race has been one of the most effective ways of achieving successful international agreements. The success of the Outer Space Treaty has led to similar efforts for the region of "inner space" and served as a model to some extent in helping to fashion a treaty for the "seabeds," a joint draft of which was presented to the Conference of the Committee on Disarmament at Geneva by the United States and the U.S.S.R. on October 7, 1969.

Growing acceptance of the concept of peaceful and cooperative space exploration has been useful in promoting a spirit of international interdependence and is a positive influence in international relations and understanding. In this spirit, President Nixon spoke to the U.N. General Assembly on September 18, 1969 and, with reference to developing earth resource survey satellites, stated that: "this program will be dedicated to produce information not only for the United States, but also for the world community."

International Cooperation in Space Activities and the Problem of Missile Proliferation—Productive multilateral and bilateral arrangements for sharing both the results and the means for exploration of space have been established in furtherance of the Nation's peaceful uses of space policy. One such action, The Space Cooperation Agreement with Japan, signed on July 31, 1969, contains a provision that any technology or equipment transferred by U.S. agencies or industries to Japan will be used solely for peaceful purposes. The Japanese Government agreed to take all available steps in accordance with Japanese laws, regulations, and administrative procedures to prevent transfer to third countries of this technology. These restrictions are consistent with our policy of "nonproliferation" of missile and weapons technology.

Aerial and Space Systems for Implementing Arms Control Agreements—The ACDA research program maintains a continuing investigation of the possible utilization of aerial and satellite platforms, spaceborne communications and associated sensors, data links, and processing systems in support of possible arms control agreement. Inspection and verification techniques are studied with a view to increasing confidence in possible future treaty arrangements. Studies indicate that satellite communications may be increasingly effective as a means for enhancing the rapid transmission of information between governments so as to promote better understanding and to remove the temptations to act hastily and through possible misunderstanding.

IX Department of the Interior

Introduction

The U.S. Department of the Interior has long utilized aircraft in the performance of its missions for exploration, development, and management of the Nation's natural and cultural resources.

The Department has played an important role, also, throughout the past decade in support of the Nation's space exploration and lunar landing programs, and in support of the development of peaceful applications of space technology.

Aircraft of several bureaus of the Department, contractor owned, and other Federal agency-owned aircraft of all types are used operationally and experimentally. Experiments are conducted to test and develop improved capabilities that the aircraft themselves afford in support of Department programs and to test new ways in which use of airborne surveying and analytical instruments from cameras to radioactivity counters can improve the efficiency and effectiveness of departmental performance.

The earth resources observation satellite (EROS) program of the Department of the Interior is a program to utilize data collected from aircraft and spacecraft for practical resources purposes. Using randomly collected data from Apollo, Gemini, and Mercury space flights, the U.S. Geological Survey has compiled photo mosaics that are maplike in quality of over 1 million square miles of the Earth's surface. Using these maps as bases, and the color "space" photos for interpretation, the Geological Survey scientists have prepared (1) a geologic terrain map of the southwest United States (essentially a soils-association map), and (2) a land-use planning map of the same region, a tectonic map, and soon will complete a land-use map of the area. Of significance is the "ability" of space images to peer far beneath the waters of the ocean, thereby, holding promise for increasing the efficiency of resources studies of near-shore areas.

Detailed performance specifications were furnished to NASA in 1966, identifying the type of data that would be the greatest of utility to the Department of the Interior. These specifications have been incorporated into the design of the proposed spacecraft NASA expects to launch in late 1971 or early 1972.

Aeronautics

In the Bureau of Land Management, Bureau operated and contracted, fixed-wing aircraft and helicopters are used for fire control, monitoring, and logistical support for fire-fighting personnel; for transportation of personnel and equipment to remote areas and for experimental development for the performance of cadastral surveys; for aerial spraying for eradication of brush and noxious plants; for seeding of areas being reclaimed after fire and erosion damage; and for aerial surveillance of pipelines, remote installations, and improvements.

Airflight equipment is vital to the operations of the Bureau because of the extent and the remoteness of the areas it must serve, especially in Alaska. On the other hand, the adaptation of surveying, fire-fighting, seeding, and spraying equipment to air-transport and aerial operation greatly increases and enhances the work of the Bureau is able to do toward the protection and the useful management of the Nation's forest, recreation, grazing, and mineral resources.

The National Park Service uses remote sensor data obtained by aircraft of the NASA, the Willow Run Laboratories of the University of Michigan, and the U.S. Geological Survey, and space data from Gemini and Apollo missions in studies to determine the applicability of remote sensors to problems of preservation of the national park environments such as coastlines, forests, waterbodies and geologic phenomena.

The Bureau of Mines obtains remote sensor data using aircraft facilities of the NASA, the U.S. Geological Survey, the Willow Run Laboratories of the University of Michigan, and several contractors. Thermal infrared data are used to monitor coal mine fires and burning culm banks. Radar data are being used in an experiment to determine their value for making analyses of geological structure in areas of oil production; and a wide variety of airborne sensor data, plus spaceflight photography from Gemini and Apollo missions, are being used in a study to determine their applicability to problems of observing and correcting surface effects of mining activities.

The Bureau of Reclamation owns and operates small aircraft and helicopters for transporting control survey parties to remote areas, for transmission line patrol inspection and for maintenance of microwave or radio repeater stations. Contract aircraft are used to acquire low altitude aerial photography for detailed topographic site surveys by photogrammetric methods and for photointerpretation. Recently the Bureau has begun experiments to determine the applications and use of airborne remote sensor data obtained by NASA, military agencies, and the National Center for Atmospheric Research. Analysis of Gemini and Apollo photography indicate that repetitive observations from satellites resulting in synoptic views of large areas on a timely basis will provide valuable information for reclamation purposes on both domestic and foreign programs.

The Bureau of Indian Affairs uses Government owned and contract aircraft for observation and aerial photography in wildfire detection and suppression as well as forest insect detections, evaluation, and control on 48.3 million acres of Indian- and Government-owned land which includes 12.8 million acres of forest land currently valued at $1 to $1.5 billion. Forest land observations and photography are repeated annually but photography for other purposes such as mineral surveys and evaluation or road and highway design and construction are obtained as needed. Future use of aircraft is expected to rise.

The Southwestern Power Administration uses contract aircraft to conduct bimonthly aerial observations of 1,600 miles of high voltage transmission lines and the associated rights-of-way. This information provides fast location of trouble areas during emergencies and is helpful to management in planning preventative maintenance of transmission lines.

The Federal Water Pollution Control Administration has used Government owned and contract aircraft in research investigations to develop operational remote sensing systems for water quality surveillance. These studies have been oriented toward the detection and monitoring of oil and thermal pollution, determining coastal outfall characteristics and measuring the discharge of pulp and paper effluents. Study grants presently underway with Oregon State University (ocean outfalls), Cornell Aeronautical Laboratory (oil spills) and the University of Michigan (systems evaluation) will help define the instrument requirements, data applications, and future aircraft needs of the Administration in developing an operational pollution detection system.

The Bureau of Commercial Fisheries employs the aircraft facilities of the NASA, the U.S. Coast Guard, and of contractors to obtain data at varied altitudes using cameras, low-light-level television systems, and multiband sensors, to study phenomena related to fish schools and the environments of fisheries.

The Bureau of Sport Fisheries and Wildlife currently employs 45 aircraft with 60 authorized flight employees to increase the efficiency and effectiveness of its extensive wildlife and habitat management programs over broad areas of the United States, Canada, and Mexico. Programs include international cooperative efforts in wildlife surveys, animal control, and agricultural applications, and in national law enforcement patrol.

The Geological Survey employs its own and contract aircraft. Contract aircraft are used to obtain aerial photography that is used operationally in the production of topographic maps of the United States. Topographic mapping of Antarctica is performed through cooperation of the Department of Defense which provides aerial mapping aircraft and crews. Its own aircraft, including propeller and jet driven fixed wing, and helicopter types are used in evaluation of airborne systems such as magnetometers, scintillation counters, light wave, radio wave, and infrared sensors, all for surveying for geologic conditions favorable for mineral exploration and in the conduct of geologic mapping.

Helicopters are used by the Department to aid in the movement of men and materials in performance of surveys of wilderness, Alaskan, Antarctic, and other remote areas.

Conventional aircraft and instrument systems aid greatly in enhancing the capability to carry out survey and management activities by providing coverage of large areas at scales commensurate with conventional mapping scales, and by aiding in the identification of areas where men on the ground are needed to solve specific problems. This utilization reduces the need to concentrate field parties in small areas to perform basic surveys and greatly increases the capability of each man to work effectively over broad areas.

Space

The Department has played an important role since 1961, in cooperative effort with NASA to develop peaceful applications of aeronautic and space technology and in support of the manned space flight program.

The U.S. Geological Survey's Astrogeology Branch has performed geologic and cartographic mapping of the moon and conducted the training of the astronauts in geologic observation, sampling, and mapping procedures. It has provided major support to the historic lunar landings of Apollo 11 and 12 by identifying the sites and providing detailed geologic maps and reports based upon photographs and voice recordings of observations made by the astronauts. These reports are supporting the scientists who are studying the lunar samples. Among these scientists, also, are 12 members of the U.S. Geological Survey. In addition, special studies of crater formation and of the effects of meteorite impact upon rocks and minerals are contributing importantly to an understanding of the nature of the lunar materials and of the Moon itself.

In 1964, the U.S. Geological Survey accepted responsibility for leadership of NASA cooperative studies aimed at the evaluation of potentials in aeronautics and space technology for the support of geologic and hydrologic research. In 1965, the areas of effort were expanded to include cartographic, and geographic research. At the same time, the Department's Bureau of Commercial Fisheries assumed a supporting role in the investigation of potential applications to oceanographic and fisheries research.

The Department established the EROS program in order to most efficiently coordinate continuing Department efforts to improve the usefulness of aeronautical and space vehicles for advancing capabilities to explore, develop, and manage natural and human resources. These efforts apply to space vehicles carrying photographic and other types of sensors to employ the unique advantages of space vantage points to obtain—

(1) Comprehensive views of regional conditions such as mineralogic provinces, drainage basins, marine, mountain, and other remote environments;

(2) Uniform conditions of viewing angle, Sun angle, and data format for nationwide observations, thereby, simplifying understanding and use of data;

(3) Fixed scheduling through year-long missions enabling firm programing and the added value of identification of features by virtue of observation of predictable changes;

(4) Timely knowledge of changes of environmental conditions over the whole continent.

The efforts apply, similarly, to aeronautical vehicles also carrying photographic and other types of remote sensors which are employed for the special advantages they offer to—

(1) Obtain rapid coverage of large areas;

(2) Meet emergency needs for information as in the cases of flood, earthquake, coastal erosion resulting from storms;

(3) Provide adaptability to carry a wide variety of instruments and to interchange instruments rapidly according to needs;

(4) Obtain high resolution data for small selected areas.

The earth resources technology satellite (ERTS) project of NASA, instituted in 1969, is in response to definitions by the Department of the Interior and by the Department of Agriculture of potential usefulness and operations specifications for such a system.

In addition, the U.S. Geological Survey, through the EROS program, has submitted to NASA a proposal for a space flight experiment on the ATS–G satellite. It asks for the development of a high resolution, long lifetime (5 years) imaging system in high altitude, geostationary orbit to augment the ERTS and to provide especially for immediate observations of areas affected by flood, hurricance, earthquake and other large scale events.

A proposal is being readied, also, for a satellite-borne magnetometer to study deep crustal and subcrustal features of the earth. Such a system would be expected to "see through" the conditions measured from aeronautical platforms and provide data much more readily applicable to the study of deep-seated conditions.

The recommendation and request to the NASA for a first earth resources satellite was a corollary to the program's long-range mission to employ to the fullest extent possible airborne and spaceborne remote sensor data to the Department's traditional responsibilities to promote the exploration, development, and efficient management of national resources.

The EROS program will serve to coordinate the use of data from spaceborne and airborne systems with relevant data and knowledge gained by conventional methods of mapping, and of field and laboratory procedures.

Under it, studies cooperative with the NASA are now established for research of applicability of airborne and spaceborne systems to cartography; geography and human resources; geology; water resources; the ecology of wetlands and uplands game areas; the inventory, preservation, and management of national parks, oil leaks and slicks; mine areas restoration; outdoor recreation planning and management; air pollution from mining, processing, and utilization of minerals and fuels; land classification for resources inventory and reclamation planning and management; and the improvement of commercial fisheries.

These studies are being carried out in appropriate Interior bureaus and, in part, by contract research in colleges, universities, and specialized research and technology organizations; and are correlated with NASA cooperative research activities being conducted by the U.S. Department of Agriculture and the U.S. Naval Oceanographic Office.

In further fulfillment of its long-range mission, the EROS program has conducted studies to determine the needs for airborne and spaceborne data among all potential users in Federal, regional, and State agencies having responsibilities in resources research and management, in educational institutions and in private industry. Continuing efforts will be devoted to the design and development of a center for acquisition, duplication, reduction, and distribution of remote sensor data and basic information therefrom to serve the greatest possible number of applications and users of the data.

Especially significant progress is being made in the study areas now being pursued. Airborne cameras, magnetometers, scintillometers (radio-activity counters), radiowave, and infrared sensors are proving to have valuable applications to mineral exploration, engineering, planning, and to other geologic research.

Results of a preliminary study of the usefulness of aerial photographic and radar data for analyzing the geological structure systems of an oil producing area indicate a potential for revealing surface expressions of subsurface conditions conducive to production stimulation techniques such as induced formation fracturing.

Valuable use of airborne thermal infrared sensors has been made in the delineation of underground mine fires, centers of fire in culm banks, of submarine springs of fresh water, and of hot spots on the surface resulting from hydrothermal and other volcanic activity.

A very significant geologic remote sensing first was established when airbone thermal infrared sensor data was combined with Nimbus satellite infrared data to study the total heat flow resultant from eruption at the Surtsey Volcano, Iceland. Another very important development has been that of the Fraunhofer line discriminator, an instrument that measures remotely (without contact) concentrations of dye used in stream flow and current dispersion studies. The instrument has been tested successfully on the ground, shipborne and helicopterborne. Future studies will be designed to test its operability in fixed-wing aircraft. Other modifications will be made with the aim of adapting the instrument to the detection and measurement of air and water polluting substances, and oil slicks indicative of the presence of fish schools.

Soil type and vegetation type maps from space photography taken by the Gemini 4 and 5 and Apollo 6 missions have been prepared. Information obtained in the color photographs and the broad regional coverage of the space photography coupled with the knowledge of one scientist enabled the mapping of soil types and vegetation associations over an area more than 80,000 square miles of the southwestern United States.

Radar maps of the State of Massachusetts have been prepared with the cooperation of the Department of Defense, a private contractor and the NASA; the U.S. Geological Survey prepared radar mosaics of the entire State. Work is underway toward utilization of this new type of map to develop a better understanding of the geology of the State. Radar instrumentation makes it possible to obtain representations of land surfaces at high speed, in darkness and through atmospheric conditions that prevent conventional photography. The system itself generates the energy used to obtain the records, therefore providing a uniformity of data not possible with conventional photography.

In 1969, Interior participated in the first national symposium dedicated to potential applications of balloon flight technology to earth resources applications. It has also cooperated, through its EROS program, with the NASA Langley Research Center in the conduct of two very high altitude balloon-borne experiments over part of the Delmarva Peninsula and adjacent Atlantic and Chesapeake Bay areas and one flight over New Mexico and Texas. Data from these flights are now being studied to determine the special advantages of balloon flight such as very high altitude, vibrationless platforms and long dwell times, as well as the scientific value of the data.

Effort has been devoted to extend information and the potential values of systems and applications developed, through participation in national and international professional meetings and symposia, addresses to educational and public service groups, briefings to individual educators, and students, to privately and publicly employed explorationists, planners, and managers, and to official delegations from foreign countries and the United States.

In addition, special attention has been given to the nations of Brazil, Mexico, and Iceland. The EROS program, in cooperation with the NASA, has aided in the conduct of training programs in remote sensing in the United States and experimental programs in Brazil and Mexico. With the Air Force Cambridge Research Laboratory and Icelandic scientists, the Geological Survey conducts a continuing study project in applications of photographic and thermal infrared sensors to hydrothermal and volcanic research in Iceland.

A total of more than 100 speeches and more than 50 published papers were presented by the EROS program in 1969. These presentations were made in nine foreign countries: Argentina, Australia, Austria, Brazil, Canada, Colombia, India, Mexico, and Venezuela; and in 46 cities in 28 of the United States. Visitors briefed in program offices have been from Australia, Brazil, Canada, Chile, Colombia, France, Germany, India, South Africa, Japan, and Mexico.

In the conduct of its EROS program efforts, the Department works closely with the NASA and its several centers and its non-Federal coöperating institutions, with the Department of Agriculture, the National Environmental Satellite Center, the Naval Oceanographic Office, the Office of Naval Research, the Office of Emergency Preparedness, the Department of Transportation, the Department of Housing and Urban Development, the Tennessee Valley Authority, the Delaware River Basin Commission, the New York Port Authority, the Tristate Transportation Commission, the Asheville and Buncombe Counties, N.C. Planning Commission, the Department of Natural Resources of the State of Washington, the Metropolitan Washington Council of Governments, the Desert Research Institute, the Air Force Cambridge Research Laboratories, and other interested Federal, State, and local bodies concerned with resources research, development, and management problems.

X Department of Agriculture

Introduction

During 1969, the U.S. Department of Agriculture (USDA) continued its research efforts in the development and evaluation of remote sensing technology and techniques for the improvement of agricultural and forestry programs. USDA is constantly concerned with improving any and all of its agricultural activities dealing with crops, forests, soil surveys, watershed management, range and wildlife management, and land use classification and management. Research in the laboratory and the field is absolutely essential in learning those physical and biological parameters that affect agricultural production. In addition to and concomitant with laboratory and field research, scientific developments based upon airborne remote sensing techniques have opened up almost unlimited horizons for the collection of earth resource data.

These techniques have accelerated the ability to collect and analyze information concerning agricultural, range, and forestry resources. One of the most enlightening and promising concepts that has emerged to strengthen remote sensing technology is that of multispectral sensing. In brief, it involves simultaneous utilization of two or more discrete portions of the electromagnetic spectrum to identify a material or condition. Airborne remote sensing equipment, such as multispectral sensors, infrared scanners, and imaging radar devices, has suddenly provided a new array of techniques for learning more about the earth's resources, and for doing it much more rapidly than has heretofore been possible.

Recent research conducted jointly by USDA and NASA has amply demonstrated that modern aircraft, properly sensor equipped, can definitely improve the activities of many USDA programs. Furthermore, a number of recently conducted experiments with remote sensing devices at suborbital altitudes indicate the eventual possibility of acquiring information on the use, productivity, and potentials of agricultural and related resources from space platforms. These experiments also indicate, however, that considerable development in the state of the arts of sensing, imagery interpretation, and data management will have to precede the acquisition and utilization of data from space. Nevertheless, the potential now exists for increasing the frequency and geographic comprehensiveness of resource data at relatively low cost with modern sensors and high altitude aircraft and satellites for both the United States and the world.

Research Results

The results of research to date lead to the following summarization of projected new capabilities resulting from the application of airborne remote sensing to agriculture and forestry:

Data gathered in the ultraviolet, visible, infrared, and microwave regions of the electromagnetic spectrum which measure the reflectance, emittance, dielectric constant, surface geometry, and equivalent blackbody temperature of plants, soil, and water will, when correlated with existing knowledge of agricultural and forestry practices and a minimum of ground sampling, permit—

(1) Identification and area measurements of the major agricultural crop types;

(2) Identification and mapping of pathogenic and insect invasion;

(3) Identification and mapping of gross categories of forest types;

(4) Identification and mapping of major soil boundaries and soil organic matter content;

(5) Identification of salinity and moisture stress in plants;

(6) Mapping of soil and water temperatures; and

(7) Mapping of surface water, including snowpack.

The research results also indicate the possibility that further development of the methods may produce a capability to—

(1) Determine and measure soil moisture content;

(2) Map silt producing and other water pollution sources;

(3) Assess crop vigor, and the causal agent where plant vigor is lacking;

(4) Previsually detect and make determinations of the extent and severity of incipient crop and forest pathogenic and insect epidemics;

(5) Identify forest and range species and make detailed inventories of their composition and density;

(6) Predict and map areas of high potential forest fire hazard; and

(7) Delineate and measure critical indicators of forest and rangeland productivity as a function of energy budget.

Earth Resources Survey Program

In cooperation with NASA and several universities, USDA continued to investigate the possible use of space-acquired data in surveying conterminous U.S. agricultural and forestry resources. The Apollo 9 Earth-orbital mission of March 1969 carried onboard a multispectral photographic system consisting of color infrared and black and white film, with appropriate filters, in four satellite-mounted cameras.

This special experiment, designated SO–65 by NASA, uniquely provided USDA with a substantive opportunity to evaluate the feasibility of monitoring U.S. agricultural resources from space. It immediately became an invaluable exercise in the overall reassessment and further confirmation of the value of utilizing Earth orbiting satellites as a distinctly advantageous means of acquiring resource data.

The results of this singular experiment further prompted USDA to request NASA to make follow-on sequential, monthly, high altitude aircraft overflights of the same orbital ground test sites, and with similar multispectral photography. These flights provide for the continuous monitoring, perhaps for the first time in history, of crops, forests, and rangeland through an entire year. The accumulated data is continuing to provide invaluable information.

Earth Resources Technology Satellite

In 1969, in full cooperation with other interested Federal agencies, USDA assisted NASA in determining the primary goals and orbital and payload requirements for a projected experimental Earth resources technology satellite (ERTS) flight scheduled for early 1972. This 496 nautical mile, Sun synchronous, high Sun angle, Earth-orbiting vehicle will have a longevity of approximately 1 year; with the capability of repeating its exact orbit every 18 days over a particular U.S. ground site and providing 20 such repeats during the year. Multispectral television cameras and a multipoint scanner will provide incalculably useful data.

The potential of surveying the agricultural scene by such a method is envisaged as a means of singularly improving agricultural and forestry programs. It would permit the very rapid accumulation, analysis, and application of information on crops, forests, soils, and water conditions.

Continuing research and development on remote sensing technology and techniques will eventually assure the practicability of fully operational earth resources satellite systems on a worldwide basis.

Aircraft Utilization

USDA was a pioneer in recognizing the merits of aerial surveys for obtaining real-time data vital to its needs and operations. Consequently, it has maintained aircraft utilization programs since the early 1930's. The continuous acquisition and use of aerial photographs by various inhouse agencies has greatly enhanced the administration of farm programs in general. Concomitantly, this approach is also used for other purposes; e.g., crop-area measurements, irrigation and flood prevention studies, soil and forest conservation work, timber estimation studies, and soil surveying to name but a few. In addition to satisfying its own prerequisites (and servicing over 3,000 county offices), a large volume of photoprints (approximately 1 million annually) are distributed to other Federal agencies and to the general public as well.

To fulfill its increasing requirements, USDA owns approximately 74 fixed-wing aircraft and helicopters. Depending upon its needs, USDA leases and/or rents annually, under a variety of contracts, some 1,000 to 1,400 aircraft of various types.

Some other important utilizations of USDA aircraft, in addition to photographic missions, are in pest control research, fire control and fire research investigations, and in the developing remote sensing program. In earlier years the increasing needs for agricultural data prompted the Department to investigate the possible use of air photos to save time, effort, and money. Today the successful application of airphoto interpretation in agriculture and agricultural development planning has well demonstrated both its feasibility and its utility. However, the constant demand to provide still more precise data to fill the ever-present needs for up-to-date information cannot be fulfilled by aerial photography alone. For the effective conduct of its remote sensing program, USDA will require properly multi-instrumented aircraft in the immediate future.

XI Department of Commerce

Introduction

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

Environmental Science Services Administration

ESSA 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 aeronautics and 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 1969—During this year only one launch—that of the environmental survey satellite, ESSA 9—was required to maintain the operational weather satellite system initially established in February 1966. ESSA 2, the first automatic picture transmission satellite of the system, was still capable of furnishing useful cloud photography by the end of 1969, after more than 3½ years in orbit.

The satellite infrared spectrometer (SIRS), carried on Nimbus III, launched April 14, 1969, by the NASA, was successful in measuring atmospheric temperatures from the spacecraft down to the Earth's surface, providing highly significant temperature profile data. This successful flight test of the SIRS instrument is the culmination of 10 years of research and development from concept to realization. Data from this instrument are used operationally in the numerical (computer) analysis programs and have resulted in forecast improvements.

The Environmental Data Service of ESSA, and NASA's Aeronomy and Meteorology Division have cooperated on the compilation of monthly cloud climatology charts over the Pacific using satellite cloud photography.

These charts, now completed for August 1962 through April 1969, are the first such compilation based on adequate data.

The spin scan cloud camera pictures from NASA's geo-synchronous (stationary) applications technology satellites (ATS) have furnished the basis for many operational experiments. Time-lapse films, made from pictures taken at 15- or 30-minute intervals, were used in near real time as an aid to forecasting the development and movement of active hurricanes. Wind information over the Pacific basin is derived from daily film loops of ATS–I pictures, and is used as input to the numerical analysis programs of the National Meteorological Center. ATS photographs were also used in support of the Barbadoes Oceanographic and Meteorological Experiment (Bomex) and the Apollo space flights.

ESSA engaged in an extensive data gathering effort during November 1969 in support of the global atmospheric research program (GARP). The United States, through ESSA, played a major role in this international observation program. The data gathered will be archived for future research, and will be used in computer experiments that simulate the behavior of the atmosphere. Another similar global data collection period is scheduled for June 1970.

Satellite data gathering and transmission capabilities have now become a routine part of Weather Bureau operations. The data are incorporated in the observation and analysis procedures of the Bureau, and the data-relay capabilities of the applications technology satellites are being used routinely to speed up both data collection and product dissemination.

During 1969, solar proton flux data obtained by ATS–I were used operationally for the first time by the Space Disturbances Forecast Center. The forecasts were used to support manned spaceflight during 1969.

NBS worked on the design of the laser reflector left on the Moon by Apollo 11 astronauts. Measurements of reflected light from laser pulses will help determine precisely both lunar and Earth orbital and physical characteristics.

NBS designed a special mass spectrometer for use by NASA in analyzing lunar material. NBS is also analyzing lunar samples by other techniques. Standard reference materials were prepared for calibrating mass spectrometry work between laboratories engaged in the lunar sample program.

Meteorological Satellites—ESSA 9 was the only satellite that had to be launched during 1969 to maintain the national operational meteorological satellite system (NOMSS). The satellites of this system furnished, for the third consecutive year, daily worldwide pictorial coverage of the Earth and its cloud systems, except in areas of polar night.

The ESSA satellite series 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. This feature will be available to the system when Tiros M, the R&D prototype of the operational improved Tiros operational satellite (ITOS) is launched by NASA in early 1970.

Operations of the ESSA Satellites—The ESSA satellites, now scheduled for replacement by the Tiros M/ITOS series, were the primary operational satellites during 1969. Two types of spacecraft are used; each is equipped with two cameras for redundancy, and each orbiting the Earth in about 114 minutes at an average altitude of 790 nautical miles.

One type of ESSA spacecraft (identified by the odd numbers in the series) is equipped with the advanced vidicon camera system (AVCS). This type takes pictures over the entire sunlit portions of the Earth and stores them for later transmission to a ground station. These stored pictures, which provide nearly global cloud coverage of the Earth, are transmitted to ground stations in Alaska and Virginia, relayed to a central processing unit at Suitland, Md., processed and made available to the U.S. and international meteorological community.

The other type of ESSA satellite (even numbers) is equipped with two automatic picture transmission (APT) cameras which 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. These pictures furnish local forecasters with a fresh (3½ minutes old) view of the cloud patterns over or adjacent to the local area.

The APT pictures have gained wide acceptance both by U.S. and foreign meteorologists. Some 500 receivers are located in over 50 countries around the world. The pictures are used as the basis for local and area forecasts, route forecasts for aircraft flying domestic and overseas routes, television weather programs, newspaper weather reporting, and, in several cases, were used for routing resupply ships through the Antarctic ice pack.

Applications Technology Satellites—The two satellites in this series (ATS–I and ATS–III, launched by NASA on December 6, 1966, and November 5, 1967, respectively) continued to furnish extremely valuable data for research and for operational experiments throughout 1969. The long, useful lifetime of the spin scan cloud cameras, and of the transmitters on these satellites, has demonstrated the potential of geostationary satellites for routine, operational observation of the environment. The operational version of these stationary satellites will be the geostationary operational environmental satellite (GOES) now being developed under NASA's stationary meteorological satellite (SMS) program. The first SMS launch is planned for the middle of 1972.

Nimbus III—This research and development satellite, launched on April 14, 1969, NASA, carried two instruments designed to obtain vertical temperature profiles of the atmosphere. The SIRS, which had been under development for 10 years, performed spectacularly well, providing temperature soundings within hours after the launch. Other instrumentation on Nimbus III is described elsewhere by NASA. The SIRS results are described below.

The Satellite Infrared Spectrometer—The SIRS instrument, undergoing operational testing aboard Nimbus III, is capable of measuring infrared radiation from various levels in the atmosphere. These measurements are converted, by mathematical processing, to vertical temperature profiles (soundings) of the atmosphere. Seven measurement channels provide data for the sounding; the eighth channel provides measurements of the temperature of the tops of clouds, or, in cloud free areas, the temperature at the surface of the Earth.

Since the first measurements were obtained on April 14, 1969, a steady stream of measurements, equivalent to some 8,000 to 10,000 atmospheric soundings over the globe, have been received every 24 hours. For practical considerations, only 400 soundings are computed daily for operational use in the Northern Hemisphere numerical weather analysis; additional soundings over the Southern Hemisphere are computed for later use in research programs. The Northern Hemisphere soundings derived from SIRS radiance measurements have been used operationally since June in the Weather Bureau's numerical upper air analyses for 1200 GMT, daily. Experimental comparison forecasts starting with 500 mb analyses without, and with, SIRS data have shown that addition of SIRS data has, at least in the cases studied, resulted in significant improvement in forecasting some major features of the midtropospheric flow.

Meso-Scale Computer Products—For several years satellite cloud pictures have been processed routinely by computer for operational use. The picture signals are digitized, rectified, and combined into mosaics for regular transmission by facsimile to U.S. weather stations. The mosaics are also transmitted experimentally, but rather routinely, to Europe, Asia, Australia, the Pacific Ocean area, and North and South America by means of transmitters on ATS–I and ATS–III. During the past year additional computerized products have been developed. These include averaged brightness charts which represent the average cloudiness over an area for the time period involved. Five-day, 10-day, 30-day, and 90-day (seasonal) averages have been produced; hopefully these will become the basis for up-to-date global cloud climatology charts. Charts of minimum brightness for 5-day periods show the extent of snow and ice fields, except in areas where clouds have persisted for the entire period. Charts comparing successive 5-day brightness charts show areas where new snow has fallen or older snow has melted.

All of the computer produced charts are stored on microfilm and listed in catalogs of cloud photography to make them available to research scientists.

Operational Applications of Satellite Data—The operational satellite system has furnished cloud data routinely and reliably since February 1966. Daily operational usage of satellite data is widespread both in the United States and abroad. Worldwide cloud mosaics are produced centrally in the United States and transmitted to many locations around the world.

Meteorologists found the satellite photographs particularly useful for discovering and tracking weather systems over approximately 80 percent of the Earth where ground-based observations are not available. The discovery and tracking of hurricanes and typhoons from their inception to final breakup is the most spectacular use of this capability. In 1969, a total of 39 tropical cyclones, including 12 Atlantic hurricanes, 10 eastern North Pacific tropical storms or hurricanes, and 17 western North Pacific typhoons, were spotted and tracked with satellite pictures. Advisories on these storms were sent to U.S. installations and foreign meteorological services worldwide. Storm tracking in the middle and high latitudes is used to provide improved advisory service particularly to coastal areas, to aviation, and to ocean shipping interests.

Winds in the 30,000- to 40,000-foot levels as estimated from ESSA photographs are used routinely in computer analyses, and are transmitted daily to users worldwide. These estimates provide wind 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—The research programs of the National Environmental Satellite Center (NESC) are, in general, long-term projects. Research includes two general areas: Studies designed to extract the maximum possible amount of data from satellite observations, and studies to determine the kinds of observations possible from satellites. In the first area the studies lead to an increased understanding of atmospheric processes, and to the development of methods for using satellite data in daily operations to improve analyses and forecasting of weather and other enviornmental features. The second area of study leads to the conceptualization and development of new instrumentation for measuring enviornmental data from a satellite platform. The following research and development programs carried on by NESC during 1969 are particularly interesting:

(*a*) Instruments to obtain measurements of the vertical structure of the atmosphere are under active design. The first SIRS was successfully flown on Nimbus III; an improved version, designed to measure mositure as well as temperature, is being readied for flight on Nimbus D, in 1970. Another instrument derived from the SIRS concept is being developed for flight testing on Nimbus E. This is the Infrared temperature profile radiometer, which will have spatial scan capability to improve operation over areas partly obscured by clouds.

(*b*) Procedures for making time-lapse motion picture film from ATS–I and ATS–III photographs have been greatly refined in the past year. It is now possible to study the conditions in a hurricane within an hour or two after the pictures are taken, and to use the information for making forecast decisions on the motion and intensity of the storm. The ATS picture films are also used daily to estimate high and middle level winds over the entire Pacific basin. The wind estimates are used as data input to the objective analysis programs processed by high speed computers. Efforts also continue toward devising automated methods for wind extraction to replace the time consuming manual techniques currently in use.

(*c*) The availability of the SIRS-derived vertical temperature profiles has engendered active and continuous development of improved mathematical methods for processing the raw data, and for making use of the processed data in analysis programs. The NESC and the National Meteorological Center are jointly developing the equations and the computer processing programs required to integrate the processed data into the mathematical (numerical) analysis models.

371-775 O - 70 - 5

(*d*) Cloud pictures are being used in the development of an objective method for deriving constant pressure heights to be used in numerical models of the atmosphere. The presence or absence of clouds indicates vertical motion; this in turn indicates vorticity, or the rate at which the air is spinning with respect to the Earth. The vorticity values are the basis for modifications to the previous 12-hour forecast map contours to arrive at a corrected current analysis. The current procedure, still under development, is primarily manual, but work is progressing toward a fully automated technique. Developments of this kind hopefully will result in greatly improved analyses over ocean, and other sparse data areas, and hence to improved forecasts.

(*e*) Studies have been initiated to conduct 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 are being mapped; the information will be used in meteorological and oceanographic investigations.

International Cooperation—During 1969, the continued worldwide availability of automatic picture transmission (APT) pictures and the experimental semioperational transmission of satellite data through the weather facsimile experiment (WEFAX) on the ATS satellites helped to maintain the image of the United States as an unstinting sharer of scientific results in space programs. At the end of 1969, 53 foreign countries had APT stations receiving direct transmissions from ESSA, and Nimbus satellites, and processed data transmitted through the WEFAX system on ATS satellites. The NESC also participated in the global atmospheric research program data month (November 1969) by furnishing winds extracted from ATS–I photographs of the Pacific Ocean area. The NESC provided training and study facilities for WMO, NATO, and AID fellows from Chile, France, Indonesia, and Japan, and briefings for many other foreign scientists during 1969.

Washington-Moscow Data Exchange—In accordance with 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 1969. The U.S.S.R. furnished data from their Meteor I, launched in 1969. The United States furnished satellite photographs and nephanalyses (cloud maps) based on ESSA 8 and 9 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, useful primarily for research purposes.

Coast and Geodetic Survey Operations

The Coast and Geodetic Survey (C&GS) continues to make significant and steady progress in the use of aeronautics and space technology in support of the the aeronautical and space programs of the United States. The basic programs of the C&GS in this area include the operational use of satellites for geodesy and precise navigation, and research to determine the feasibility for using satellite techniques in performing assigned tasks and the use of aircraft for operational photography. In addition, the Survey provides support to space facilities and activities through its seismic and geomagnetic functions.

Geometric Satellite Triangulation—Work continued during 1969 on the worldwide geodetic network known as the national geodetic satellite program (NGSP). The network is being established through the joint efforts of NASA and the Departments of Defense and Commerce, in cooperation with other nations on whose territories camera stations of the network are located. In addition to the countries cooperating in the observational program, several others are assisting in scaling the network by measuring highly accurate geodimeter traverses between their borders.

Of the present 14 BC–4 camera systems owned by the United States, four are operated by the Army Topographic Command (Topocom), seven by the C&GS, and one each by the United Kingdom, South Africa, and Australia. Two BC–4 camera systems are owned and operated by West Germany. In addition, two U.S. Air Force teams equipped with PC–1000 cameras joined the program in May and August of 1969 to assist in meeting the proposed June 1970 completion date for the survey. A C&GS employee is attached to each team except those operated by Topocom. The C&GS has the overall technical responsibility for the program, including maintenance of all BC–4 camera systems and furnishing time correct to a 50-microsecond accuracy.

The combined systems were manned and operated at 23 stations around the world: eight by the C&GS; four by Topocom; two by the USAF; two by West Germany; one by the United Kingdom; one by Australia; one by South Africa; and five by the combined efforts of Topocom, C&GS, and other nations. At present, 42 of the 44 stations in the world net have made observations. The Pageos satellite was used for all but two of the successful simultaneous photographic observations from two or more stations. Echo II was the target for the other two simultaneous observations. (On June 7, 1969, the Echo II satellite entered the Earth's atmosphere and decayed.)

Field evaluation of all observations shows 1,139 successful single plates, of which 274 were simultaneous observations (252 two-station observations, 21 three-station observations, and one four-station observation). Photogrammetric processing during 1969 included 353 plates measured and 360 processed through analysis and computation. Thus far in the program, a total of 1,365 plates have been measured and processed through analysis and computation.

The preliminary results obtained at 35 stations of the world net are consistent in accuracy with previous results. A complete new generation of reduction programs has been computed. These new programs were required to make use of the refinements both in theoretical analytical modelling, and in field data acquisition and reduction techniques. The three-dimensional positions of the world net stations will have a final accuracy of at least one part in one million in terms of Earth dimensions.

The project in which a surface density layer is substituted for spherical harmonics in the gravitational interpretation of orbital tracking data has, on a pilot model, produced a stable solution. This indicates a promising approach for relating satellite data to surface gravity measurements and for determining the position of the center of mass of the Earth in connection with the results for the world geodetic network. In addition, a proposal for determining the high frequency variations of the geoid using satellite-altimetry has been forwarded to NASA in connection with the Geos C satellite launch.

Time Transfer in Support of Geodetic Measurements—With the movement of the ATS satellites to the Pacific Ocean area, the use of the ATS method of time transfer has been limited to Pitcairn and Pago Pago. An alternate system utilizing the Navy navigation satellites has proved very satisfactory. It is now in use at the Palmer, McMurdo, Mawson, and Wilkes Stations in Antarctica as well as at Heard Island in the South Indian Ocean; accuracies of better than ± 50 microseconds are being achieved.

Loran C continues to provide accurate timing at other stations in the Pacific and Indian Ocean areas, where the loran C coverage is adequate.

Earth Resources Program—During 1969, the C&GS directed its efforts in the Earth resources program to assist NASA in the implementation of an R&D flight program leading to potential cartographic-geodetic satellites. It is anticipated that these satellites would have application for mapping and would generally support the Earth resources technology satellite (ERTS) program interests of the Department of the Interior.

Further work has been accomplished in preparing to test a NASA procured laser-altimeter for its possible application in the Earth resources program.

Seismological Activities—The C&GS provides a seismic vibrations measurement program and consultant services for the AEC's Nuclear Rocket Development Station at Jackass Flats, Nev. The effects of ground motions caused by nuclear detonations upon the rocket test structures are analyzed to provide information for the development of safety criteria. Plans have been completed to monitor ambient vibration at locations proposed for the laser communications experiment in Goldstone, Calif. The vibration project will locate the optimum site for the laser transmitter-receiver facility.

Tsunami Warning System Development—Plans are being developed for an automated tsunami warning system. Telemetry of data from an expanded network of 30 seismic and 120 tide stations throughout the Pacific will be via communications relay through the proposed GOES. In addition to the transmission of seismograms and marigrams in digital form to Honolulu Observatory, tsunami watch and warning information will be broadcast via a voice channel to all areas of the Pacific.

Geomagnetism—The C&GS continued to support NASA in the development of geophysical instrumentation for space applications. The facilities of a controlled magnetic environment test chamber at the Fredericksburg Geomagnetic Center were made available for testing and instrument calibration. This cooperative work has continued since the initiation of geophysical experiments in the space program. The C&GS also provided facilities and technical assistance to the U.S. Naval Oceanographic Office in the testing and calibration of instrumentation employed on Project Magnet, a worldwide aerial geomagnetic survey program.

In a joint effort with NASA, analog records of geomagnetic data from some 40 worldwide magnetic observatories were processed, digitized, and prepared for use in correlation studies of geomagnetic data collected by satellite and space probes. These cooperative efforts have been in progress for the past 6 years.

C&GS personnel assisted the World Magnetic Survey Board of the International Union of Geodesy and Geophysics (IUGG) in conducting a symposium on "Description of the Earth's Magnetic Field" in Washington, D.C., in October 1968. At this international meeting, C&GS scientists participated with some 100 scientists from 20 countries in the discussion and final adoption of an International Geomagnetic Reference Field (IGRF). This analytically described field will serve as a common international base for calculation of main field values at points near and above the Earth's surface. An internationally accepted IGRF has been an urgent requirement of the world scientific community for many years, particularly since the advent of the space age.

Compilation of the 1970 issue of the World Magnetic Charts was in progress throughout the year. For the first time it was possible to use analytical methods for describing secular change patterns as well as distribution of the field. Among many important uses, these charts serve as the base for magnetic navigational data for worldwide nautical and aeronautical charts.

Use of Navigation Satellites—The Navy satellite navigation system, operating aboard one C&GS ocean survey vessel, continues to provide the required accuracy of position-fixing necessary for deep sea surveys. This technique will be used on other C&GS ocean survey vessels as comparable equipment on order is delivered.

Satellite Telemetry Experiments—The C&GS is involved in two experiments combining the environmental and space sciences.

The first experiment involves the use of a free-drifting buoy equipped with a NASA-supplied telemetry package, the omega position location equipment (OPLE). Oceanographic data, meteorological data and the geographic position of the buoy are telemetered in real time via the ATS–III satellite. The purpose of this experiment is to examine the feasibility of gathering data via satellite from a free-drifting ocean platform and determine the reliability of communications for various sea conditions. The system was successfully exercised during a 2-day period of drifting in the Gulf Stream off the Florida east coast. A long-term (20 to 25 days) operational test is tentatively planned for the latter half of 1970.

The second experiment is being performed in cooperation with NASA and the Navy. This involves the telemetry, via the ATS–III satellite, of real-time environmental and equipment status data, from instruments located on and suspended from a submerged stable moored buoy platform. The platform with its associated sensors, electronic equipment and Navy supplied radioisotope thermoelectric generator is scheduled for installation off the east coast of Florida in mid-1970. One of the many uses projected for the system is as a detection unit in the tsunami warning network in the Pacific.

Aerial Photography—The Coast and Geodetic Survey operates two air photo missions in connection with ESSA programs. One mission uses a Government-owned, twin-turboprop; the other, a leased, twin-engine aircraft. Officers in ESSA's commissioned corps, trained by the U.S. Army Flight School, command the missions. Air photo mission operations normally begin in March and continue into November. During the winter lay-up, major maintenance and modifications are made.

Coast and Geodetic Survey aerial photography is used in connection with nautical and aeronautical charting programs. Coverage includes U.S. coastal areas and most civil airfields. Other photogrammetric applications are surveys of earthquake damage, measurement of ocean currents, and monitoring slow earth movement along major faults.

The Environmental Data Service

The Environmental Data Service (EDS), a major subunit of ESSA, archives satellite data after they have been used operationally. Both raw and processed data are stored at 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 microfilm, photographic, or magnetic tape form. Data catalogs are published to provide customers a means to identify the particular items desired.

The EDS Laboratory for Environmental Data Research is investigating the uses of meteorological satellite data for climatological analysis. In the area of cloud climatology, the Environmental Data Service is cooperating with NASA's Goddard Space Flight Center to compute the mean monthly cloud cover in the Pacific Ocean for selected months. Monthly climatologists covering August 1962 to April 1969 have been completed. This laboratory is also investigating large-scale atmospheric circulation through the use of satellite cloud photographs. Periodic changes in total cloud amount in the Pacific Ocean have been shown to be related to large scale changes in the atmospheric-ocean interaction. In addition, the preliminary results in the study of these periodicies permit the inference that changes the stratosphere can be linked to tropospheric changes caused by variations in Earth albedo.

Weather Bureau Operations

Weather Bureau participation in the space program is twofold. The Bureau is involved in experimental determination of the usefulness of space technologies for its data gathering and dissemination systems and the usefulness of space-acquired data for its analysis and forecasting operations. During the past year the Bureau has greatly expanded its operational use of space technology both by the incorporation of satellite data in its observation and analysis procedures and by its use of the data relay capabilities of NASA's applications technology satellites. The other facet of involvement is the Bureau's function in supplying meteorological guidance or support to space test facilities and space operations.

Experimental Collection and Relay of Data by Satellites—The ATS–I satellite has been used experimentally since 1967 to collect hydrological data (river stage and rainfall measurements) from automatic stations, and to relay the data to a central analysis point. The experience gained from these tests provides a sound basis for the design of a system for use with the proposed GOES system.

An operating system of this kind will be useful for the preparation of flood forecasts, the timely dissemination of warnings, and in the solution of many water management problems. The ATS–III transponder also was used in the test of an inexpensive shipboard data transmitter in connection with the design of a system for the rapid collection of weather data from ships at sea.

ATS Cloud Pictures—Cloud pictures are collected routinely from the ATS satellites by ESSA's Wallops Station Command and Data Acquisition (CDA) Facility, and are processed for retransmission by the ATS transponders. Retransmitted pictures are received at local Weather Bureau (APT) grounds stations at Honolulu and San Francisco, where the pictures are used in the daily operations of the forecast offices.

Sequences of pictures taken by the ATS–III spin scan cloud camera were used in studies of destructive hurricanes that reached the U.S. mainland in 1969. Near the end of the hurricane season in September and October of 1969, techniques had been developed to make use of these pictures for operational analysis and forecasting during the progress of the storm.

The ATS cloud pictures also were used in the preparation of operational forecasts for the Apollo 10, 11, and 12 missions.

Sensor Study—The initial phase of the electromagnetic correlation study, involving the use of microwave and infrared sectors of the spectrum, has been completed. The purpose of the study is to ascertain normal radiances (common signatures) of environmental factors relevant to hydrological problems.

Digitized Cloud Mosaics—Digitized mosaics of satellite cloud pictures are now being transmitted operationally from the National Meteorological Center to Weather Bureau forecast offices throughout the United States. The mosaics are an integral part of the guidance material that is transmitted routinely to forecast offices.

Automatic Picture Transmission—Early in 1968 the Weather Bureau began the transmission of raw APT signals on an existing central facsimile network. The APT data acquired at Wallops Station, Va., San Francisco, Calif., and Kunia, Hawaii, are transmitted to stations on the network within minutes after receipt from the satellite. This operational network has been expanded to include a large number of Air Force and Navy installations in the conterminous United States. The number of APT stations needed for Government weather stations has decreased materially as a result of this network operation.

Under the voluntary assistance program the Weather Bureau has provided technical assistance and advice for installation of complete APT systems in five underdeveloped countries.

Experiment With Nimbus III—The remotely sensed radiometric measurements obtained from SIRS aboard this spacecraft are being evaluated quasi-operationally to determine their usefulness and validity. The information is being incorporated through special computer programs into computer-produced forecasts. Early results have shown considerable promise. Availability of these data globally in real time could conceivably lead not only to improvement in the computer forecasts but also to economic savings from reprograming of the current ground-based upper-air observation network.

Meteorological Support—Through its Space Operations Support Division, the Weather Bureau again furnished the primary meteorological guidance for several NASA activities. For the manned spaceflight program, Weather Bureau items provided the staff and local forecasting support for the Kennedy Space Center and the Manned Spacecraft Center, and the forecasts of weather and sea conditions for the four Apollo flights in 1969.

In the case of Apollo 9, in March, much of the effort was in support of Earth-oriented photographic experiments, some requiring relatively clear skies and others involving photography of selected cloud systems. A particularly significant operational forecast was that which led to a 200 mile shift in the landing point of the Apollo 11 spacecraft to avoid an area in which thunderstorms were expected (and later observed).

At the NASA Mississippi Test Facility a Weather Bureau team made weather observations and forecasts for ground tests of large rocket engines. Meteorological advice was provided to assist the testing agency in choosing periods to minimize excessive noise levels in nearby communities.

The Weather Bureau group at NASA's Wallops Station facilities provided extensive observation and forecast support for the varied space probe activities of the installation.

Utilization of Aircraft—Rental and privately owned aircraft are used in the Weather Bureau aviation weather services quality control program. Meteorologist/pilot personnel on the quality control staffs at the Weather Bureau headquarters, regional headquarters and area offices fly light aircraft (single or twin engine) in connection with the quality control duties.

These flight operations provide a very valuable tool for the quality control program by permitting in-flight monitoring and evaluation of the aviation weather services. The use of aircraft also provides an effective means of travel for station visitations and on station services evaluations.

In addition, aviation forecasters take familiarization trips as passengers in airline and other aircraft to become better acquainted with their areas of forecast responsibility and the use made of Weather Bureau services.

Services to Aviation—Specialized weather information is provided to pilots, controllers, and aircraft operators in order to promote efficiency in aviation activities. This information is in the form of observations, forecasts, warnings, and pilot briefings.

Observations are made at 908 locations, many of which are taken by other government agencies, airlines, and airport personnel. Terminal forecasts are made for 425 airports, generally every 6 hours. Area forecasts and in-flight advisories are also provided. Forecasts for international aviation covering most of the Northern Hemisphere and part of the Southern Hemisphere are also provided in facsimile and digital forms, the latter being used extensively in computer flight planning by the airlines.

Pilot weather briefings are available through 248 Weather Bureau offices, plus 334 FAA offices and 159 unmanned FAA facilities. About 2 million briefings are provided annually by the Weather Bureau and about 13 million by the FAA.

ESSA Research Laboratories

The ESSA Research Laboratories (ERL) conduct research in oceanography, geomagnetism, Earth sciences, and physics of the troposphere, ionosphere, and magnetosphere. The main offices in Boulder, Colo., and the field laboratories also provide services in support of the many ESSA mission requirements. Programs include studies of tropospheric and ionospheric radio propagation, optical wave propagation, solar radiation-magnetosphere interactions, and the monitoring and forecasting of solar activity and its effects on the Earth environment.

The Office of Programs, under the Office of the Director, ERL, has established a Consulting Service to provide quick response on NASA problems. Under this contractual arrangement, an ad hoc team of ERL experts are assembled on short notice to provide advice to NASA on problems connected with the scientific evaluation of proposals and plans. An ERL Task Group was formed to deal with such a problem in connection with the proposed NASA Sunblazer program. In this program a spacecraft would be placed in an orbit around the sun to study properties of the solar corona, such as its spatial and temporal variations, electron densities, etc. The ERL Task Group assembled available information for determining the theoretical model of the corona best suited for use in this experimental program.

Perturbations in the Earth's magnetic field are among the significant effects produced by solar disturbances. Magnetic studies using the ATS–I have so improved understanding of these phenomena that they can be utilized for monitoring space disturbance. To develop further the operational use of such phenomena, the Earth Sciences Laboratory has participated in the conceptual design of a magnetometer as part of the space environment monitor for the geostationary operational environmental satellite. This instrument will monitor the three components of the Earth's magnetic fields, its perturbations during solar activity, and magnetic phenomena propagating on the field. The measurements obtained will be transmitted to the Space Disturbances Forecast Center for incorporation with other data used routinely and continuously by the Center. These data are expected to provide a means for space monitoring of magnetic field activities; at present such monitoring is accomplished by inference based on magnetometer data from ground installations.

The Earth Sciences Laboratory is engaged in the design and fabrication of systems to relay selected magnetic data from the Antarctic to Boulder, Colo., by means of the interrogation recording and location system (IRLS) on Nimbus III. The ground system under development is expected to be in operation early in 1970. Rapid transmission of these data would permit more immediate comparison with the data acquired in the Northern Hemisphere. Under current conditions, as much as 6 months may elapse between the acquisition of the data in the Antarctic and its receipt at ESSA laboratories in the United States. Experience with the transmission relay system also is expected to provide information valuable for the development of more advanced general purpose data collection systems.

Research programs of the Aeronomy Laboratory include studies of the high atmosphere, the ionosphere, and the magnetosphere using theoretical, laboratory, and observational techniques. Until September 1969 the laboratory operated, jointly with Peruvian scientists, a large radio ionosphere observatory at Jicamarca. The great volume of data accumulated is being analyzed. Interesting discrepancies exist between electron and ion temperature measurements made from the ground and these acquired by probes and ion-trap sensors on satellites. Concurrent theoretical investigations suggest these differences may be caused by local effects around the space vehicle carrying the sensor. The data also are yielding much new information on the inherent instability of the ionospheric plasma near the magnetic equator. Theoretically, this information is applicable to an equivalent instability in the auroral-zone ionospheric plasma at high latitudes. This concept is being verified experimentally by observations with an "auroral" radar at Anchorage, Alaska.

A rocket-borne sensor for atomic oxygen is being developed. Although troubles with contamination of the exposed rocket sensor have been encountered, a satellite sensor has performed well and confirms the usefulness of the concept. If the troubles experienced with rocket-borne sensors can be overcome, a new and powerful tool for the investigation of atomic oxygen in the atmosphere will be available.

The Aeronomy Laboratory is studying the rates of chemical reactions occurring in the lower ionospheric regions. These reactions are of great importance in such widely diverse areas as space vehicle reentry, the occultation of radio signals from a deep-space probe by Mars, and the wetness of the upper stratosphere and mesosphere. The laboratory work also leads to an understanding of the effects of pollutants at these levels. A recent experience uses a tunable dye-laser for precise dissociation and ionization measurements.

A program of ground-based optical observations includes investigations of meteoric debris, and temperature variations in the high atmosphere. The observations of meteoric debris are yielding information on how vertical mixing and horizontal winds affect the composition and properties of the high atmosphere; this knowledge is of direct interest in problems related to spacecraft reentry and supersonic flight at these altitudes. The temperature measurements shown unexpectedly large variations at high levels, information which may result in a reassessment of current concepts of atmospheric structure. Existing satellite data are being used to study the effects of magnetic storms on the high ionosphere; ground-based optical observations of the subvisual auroral midlatitude red arcs are also used in this study.

In addition to these environmental studies, there is a strong laboratory and theoretical plasma physics program. Experiments of direct interest for the interpretation of ionospheric observations include plasma diffusion, the propagation of ion-acoustic waves in a plasma, and derivation of plasma properties by studies of the statistical behavior of irregularities in a plasma.

The Rocket and Satellite Experiment Section of the Aeronomy Laboratory has developed a theory that explains ionospheric resonances observed by satellite radio sounders. This theory has been used to develop a new technique for measuring electron densities and temperatures of the ionosphere.

Five ionospheric rockets were successfully launched into a polar gap absorption event (period of intense activity) at Fort Churchill, Canada. Electron density profiles were obtained in disturbed parts of the ionospheric D-region by radio signals transmitted to the rocket using Faraday rotation techniques. Analyses of the profiles should provide significant insight into processes occurring in these disturbances.

Data from the Canadian Alouette I and II and ISIS–I topside sounder satellites, and from Explorer XX, have been analyzed to determine the effects of disturbances, such as red arcs and magnetic storms, on ionospheric electron density. In both kinds of disturbances electron density decreases, while electron temperature increases. The decrease in electron density is believed to be caused by the higher recombination rate of the electrons that results from higher temperatures.

Since observations indicate that production of nitric oxide in the high atmosphere is responsible for most of the ionization of the D-region; a theory was developed to explain the presence of large concentrations of this gas. The theory, based on the reaction of molecular oxygen with excited atomic nitrogen, appears satisfactory.

The Institute for Telecommunication Sciences (ITS) conducts studies to promote the effective use of communication satellites. For example, an investigation of the frequency-sharing aspects of a satellite air traffic control system is being conducted for the Federal Aviation Administration. This work included the development of a transmission-loss atlas and the analysis of required signal-to-noise ratios for the VHF air traffic control (ATC) system, which would have a satellite terminal. Both subjective and objective performance evaluations were made using simulated ATC transmissions and VHF communication receivers. Objective performance measurements were made using the speech communications index meter (SCIM). The SCIM system has subsequently been used in operational tests over live satellite circuits on ATS–1 and ATS–3 by a commercial contractor. ITS personnel assisted in an advisory and consultative capacity during the operational tests.

Atlantic Oceanographic and Meteorological Laboratory's Physical Oceanography Laboratory is conducting research on the use of sea surface temperatures to map ocean currents over the Western North Atlantic. Unique data, which relate observable space-time changes in sea surface temperatures to the deeper thermal structure of the Gulf Stream, are available.

High resolution infrared data, observed by Nimbus II during part of the period of investigation, were used to construct sea surface temperature maps. The NASA provided the computations necessary. The observed sea surface temperature gradients (temperature changes) are being related statistically to the structure of the current. As a first approximation, it has been found that the fastest moving surface current occurs 14.5 kilometers on the warm side of the maximum temperature gradient; for the Gulf Stream this means the strongest surface currents occur 14.5 kilometers (about 9 statute miles) east of the line marking the change from cold coastal waters to warm Gulf Stream waters.

Work continues in support of the NASA Apollo telescope mount (ATM) program; requirements for identifying and forecasting solar data are determined, and procedures are developed to meet the requirements. Forecasts of the probable occurrences and locations of solar flares are to be furnished so the ATM instruments can be oriented properly to obtain measurements. A manual on solar flare prediction, based on various studies of the laboratory, has been drafted and the techniques described are being tested.

The Space Disturbances Laboratory has been using a 60-foot parabolic antenna at Table Mountain (near Boulder) to track the ATS–1 satellite and to receive proton data in the 5- to 20- and 70-Mev ranges from the recording instruments aboard the satellite. These data are relayed to the Space Disturbances Forecast Center (SDFC) for early identification of active solar flares.

Solar X-ray data from solar radiation satellite are transmitted daily from the Naval Research Laboratory to SDFC. Data for the preceding day reach the Center every morning; notice of the observation of a solar X-ray event is sent immediately to all users via a special teletype network.

In the rocket program, the data from four SKUA II rocket flights in 1968, were analysed. These analyses resulted in a description of the diurnal (day-night) variation of excited oxygen molecules in the high atmosphere. Six ARCAS II rockets were flown from Fort Churchill in April 1969; three carried instruments to measure pròton flux and electron densities during a polar cap absorption event, the other three were instrumented to measure the excitation of the OH radical. These measurements provide information for determining the coefficient of the rate of effective recombination as a key to describing the interaction of ionizing radiation with the Earth's atmosphere, and also lead to an increased understanding of the high atmosphere.

The SDL is also a participant in the ISIS program. The data gathered from the Alouette I and II, and the ISIS–I satellites are processed by SDL and distributed for analysis by scientists of ESSA and other participating agencies.

The Atmospheric Physics and Chemistry Laboratory is employing remote sensing to observe and obtain measurements of parameters to describe the physical and dynamic structure of the stratosphere. Infrared sensos carried on aircraft are currently in use. A special, narrow-field high-sensitivity infrared radiometer, developed by the laboratory and installed on a NASA CV–990 aircraft, obtained data during a number of long-range flights in 1969. Analyses of these data have yielded quantitative information on the transmissivities of cirrus and contrails, and the effects of these ice crystal clouds on the atmospheric heat budget. The measurements have also been used to determine water vapor concentrations in the stratospheric layers above the flight level of the instrumented aircraft.

National Bureau of Standards

NBS is the Nation's central measurement laboratory. It provides technological support for many national programs, including those in space and aeronautics, through efforts in three broad categories:

Basic Measurements and Standards.—developing a complete and consistent system of physical measurements, which is the essential foundation of all advanced research and technology.

Materials Measurement and Standards.—providing a basis for the determination and understanding of the properties of materials.

Technological Measurement and Standards.—developing means for measuring the properties of products, commodities, devices, processes, and systems.

Basic Measurements and Standards

Apollo 11 Lunar Range Experiment—NBS cooperated with scientists from the University of Maryland and other institutions in preparing the optical retroreflector that was left on the moon by Apollo 11.

Using this instrument, the round-trip light travel-time from the Earth to the Moon and back is now being measured using short laser pulses. Resulting data will be used to determine the lunar orbit, radius and other characteristics, the wobble of the Earth about its rotation axis, the rotation of the Earth, and the difference in longitude between widely separated observing stations. Such geophysical information should help in understanding the interaction between the core and the mantle of the Earth, and should provide a direct test of whether the large-scale crustal movements predicted by recent theories of ocean floor spreading and continental drift are actually taking place.

Radio Line Spectra of Hydroxyl—NBS made precision measurements of the radio waves given off by two excited states of the hydroxyl (OH) molecule at the request of Harvard radio astronomers. Using the large radio telescope at Greenbank, W. Va., and the NBS measurements as the basis for their search, they were able to detect faint OH signals in a single night of observation. Without the NBS measurements, the search would have required a great deal more telescope time, which is expensive in terms of both money and delays in other scheduled observations; and indeed, according to the astronomers, probably would not have succeeded at all.

Speed of Light Measurements—NBS is working to measure the speed of light with a greater degree of precision than previously possible. Better speed-of-light determinations are needed, among other things, in making orbital calculations and long distance measurements—from the Earth to the Moon, for example.

New Radio Noise Standard—At the request of the Communications Satellite Corp. (Comsat), NBS built a new standard for measuring radio noise power. It will enable Comsat to measure accurately the background noise level in amplifiers and antennas used for ground receiving stations. Prior to this develop-making such noise measurements and could not properly evaluate the component of their receiving equipment.

Apollo 9 Cameras—Four mapping cameras carried on the Apollo 9 mission were calibrated by NBS. Many optical characteristics of the camera lenses and mechanical properties of the shutters were checked.

Atomic and Molecular Physics—Much of the data gathered by the space program requires supplementary information to assess it. NBS has major programs in atomic and molecular physics at its laboratories in Gaithersburg, Boulder, and at the Joint Institute for Laboratory Astrophysics, an NBS-University of Colorado joint effort. Some of the year's accomplishments were—

1. A critical evaluation of the atomic transition probability data for the 10 elements sodium through calcium.
2. Experimental and theoretical investigations of the light emission from a hydrogen arc plasma.
3. New energy level measurements for atoms of technietium, tungsten, chlorine, the rare earths, and thorium.
4. Transition probability measurements of neutral and ionized argon.
5. Studies of the effects of absorbed gases on the photoelectric emission from tungsten surfaces.
6. Establishment of a data bank containing evaluated experimental cross sections for electron impact on atoms and small molecules.
7. Photodetachment studies of the ion $(H_2O)OH$ which show it may play an important role in controlling electron densities in the D region of the Earth's upper atmosphere and lower ionosphere.

Moon Gun Constructed—NASA has devised an experiment to measure electric fields on the surface of the moon by observing the deflection of an electron beam. NBS designed a suitable electron gun, and built two of them for NASA. Now NBS is consulting with NASA on construction details of a flyable model.

Radiation Protection in Spacecraft—NBS has made several theoretical and experimental investigations to determine how electron radiation penetrates various materials used for shielding spacecraft against Van Allen belt electrons, and other radiations. The results are vital to the safety of space travelers.

Thermal Conductivity of Gaseous and Liquid Hydrogen—NBS recently completed a ten year NASA-supported program to gather data on the physical properties of hydrogen at low temperatures. Because hydrogen is an important space fuel, data on its properties are vital to the design and operation of rocket engines. Other recent work has included the determination of many physical properties of liquid hydrogen, oxygen, and fluorine, and engineering studies of these fuels.

Materials Research and Standards

Lunar Sample Program—NBS is involved in the lunar sample program in instrument development, standard reference materials, and in analyses of lunar samples. A mass spectrometer was designed and constructed for NASA to use in analyzing moon material. NBS will also make analyses of moon materials in its own laboratories by mass spectrometry, X-ray and Mossbauer spectrometry, electron microprobe and other techniques. Standard Reference Materials of simulated lunar samples were prepared to serve as the basis for analysis of moon material by other investigators. These materials were described at a NASA meeting and were considered highly useful in calibrating mass spectrometric work between laboratories in the lunar sample program.

Physical Chemistry of Planetary Atmospheres—This project involves many programs in atomic and free radical chemistry and the chemistry of excited states related to atmospheres which may be encountered on other planets. A paper on the photochemistry of Jupiter was published during the year. This work is expected to develop valuable data for use in planning planetary exploration.

Standard Reference Materials—Standard Reference Materials (SRM) 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. One more metallo-organic SRM was developed and made available for testing the wear of modern jet engines, permitting predictions to be made of failure rates. Metallo-organic standards are used in the air transportation industry to detect engine failure before they occur. The additional metallo-organic material brings to nine the total available from NBS. Sixteen new gold plating thickness standards were issued to check precise measurements for the thickness of metal coatings. Gold is often plated on electrical components to provide stability and resistance to oxidation and corrosion.

Technological Measurements and Standards

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. NBS is investigating to determine the cause of failure in NASA satellite tape recorders due to tape head sticking. The program will also give information needed to properly specify magnetic tapes and recorder head materials for use in satellites.

Development of Space Radiation Detectors—NBS developed a nuclear radiation detector configuration that lengthens the useful life in a low-energy-particle environment by a factor of about 10,000. This development will extend life of space craft experiments and reduce the number of such experiments needed for equivalent amounts of data. Solid state nuclear radiation detectors are used to measure the exposure of satellites to high energy radiation during flight.

Performance of High Temperature Thermocouples—NBS is investigating the performance of high temperature thermocouples used to improve the accuracy of measurements made during tests of advanced propulsion systems for aircraft. These improvements will permit a more accurate evaluation by NASA of performance of development propulsion systems.

Heat Sterilizable Magnetic Tape—At the request of Goddard Space Flight Center, NBS is acting as technical monitor of a program at Battelle Memorial Institute to produce heat sterilizable magnetic tape. The tapes are needed for recorders aboard spacecraft designed to land on other planets.

Radiation Detectors in Space Vehicles—The safety of space travelers requires that radiation hazards be promptly and properly detected; however, present detectors degrade rapidly in the harsh radiation environment of space. NBS research has made possible the prediction of the useful life of detectors and has yielded information on the proper use of detectors in these environments.

Aeronautics Research—The Office of Vehicle Systems Research (OVSR) of NBS conducts research on tires, restraint systems, and brake systems for commercial and military aircraft.

A USAF Flight Dynamics Laboratory funded program is being conducted by the OVSR to develop a mathematical model of the aircraft tire wear problem. Both the Air Force and NASA are being informed. Other programs sponsored by the NBS Tire Systems Section relating to aircraft tires include: preparation of the first English language textbook on pneumatic tire mechanics; a study of the internal stress in statically deformed pneumatic tires; a dynamic analysis of skidding; fatigue failure and impact performance; wave geometry; and test instrument development.

In addition, the OVSR has organized a forum for the exchange of fundamental knowledge and information on tire mechanics. The Tire and Brake Research Sections at NBS cooperate closely with NASA. Activities in NBS related to fog, landing strip lighting, etc. are also applicable to aeronautical research being performed by other agencies.

Office of State Technical Services

The Department of Commerce's Office of State Technical Services (OSTS) has continued its program of making available to the non-Government sector of the American economy the technologies and scientific knowledge developed in Government programs. In the area of aeronautics and space technology the OSTS cooperates with the Technology Utilization Division of NASA in monitoring these programs to identify information of possible use to private or other non-Federal activities. The major method for transferring this information is by means of person-to-person contact through the OSTS technical field service, which is supported by information, reference, and educational services. The OSTS field services personnel also work closely with appropriate State agencies. This office and the NASA Technology Utilization Division also participate jointly in national conferences on information dissemination and technology transfer. The NASA offers additional assistance through the regional dissemination centers of its Technology Utilization Division.

Maritime Administration

In 1961 the Maritime Administration concentrated on the preparation, with the Radio Technical Commission for Marine Service, of position papers for participation in the 1971 World Advisory Radio Conference in Geneva. Papers were prepared outlining international positions for mobile marine communications via satellites. Based on the Administration's experience with satellite-to-shipboard communications tests during 1968, a specification ("Marine Mobile VHF Satellite Communications Terminal Specification," available to the public from the Clearinghouse for Scientific and Technical Information, U.S. Department of Commerce) was written for a marine mobile VHF satellite communications terminal. Since the potential viability of a system of mobile satellite communication for marine services depend on the costs of shipboard equipment, the Maritime Administration is preparing to participate in tests of a UHF satellite transponder system. Test results will be used to determine the relative reliability of UHF and VHF systems, and to arrive at the cost-benefit ratios between UHF and VHF shipboard antennas.

XII Department of Transportation

Introduction

During 1969, the Department of Transportation was engaged in a variety of research and development programs pursuing goals contemplated by the National Aeronautics and Space Act of 1958, all such programs being carried out through the Federal Aviation Administration. The single most notable enterprise of this kind was the supersonic transport development program. Another major area concerns itself with efforts to modernize the air traffic control and navigation system on which aviation's efficient use, without sacrifice of safety, of the increasingly crowded airspace depends. Improved safety in aviation, a perennial objective, continued to receive major attention. Other important programs were concerned with human factors as operational elements in aviation, and with preserving the quality of the environment upon which an ever-expanding aviation tends to encroach.

The Supersonic Transport

For the supersonic transport development program, the year was marked by a series of major evaluations and decisions.

The process began in January, when the airframe contractor submitted to FAA a new configuration to replace the variable-sweep-wing configuration judged in 1968 to be uneconomical. The new configuration, incorporating a delta wing with a horizontal tail, passed the technical evaluation of a Government review team of 100 members drawn from FAA, the National Aeronautics and Space Administration, and the Department of Defense. Thereupon, the Secretary of Transportation recommended that the President approve the start of prototype construction. The President, however, late in February, appointed a 12-member interdepartmental committee to review and make recommendations on this subject in the light of overall U.S. priorities. On September 23, after considering all aspects of the significance of this project, including the committee's report, the President announced his decision that the program should go forward; stating that if U.S. supremacy in air transport was to be maintained, the building of this airplane was essential.

To finance the start of prototype construction, the President asked Congress to supplement the $99 million available in carryover funds with an appropriation of $96 million (fiscal year 1970). Congress reduced this amount to $85 million which was approved by the President on December 29.

Air Traffic Control and Navigation System

Notable efforts underway during 1969 to improve the air traffic control and navigation system continued from work in previous years with the advanced radar traffic control system (ARTS) concepts. (Testing and appraisal of ARTS I, completed in 1966 at Atlanta, Ga., showed the advantages of electronically displaying "data tags" on the ATC radar scope which provides the controller with aircraft identification and altitude data adjacent to the aircraft targets.) The 1969 efforts included the following:

ARTS II—Direct Altitude and Identity Readout (DAIR) System—During 1969, FAA and DOD completed joint operational testing and evaluation of both civil and military DAIR prototype configurations at the FAA National Aviation Facilities Experimental Center (NAFEC), Atlantic City, N.J. In late 1969, DOD awarded a contract for quantity production of the military configuration.

The DAIR system, jointly developed by FAA and the Department of Defense, is designed for use at terminal facilities with only moderate aircraft activity, whether these be civil airports with FAA control towers or military bases with radar approach control. The system is being developed in essentially similar but distinct civil and military configurations, and both types will supply numerals giving a coded identification of the aircraft to the controller's radarscope, from instruments in the in-flight aircraft. These numeral codes also indicate the pressure altitude of the aircraft. Appearing adjacent to the radar image of the aircraft, these numerals will accompany the image across the scope or display.

The chief operational benefits expected from the system are (1) reduction of controller-to-pilot radio voice communications by more than 30 percent, and (2) increased air traffic controller efficiency resulting from positive identification of radar targets (aircraft) on the radar display and from continuously reported altitude information for such targets with a minimum of radio communication.

ARTS III—In the ARTS III program during 1969, FAA awarded a contract for fabrication, testing, delivery, and installation of 62 ARTS III systems for operating terminal facilities, plus one system for research and development and one system for training.

This equipment is designed to semiautomatic air traffic control operations at airports where air-traffic density is medium or higher. Deliveries under the contract are to take place over the period between May 1970 and October 1972.

The ARTS III systems uses letters as well as numbers (alphanumerics) in the electronic tags beside the aircraft's radar image to show such information as the aircraft's identification and altitude. After initial acquisition, each alphanumeric tag in this system will under normal conditions follow the appropriate aircraft target across the radar display without intervention by the controller. Alphanumeric tags will be prepared and displayed only for aircraft under the jurisdiction of the terminal, and within the terminal they will be presented only to the display or displays controlling the aircraft.

Other major capabilities of the system include (1) intrafacility handoff, or transfer of the alphanumeric tags from one operating position to another within the same terminal; (2) interfacility handoff, or transfer of the tags between positions in the terminal and positions in adjacent air route traffic control centers having the proper equipment; (3) quick-look capability, which will permit one position to look at alphanumerics displayed at another position; (4) automatic repositioning, which will automatically reposition the tags to avoid display clutter; and (5) automatic track drop, which will eliminate the tags from the radar display when the aircraft concerned have reached a predetermined range or altitude.

The modular character of the ARTS III system will permit (1) tailoring to the particular and sometimes unique requirements of given terminal facilities, and (2) expansion to perform additional functions or provide higher levels of automation.

National Airspace System en Route Stage A—Like ARTS III at terminal facilities, the National Airspace System en route stage A equipment will semiautomate operations at FAA's air route traffic control centers. During 1969, shakedown testing of the system continued at NAFEC, and implementation of the system at the Jacksonville, Fla., air route traffic control center proceeded in preparation for operational testing there in calendar year 1970.

Radar Weather-Clutter Techniques—Radars now in use for air traffic control employ techniques which prevent light rainfall from obscuring aircraft targets on the radarscope, but are ineffective against heavy rainfall which appears in the controller's display as clutter. Because the controller needs to know the location of rainstorms in directing aircraft movements, the entire elimination of rainfall clutter is undesirable. A contract was awarded during the year for the development of a radar model capable of showing the location and extent of precipitation—by line contours, for example—without obscuring aircraft targets.

All-Weather Landing System—FAA continued work in 1969 on the long-range undertaking to develop an all-weather landing system (AWLS). This involves integration of three major technical-area efforts: the ground-based guidance system, the airborne (i.e., in the aircraft) system, and the lighting system. The purpose of the AWLS is to enable aircraft to land under visibility conditions so poor as to fall technically within category III weather minimums—that is, conditions under which the pilot cannot see the ground or runway before landing and under which the runway visual range is between 1,200 feet and zero.

Outstanding in the year's work was the flight testing of a category III airborne system design in a C–141 aircraft, under the joint sponsorship of FAA and the U.S. Air Force. This system lands the aircraft automatically while the pilot, with the aid of a cockpit display, serves as a backup to the automatic system. The flight tests included operation to a full stop on the runway with the pilot under the hood. They indicated that, within certain limitations, the total air-ground system involved should be suitable for category III–A operations (runway visual range less than 1,200 feet but not less than 700 feet).

Mobile Facilities—During 1969 FAA continued an effort begun in 1967 to develop and fabricate mobile elements of the air traffic control and navigation system for use in emergencies. Such emergencies may arise from temporary outage of permanent facilities for any of a variety of reasons (e.g., relocation, or damage from fire, storm, or earthquake), or because no permanent facility is available where service is temporarily needed (as at a fly-in by a general aviation organization).

By the end of 1969, mobile versions of the following elements of the system had been fabricated, and most had been used repeatedly: airport traffic control tower; one type of long-range radar; compass-locator/marker (used to assist aircraft in transition from en route navigational aids to an instrument landing system, in flying a holding pattern, and in using the instrument landing system); engine-generators (usable as either prime or backup power sources for other facilities); VOR and Tacan (the basic en route short-range navigational aids for the air traffic control and navigation system); and a communication van.

Also completed during the year were the engineering-requirement plans for the next decade. Besides improvements in the design and performance of the foregoing mobile elements, the plans call for fabrication of mobile versions of the principle remaining system elements, as follows: instrument landing system, distance-measuring equipment, airport surveillance radar, Tracon (terminal radar approach control), air route surveillance radar (another type of long-range radar), and flight service station.

Preparation for Future Air Vehicles and Equipment—The air traffic control and navigation system must be ready to accommodate the aircraft of the future and aircraft-equipment innovations significantly affecting the procedural and operational structure of the system. The most notable preparations of this kind in progress during 1969 were those in anticipation of the following:

(*a*) *Area navigation.*—In September 1969, FAA established 16 new "off-airway" routes in widely scattered regions of the country for use of qualified pilots using FAA-approved area-navigation equipment. Area navigation permits pilots to use navigational aids without homing in on them, as must be done on the conventional airways, which pass over navigational aids. The area-navigation routes, capable of going directly from starting point to destination independently of navaid locations, are generally shorter and more convenient than the conventional airways, on which they also help relieve congestion.

(*b*) *Jumbo jets.*—The principal adaptive changes will be at terminal facilities for these aircraft, the first of which will be operating in 1970.

(*c*) *V/STOL and STOL aircraft.*—FAA both conducted and participated in operational testing of such aircraft in 1969 bearing on airport and systems design and standards for operation of such aircraft.

Aviation Safety Research and Development

During 1969, in previous years, FAA was engaged in numerous research and development efforts aimed at making aviation safer. These efforts are complementary to more fundamental studies in this area conducted by NASA resulting in a coordinated interagency program in aeronautical safety. Broadly described, FAA's efforts sought ways to reduce or eliminate hazards incident to both en route aircraft operations and those connected with takeoff or landing, and also means to increase the likelihood of the occupants' survival of such airplane accidents as do occur.

En Route Operations—Fire, collision, weather turbulence, and sabotage are all in-flight aircraft hazards against which R&D efforts by FAA are of long standing. Similar efforts against hijacking, another hazard generally manifesting itself after the aircraft has taken off and is well underway, are of more recent origin.

During 1969, developmental work to counter the in-flight fire hazard was highlighted by feasibility tests indicating liquid nitrogen to be an effective agent for extinguishing powerplant fires; additional tests are being conducted.

On the subject of midair collision, FAA was, among other things, (1) assisting the Air Transport Association in flight-testing and evaluating one type of collision-avoidance system, delivered by the contractor earlier in the year, and (2) continuing computer simulation studies of the situation resulting from introducing a collision-avoidance system into the air traffic control system.

Turbulence, in the common form of thunderstorms, can be detected by both ground-based and aircraft-carried radar; but no effective operational instruments have been devised for detecting the invisible and inaudible phenomenon called clear-air turbulence (CAT). In 1969, the search for a solution to the CAT problem took a new direction. Two principal circumstances contributed: (1) Regions of low and high probability of CAT can be identified by certain computer-based techniques of probability analysis resulting from

371-775 O - 70 - 6

studies recently completed by a private institute under FAA contract, and (2) the National Meteorological Center (NMC) recently put into operation a new model for forecasting temperatures and winds up to 40,000 feet. From these circumstances, FAA and NMC developed a plan for forecasting CAT by combining the probability-analysis techniques with NMC's new model for forecasting winds and temperatures. The premise is that the future location of the regions of probable CAT identified by analysis techniques can be forecast with accuracy comparable to that attained currently in NMC's wind forecasts by allowing for advection (horizontal movement) of the regions of probable CAT with the wind field. Revision of the prepared computer programs on probable CAT regions to make them compatible with the NMC computer programs for wind and temperature forecasts was being carried out in 1969.

After nearly a decade of R&D effort by FAA, prevention of aircraft sabotage remained an unsolved problem in 1969 though some progress has been made and the effort continues. In February 1969, results of testing and evaluation of an engineering model of an antisabotage device delivered to FAA by the contractor in 1968 became known. The testing and evaluation had been carried out by a panel of scientists drawn from Government, industry, and academic institutions, and they agreed that the device, a "Chemosensor" designed to detect explosive vapors, had potential; but they also agreed that major improvements in sensitivity and selectivity were needed. At year's end, the direction of further work on this principle was being established. A contractual effort on another principle was started during the year—to explore the feasibility of a passive explosive-detection system using analysis of neutron activation.

An unprecedented epidemic of aircraft hijacking that started in 1968 and carried over into the first part of 1969 caused FAA to establish in 1968 a project to develop, as one countermeasure, a means of detecting weapons on potential hijackers before they could board an airliner. Such a device was field-tested in 1969 as part of a system including also a hijacker "profile" based on personal characteristics of past hijackers. Several months of field-testing at 9 metropolitan airports in various parts of the eastern half of the United States and Puerto Rico produced encouraging results, and at year's end the agency, in cooperation with one of the Nation's trunk airlines, had placed the system in operation at unannounced locations for preboarding screening of the airline's passengers.

Besides projects like those discussed above, designed to reduce or eliminate hazards that might be encountered by any aircraft, FAA continued in 1969 a number of projects designed especially to make the flying of general aviation aircraft safer. During the year, the agency (1) was working on technical and operational criteria for improved stall warning systems for general aviation aircraft, (2) was well into a project involving analysis of general aviation accident data by make and model of aircraft to determine in a statistically significant manner those design practices, both good and bad, that contribute to accidents involving pilot error, (3) completed tests of anti-icing wing-coating materials in the icing research tunnel at NASA's Lewis Research Center, Cleveland, Ohio, and began flight tests of the most promising of these materials, (4) in cooperation with NASA and DOD, using variable-stability research airplanes supplemented by both ground-based and in-flight simulators for the wide range of civil aircraft configurations, continued programs concerned with improving the handling qualities of both current and emerging forms of aircraft through determining optimum stability and control characteristics for use in system design and through promoting the development of promising new aircraft control concepts, and (5) continued a study of the hazards to small aircraft posed by the vortex wake turbulence created by very large aircraft.

Airport and Vicinity—Highlights of R&D programs to achieve greater aviation safety on and near airports included developments connected with runway-traction problems, with airport surface detection equipment (ASDE), and with a project studying jet-transport landing characteristics.

Taking advantage of NASA's extensive research in the runway-traction area, FAA studies began in fiscal year 1965 to apply these results to actual airport operations. Runway grooving has been found to make aircraft easier to control and stop when they land on wet runways, and runway-friction-measuring equipment and procedures have been developed by FAA and others for providing pilots with stopping-distance information for slick runways. By the beginning of 1969, runways at several airports, including Washington National, had been grooved. During the year, grooving was applied to certain runways on the airports at Dallas and Atlanta. Further study of the correlation between wet-runway friction and airplane stopping distance was being pursued during the year in two ways: one by using a computer to simulate the airplane, and the other by adapting a military methodology to civil operations.

Improvements in the operational usefulness and economy of airport surface detection equipment (radar equipment used by the controller to monitor the surface of the airport when direct visibility conditions from the tower cab are poor) resulted in a selection order in 1969 (i.e., approval for incorporation in operationally authorized ASDE's upon authorization of funds). High maintenance costs in comparison with restricted operational utility had caused all but four of 11 ASDE's in operation to be shut down under an FAA order issued in February 1966. Since then, maintenance costs have been reduced by use of solid-state components and otherwise, and operational utility has been much improved by incorporation of a bright-display capability, which eliminates the need for a hood to make the display visible to the controller under the normal light conditions in the control-tower cab.

The objective of the project concerned with jet transport landing characteristics—i.e., to accumulate data for a review of certification criteria applying to these characteristics—was achieved in 1969. The method used was to photograph and analyze the performance of jet transports in approaches and landings at six different airports. The project began late in 1967.

Among other projects active during the year to improve aviation safety on or near airports were those concerned with airport firefighting equipment and techniques, antiskid runway paint, runway emergency arresting systems, and the prevention of birds from being drawn into the engines of jet aircraft.

Postcrash Safety—A number of FAA's R&D programs during 1969 were addressed to various aspects of the problem of achieving greater aircraft crashworthiness—i.e., basic design, materials, and construction, such that aircraft occupants have a better chance to survive if the aircraft crashes:

(*a*) Crash impact tests made on large-scale fuselage models during the year completed development of a program begun in previous years to use an analytical digital computer to calculate, for a survivable accident, the probable forces of distortion acting on a typical transport fuselage, and their effects. The test data show that the computer program provides a usable tool for evaluating, in the design stage, new concepts in fuselage crashworthiness.

(*b*) A prototype of a system for providing emergency exits for occupants of a crashed plane by the use of high-energy liquid explosives underwent evaluation tests during the year. The basic development work on the system was accomplished in prior years in cooperation with the U.S. Army's Picatinny and Frankford Arsenals. At year's end, further refinement of the system was in progress.

(*c*) Further studies were made of flammability and smoke characteristics of burning cabin interior materials, of the kind supporting new safety regulations in 1967 and 1968, and additional laboratory and flammability smoke tests of newly developed materials proposed for the next generation of jet transports were conducted by FAA and the National Bureau of Standards. Resulting data are being used to support more stringent standards proposed by FAA in August 1969 for flammability and smoke characteristics of materials installed in transport aircraft.

(*d*) Interior features of aircraft cabins were investigated in several dozen accidents by FAA medical officers, and medical findings were made available to engineers as a contribution toward appropriate modification of features that inflict death or injury upon aircraft occupants in crashes.

(*e*) Simulated crash tests of full-scale wing sections incorporating fuel-tank systems employing improved materials and crash-actuated shutoff valves were performed on FAA's catapult facility; little or no leakage occurred, despite test conditions significantly nearer those of an actual crash impact than were applied in 1968 tests. In another program, new crashworthiness concepts for integral tank structure and sealing material components subjected to laboratory tests during the year promise to minimize postcrash fuel spills.

(*f*) Tests during the year on compatibility of jet transport fuel-system components with fuels thickened to reduce postcrash fire hazard indicated that gelled fuel presents fewer system problems than emulsified fuels. An analysis was begun to compare the cost of using gelled fuel in commercial air carrier service with the cost of other methods of reducing the same postcrash fire hazard. Preparations were also begun to run a jet engine on gelled fuel in a 50-hour endurance test as part of the qualification of gelled fuel for flight tests.

Other Safety (R&D)—Notable aviation safety R&D activities not mentioned above include—

(*a*) Continuation of work begun in June 1968 to improve survivability of magnetic tapes or other recording media used in airborne flight data recorders, which are of vital importance to both FAA and the National Transportation Safety Board in investigating aircraft accidents. NASA assisted in the theoretical calculations required to analyze properties of various ablative/charring materials.

(*b*) Completion of a project begun in 1968 to provide a remote-control device giving a parachute jump instructor immediate control of his student jumper's auxiliary parachute.

(*c*) Conducting of tests to determine hazards of possible aircraft collision with instrumented balloons called for in substantial numbers at altitudes between 18,000 and 100,000 feet as part of a worldwide weather system developed in 1964.

(*d*) Evaluation in cooperation with the Office of Naval Research, of an industry-developed technique for achieving from the normal shades of gray in conventional X-ray negatives a greater contrast of colors, which greatly enhances accuracy in interpreting the data. Successful demonstration of this technique to assist airworthiness inspection of airframes and aircraft engines has prompted others to support follow-on development of automatic X-ray processing equipment.

These include NASA, the Federal Highway Administration, the U.S. Coast Guard, the Office of Naval Research, and the U.S. Air Force.

Human Factors in Aviation

Studies concerning human factors in aviation being pursued or participated in by FAA during 1969 applied in particular to pilots, air traffic controllers and passengers. These included—

(*a*) A study, completed in 1969, to determine the actual flying habits and flight profile of the private pilot population, and similar studies started during the year concerning the commercial pilot and the instrument-rated pilot populations, the data to be used for developing obective standards of operational competence applicable in certification of such pilots.

(*b*) A study begun in 1969 to examine effects of postcertification time lapses on instrument flight skills of private and commercial pilots with instrument ratings.

(*c*) A project begun in 1969 to correlate pilot preflight practices with subsequent safe or unsafe flying.

(*d*) A long-range study by the Navy Aerospace Medical Institute, Pensacola, Fla., of the relationship between physiological and chronological age in some 800 Navy and ex-Navy pilots first studied in 1940 and periodically reassessed since.

(*e*) A study begun in 1968 to assess medically, in terms of specific quantification, stress experienced by air traffic controllers while on heavy-shift work and on light-shift work. Findings were being put in final form at the end of 1969.

(*f*) Studies that developed through statistical analyses such aids in recruiting, training, and utilizing air traffic controllers as correlations between the controller's age, experience, and personality on the one hand, and, on the other, objective criteria of proficiency determined during air traffic control exercises performed in an air traffic control simulator.

(*g*) Studies that determined the optimum combination of lighting, screen type, screen size, viewing distance, and color filters for large screen radar displays to be used by air traffic controllers. These studies also determined that large displays should only supplement individual displays provided for primary control.

(*h*) Studies concerned with standards and limits applying to maintenance of a livable atmosphere in the SST—including cabin pressures, degree of exposure to cosmic radiation, and oxygen requirements for portable oxygen equipment to be used by stewardesses to assist passengers during emergencies.

(*i*) A study, begun in 1968 in cooperation with the U.S. Public Health Service, to assess the actual level of tobacco-combustion products in air transport aircraft cabins during routine flights.

Aviation and the Environment

Several of FAA's R&D programs or activities during 1969 were addressed to aspects of maintaining the quality of the environment, an area of increasing importance as technological civilization advances.

Abatement of aircraft noise has long been an FAA concern. Continuing past efforts to develop acceptable jet transport noise abatement procedures, the agency was, during 1969, operationally evaluating a computer designed to be carried in aircraft for guiding the aircraft on a two-segment approach to landing. (The two-segment approach is designed to keep the airplane and its jet noise as high as possible, within safe operating limits, above the communities surrounding an airport as the airplane makes the earlier part of its approach.) During 1969, the scope of the evaluation was expanded to include more aircraft and pilots. At year's end, the evaluation was scheduled to be completed in mid-1970.

The effects of sonic booms on the quality and quantity of sleep are to be assessed in a project being prepared for by FAA in 1969. To provide data, 20 subjects will sleep for 28 nights in special sonic-boom chambers being installed at the agency's Civil Aeromedical Institute, Oklahoma City.

Engine smoke in the atmosphere was another FAA concern during the year. As a participant on a technical committee of the Society of Automotive Engineers (SAE), the FAA conducted engine smoke measurement tests which were a factor in the preparation of an SAE Aeronautical Recommended Practice on the measurement of engine smoke. Relationships between smoke measured in a test cell by this method and aircraft smoke trails in flight are being determined by further tests. Resulting data will assist in the establishment of engine smoke limits if the National Air Pollution Control Administration of the Department of Health, Education, and Welfare should conclude that such limits should be adopted.

XIII National Science Foundation

Introduction

In 1969 the National Science Foundation (NSF) supported a variety of programs in aeronautics and space. The largest part of NSF activities consists of support given to research projects at colleges and universities. The Foundation administers a number of national programs and supports national research centers throughout the country. Facilities such as radio telescopes, scientific balloons, and experimental aerodynamic facilities are also provided by NSF for scientific and engineering research related to aeronautics and space. Participation and cooperation with NASA's airborne science aircraft has yielded significant data on the aurora, upper atmosphere, and planetary observations.

Solar-Terrestrial Program—Effects of the radiation, particles, and plasma waves from the Sun which control the Earth's outer environment are studied in the solar-terrestrial program and associated parts of the aeronomy program. These selected studies of space-related problems in fiscal year 1969 included the following areas:

1. Nature of solar flare outbursts and their terrestrial influences

2. Interaction of the Earth's magnetic field with the solar wind, producing the enveloping magnetosphere and the trapping of particles in the radiation belts.

3. Structure of interplanetary magnetic fields as revealed by effects on cosmic rays reaching the Earth.

4. Analysis of the variable magnetic fields of the Earth, which significantly shields the terrestrial environment from solar particles. Insight is gained through satellites, rocket measurements of fields, and ground-based studies of electromagnetic wave propagation and optical emissions indicating partial conjugacy of field lines in the Northern and Southern Hemispheres.

5. Study the theory and experiment of the transport of energy from solar plasma into the Earth's atmosphere and of its subsequent coupling into the atmosphere. Special effects probed in detail include the creation of electrical current systems in the ionosphere, abnormal absorption of radio waves, and production of auroral light.

6. This program was given the responsibility of providing coordination for Federal activities related to the March 1970 solar eclipse by the Office of Science and Technology of the Executive Office of the President. Plans for coordination of researches were set into operation by the Director of the Solar-Terrestrial Program, and initial grants for research support were made.

7. Operation of the outer atmospheric facility at the Arecibo Ionospheric Observatory, in which these programs participated, produced information on the density and temperature of charged particles in the ionosphere which augmented measurements by satellite probes.

National Center for Atmospheric Research (Colorado)—Continuing studies of the Sun and interplanetary medium were pursued during fiscal year 1969 at the High-Altitude Observatory of the National Center for Atmospheric Research (NCAR). One major new effort involves the development of a coronagraph to be carried in orbit aboard the Apollo telescope mount as part of NASA's Apollo applications program in early 1970. The thermal-mechanical model passed various environmental tests at the subcontractor laboratory. A prototype version was delivered and being readied for a balloon flight test from Palestine.

The various studies produced the following results:

1. New interest in the rotation of the Sun was revealed, allowing for a satisfactory explanation of phenomena such as the equatorial acceleration, and the role that differential rotation may have on driving the solar activity dynamo. Powerful computers have been used to calculate coupling effects with greater accuracy than was possible by analytic solutions.

2. The role of magnetic fields in prominences have focused on the accumulation of a unique body of measurements of prominence fields and on analysis to determine how a field is oriented with respect to a prominence axis and how it is involved in support of the prominence. It has become clear that electric currents are significant in many prominences.

Another NCAR program resulted in the collection of high altitude air in order to determine the concentration and properties of traces of gases in the upper stratosphere. Preliminary analyses of the air between an altitude of 27 and 39 miles revealed nearly the same volume concentration of molecular hydrogen and carbon dioxide as found in surface air, but considerably less methane and no carbon monoxide or oxides or nitrogen were detected. Tritium was found to be about two orders of magnitude higher than estimates based upon the action of cosmic rays in the upper atmosphere. The difference is due to thermonuclear explosions. Additional rocket launches are being planned.

U.S. Antarctic Research Program—Many Antarctic studies relate directly or indirectly to the space program. Informal consultations on mutual problems are frequent between NSF and NASA, and a NASA official presently serves in an advisory capacity to the U.S. antarctic research program.

Space program officials have shown particular interest in the management of the antarctic program, as it operation at the end of a long logistic line bears some resemblance to the lunar exploration program. There are parallels, as well, between the antarctic environment and those that may be encountered on other planets. For this reason, soil microbiological studies have been carried out in Antarctica for several years. The NSF-sponsored development of an automatic antartic research station has benefited from the interest and advice of NASA scientists.

Satellites have many uses in the antarctic program, ranging from the photography of weather and ice patterns, through geodetic measurements, to applications in upper atmosphere research. Ionospheric and magnetospheric data in general from the high-latitude antarctic stations are of great consequence in space physics.

Engineering—The Engineering Division supports a number of research programs related to aeronautics and space activities. There has been an increasing amount of interest in applying aeronautical knowledge and techniques to Earth-based problems such as wind effects on structures, dispersion of contaminants in the atmosphere, and flight of birds and insects, as well as general basic research in aerodynamics and structures.

A number of research projects supported during fiscal year 1969 involve the study of low density gas flows and supersonic-hypersonic aerodynamics. Typical examples are the studies at the University of California, Berkeley, and at Princeton using rarified gas flow tunnels constructed with NSF assistance. Studies are being made of free jet density fields for monatomic gases by electron beam fluorescence, on the formulation and analysis of neutral gas flows in the transition regime to provide theoretical inputs for an experimental program, the formulation and analysis of ionized gas flow problems in which local electrostatic effects play a dominant role, and an experimental detailed probing of flow fields (from continuum to free-molecular flow regimes) on simple, curved, and nonaxisymmetric bodies with various surface conditions and inclinations using a variety of special instruments. Studies on hypersonic rarified gas flow and hypersonic the instability are under way at the State University of New York, Buffalo, and at Brown University. The stability of blunt body flow fields in hypersonic flow is being investigated at the University of Mississippi.

In the low-speed regime a study is underway at the University of Michigan on axisymmetric turbulent wakes. A study at the Polytechnic Institute of Brooklyn is considering the vortex superstructure of turbulent jets. At the Oklahoma State University an investigation is being made of wind tunnel wall effects on a wing with large wake deflections and a study at the University of South Dakota is investigating separation prevention by injection for flow over an axisymmetric body.

Both deterministic and probabilistic studies are underway on the development of numerical methods of analysis for structures under static or dynamic loads. One program at the University of Dayton is investigating the dynamic response of fuselage structures. A study at MIT is developing computer-aided design techniques for structures. A research program at New York University is looking into the mechanism of flight of microscopic insects. The flight of small insects is unusual because of the low Reynolds numbers of the motion; it can be shown that conventional lift forces resulting from fluid inertia considerations are relatively ineffective for these insects. It is generally surmised that microscopic insects sustain themselves through a differential drag procedure where an excess of drag on the downstroke as compared to the upstroke is presumed sufficient to oppose insect weight.

A bustle excitation concept is being investigated theoretically and experimentally along with several other fluid mechanics based differential drag schemes in order to increase our knowledge of insect aerodynamics and low Reynolds number fluid mechanics. A better understanding of insect flight will be of value in the study of micro-aerodynamics, to life scientists and possibly in understanding how to control insect populations.

National Radio Astronomy Observatory (West Virginia)—The facilities of the National Radio Astronomy Observatory at Green Bank, W. Va., include a 300-foot-diameter transit telescope, a 140-foot-diameter fully steerable radio telescope, a three-element array of 85-foot-diameter radio telescopes used as an interferometer, and a 36-foot-diameter millimeter-wave telescope at Kitt Peak, Ariz. In addition, the Headquarters Building in Charlottesville, Va., maintains computing facilities for data reduction, offices, library, etc. The observatory continues to have extensive use of radio astronomers and students from institutions throughout the country. Very long baseline interferometry experiments are being conducted in collaboration with other observatories both in this country and abroad. Notably, this year, such experiments have been jointly undertaken in cooperation with the Soviet Union.

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 continued 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.

The Arecibo Observatory (Puerto Rico)—This observatory, with the world's largest radio telescope of 1,000-foot diameter, was this year transferred to the NSF from the DOD. This huge telescope has made significant contributions in investigations both of characteristics of the Earth's atmosphere and in radio astronomy. The facility, as a national center, will now be made available to scientists and students from institutions throughout the country for wide range studies of radio sources and of atmospheric properties.

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.

Educational Activities—In fiscal year 1969 approximately $4.8 million was obligated by the Foundation's three education divisions for activities which were, either in whole or in part, related to aeronautic and space sciences. Since many of these awards were multidiscipline in nature—e.g., a project providing training in several disciplines—it is therefore estimated that approximately $2.95 million was awarded in fiscal year 1969 for education in the aeronautic and space sciences per se.

These funds provided for fellowships and traineeships, upgrading the subject matter background of teachers, training for students, and contributed through a varety of mechanisms to the improvement of education in aeronautic and space sciences in junior and senior high schools as well as institutions of higher education.

During fiscal year 1969 approximately one-half of the funds obligated by the three education divisions for aeronautic and space science-related activities had its principal impact on graduate education. The proportion was graduate education in the aeronautic and space sciences, 52 percent; undergraduate education in the aeronautic and space sciences, 13 percent; precollege education in the aeronautic and space sciences, 35 percent.

Over 3,500 individuals received training in the aeronautic and space sciences in projects supported by the three education divisions in fiscal year 1969. The majority of these individuals were teachers at the junior and senior high school level.

XIV National Academy of Sciences National Academy of Engineering National Research Council

Introduction

The National Academy of Sciences and the National Academy of Engineering are private organizations of scientists and engineers that serve as official advisers to the Federal Government under a congressional act of incorporation. These advisory services are carried out largely by the National Research Council, which was established by the Academy to act as an operating agency.

In terms of the objectives of the National Aeronautics and Space Act, the work of the Academies-Research Council is primarily concerned with the establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes; cooperation with other nations in these fields; and the most effective utilization of the scientific and engineering resources of the United States, with close cooperation among all interested agencies in order to avoid unnecessary duplication of effort, facilities, and equipment. Accomplishments of 1969 include publication of "Lunar Exploration: Strategy for Research, 1969–1975," "The Outer Solar System: A Program for Exploration," "Scientific Uses of the Large Space Telescope," "A Study of Technology Assessment, Civil Aviation Research and Development," "Useful Applications of Earth-Oriented Satellites," "Atmospheric Exploration by Remote Probes," and "Plan for U.S. Participation in the Global Atmospheric Research Program."

Space Science Board

The Space Science Board is a consultative group concerned with shaping the most effective national program in space research. On behalf of the National Academy of Sciences, it advises the Government on scientific aspects of the space program and represents the U.S. scientific community internationally on the Committee on Space Research (CoSPAR) of the International Council of Scientific Unions.

The Board met four times during 1969 to discuss outstanding matters in space research with NASA management and senior staff of the National Science Foundation, the National Aeronautics and Space Council, the 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.

Future Goals—The Board convened in executive session on June 21 and 22, 1969, to consider its response to the invitation of the Special Assistant to the President for Science and Technology for the Board's views on the future national space program. Discussion centered on the issues of the desirability of a future space goal, future manned spaceflight, the role of Earth-oriented applications, and the role of science. The Board's conclusions were embodied in a letter from the Board's Chairman to the Special Assistant to the President for Science and Technology dated June 23. Copies of the letter were also made available to the PSAC Panel on Space Science and Technology.

In the near future, a Space Science Board group will meet with the Division of Physical Sciences' Panel on Solid State Sciences to seek to devise means to improve the efficiency of solar cells, an energy source widely used in spacecraft instrumentation.

Lunar and Planetary Studies—A study on the exploration of the outer solar system was convened by the Board during June 1969 to recommend scientific priorities for investigations of the outer planets. Twenty-three scientists representing a wide range of disciplines participated and, as is customary, findings and recommendations were presented to NASA management at a final session. The report of the study, "The Outer Solar System: A Program for Exploration," recommends that NASA formulate a long-term plan for the exploration of the outer parts of the solar system and endorses earlier studies that call for substantially increasing the fraction of the total NASA budget devoted to planetary exploration. It itemizes seven prime scientific objectives of the exploration of the outer solar system and recommends, in order of scientific significance, a series of unmanned missions with conventional propulsion for the period 1970–79. The study calls for the development of a new spacecraft and for design studies of atmospheric probes, mass spectrometers, and imaging systems. Additional recommendations relate to ground-based studies, Earth-orbital observations, and the development of advanced methods of propulsion.

A study on the scientific objectives of lunar exploration was convened in August 1969 at Woods Hole, Mass. The report of the study, "Lunar Exploration: Strategy for Research, 1969–75," is based on the assumption that broad national policy will entail a continuing commitment to manned spaceflight. The participants recommended that the best use of the manned lunar-landing capability to realize the scientific objectives of lunar exploration should entail a shift of emphasis from the development of new technology to the exploitation of existing Apollo technology. The report supports modest extensions of this technology, including a surface mobility aid, and development of an automated traversing vehicle for later missions. It called for increasing the role of scientists in influencing basic policy and mission hardware, and increased attention to the problem of management, handling, distribution, and analysis of lunar samples returned to Earth.

Lunar Science Institute—As noted in last year's report, the Academy accepted responsibility for activation and initial operation of the Lunar Science Institute (LSI) adjacent to the Manned Spacecraft Center, Houston, until arrangements could be made for its permanent administration. The LSI provides an institutional base for visiting scientists in lunar research, with access to the unique facilities of the Lunar Receiving Laboratory. A consortium of some 48 universities, the Universities Space Research Association (USRA), is expected to take over the operation of LSI in the near future.

Large Space Telescope—"Scientific Uses of the Large Space Telescope," published in 1969, is the result of a 3-year study by a Space Science Board committee into the scientific function and practical feasibility of a telescope placed in Earth orbit or, conceivably, on the Moon. The report, which represents the ideas and suggestions of many astronomers, discusses the scientific advantages of a diffraction-limited telescope in space with an aperture of at least 120 inches, delineates scientific problems that are accessible only to such an instrument, and outlines the specifications thought to be essential to satisfactory performance.

Rocket Research—The Committee's Report, "Sounding Rockets: Their Role in Space Research," was issued in January 1969. Based in part on results of a questionnaire sent to some 200 rocket experimenters in the United States and Canada, the report appraises the relative advantages of sounding rockets as a research and educational tool, reviews the major scientific findings obtained by rockets during the past 3 years, and examines the current level of rocket support. The Committee recommends a 35-percent increase in support by 1971 and a 12-percent increase annually thereafter until about 1975.

Space Medicine and Biology—Early in 1969, a Committee on Space Medicine was constituted in response to a longstanding need for a permanent group of physiologists and medical and behavioral scientists to respond to questions and problems arising within the manned space programs of NASA The new committee is presently reviewing the Office of Manned Space Flight plans for space medicine in the Apollo and Apollo applications programs.

Comparable evaluations of NASA research programs are being made by the Cardiovascular Review Panel and the Radiobiological Advisory Panel. As a result of recommendations made in a Life Sciences Committee report, "Physiology in the Space Environment: Volume I, Circulation" (NAS Publ. 1485A, 1968), NASA has made certain commitments to research that have resulted in a rather broad program of investigation into the effects of the space environment—particularly long periods of weightlessness—on the heart and circulation. At the request of the agency, a small panel of cardiologists was organized to review the ongoing NASA research in this area on an approximately annual basis. The Cardiovascular Review Panel began its task at the Ames Research Center in February; a second review was held in Washington in December.

The use of nuclear propulsion for space missions, as recommended by the President's Space Task Group, will cause some increase in the radiation to which astronauts are exposed in the space environment. The Radiobiological Advisory Panel, whose members participated in the 1967 evaluation of "Radiobiological Factors in Manned Space Flight," has been asked by NASA to examine this added factor in terms of amount and type of radiation, dose rate, total allowable dose per mission, and allowable career dose. The study got underway at a 2-day meeting in October attended by AEC, FAA, industry representatives, and other interested parties.

A study on infectious disease in maned spaceflight was undertaken during July 1969 at Woods Hole on the request of NASA's Office of Advanced Research and Technology. The study explored the kinds of microbiological problems that may arise in flight, such as the spread of infections among the crew and changes in the immune response to disease, and estimated the potential hazards of an accumulation of microbes within the space cabin. It has long been recognized that certain factors in the space environment, such as artificial atmosphere, confinement, lack of exercise and of antigenic stimuli, radiation, and altered biorhythms, may influence the spread of microorganisms. The report of the study, "Infectious Disease in Manned Spaceflight: Probabilities and Countermeasures" (1969, in press), cites illnesses that have already arisen in flights to date and stresses the importance of a preflight isolation period for astronauts. Other recommendations include screening and microbiological surveillance of asronauts and subjects for microbiological research.

The problem of desynchronosis—the disruption of biological rhythms caused by flying across multiple time zones—has been assessed by an ad hoc panel of the Space Medicine Committee. This disturbance is commonly experienced by long-distance air travelers and pilots and is particularly serious because it affects decision-making abilities and performance. The panel has proposed specific experiments to determine the precise mechanisms and effects of desynchronosis; from the findings it should be possible to develop counter-measures to the problem.

Two reports on aspects of spacecraft bioengineering were issued during 1969. The "Report of the Panel on Atmosphere Regeneration," published in April, evaluates different methods for regenating breathable spacecraft atmospheres, such as algal, bacterial, and physical-chemical systems and makes recommendations concerning those that appear most promising for long-term manned missions. The "Report of the Panel on Management of Spacecraft Solid and Liquid Wastes," issued in November, concludes that systems and methods in this area are still primitive, and that substantial research and development will be necessary to qualify them for long-duration missions.

In the field of environmental biology, the Space Science Board conducted a summer study at the University of California, Santa Cruz, during the latter half of July. Approximately 30 members and 35 consultants representing both science and engineering participated. The objective of the study was to reassess the Nation's fundamental space biology program in the light of its 8-year-history, current and long-range plans, and the more important scientific questions confronting biology for which the space environment may provide a unique setting. The results of the study were communicated to NASA management at the conclusion of the study and will released in report form.

International Relations—While the Board maintains a continuing interest in worldwide space science, its formal international activities are centered in the Committee on Space Research (Cospar). Cospar, as an interunion organization of ICSU, fosters fundamental research in space science through the use of rockets, satellites, and deep-space probes. Data and significant results are exchanged on a cooperative basis through the World Data Center system. (In accordance with plans described in last year's report, WDC–A for rockets and satellites was transferred from the Academy on January 1, 1969, to the National Space Science Data Center at Goddard.)

The 12th annual meeting of Cospar took place in Prague, Czechoslovakia, May 11–24, 1969. Three major symposia were held: Dynamics of Satellites; Life Sciences in Space Research (Biological Rhythms and Nutrition in Man in Space); and Thermospheric Properties; and nine critical review papers on recent progress in various fields of space research were given in special sessions. The Cospar working group structure was reorganized in order to reduce the degree of overlapping interests that had evolved over recent years. As in past years, the SSB Committee on International Relations organized the U.S. participation in the Cospar meeting, reviewed U.S. contributed papers, and prepared the annual report to Cospar on U.S. space research during 1969.

The possibility of contaminating the Moon or planets with terrestrial organisms adhering to space probes has for some years been a matter of concern to the United States and other nations involved in space research, and thus to Cospar. The Cospar sterilization objectives, passed by resolution in 1964, include the request that member nations annually review these formulas for planetary quarantine in the light of new information and techniques. In 1969, the Space Science Board's annual review committee, meeting in Stanford on April 18, reaffirmed the validity of the Cospar sterilization objective and noted the progress being made in the refinement of some of the unknowns on which contamination probabilities are calculated.

Aeronautics and Space Engineering Board

The National Academy of Engineering's Aeronautics and Space Engineering Board is concerned with bringing the expertise of the national engineering community through study of major Federal policies and programs in aeronautics and space engineering. The Board recommends to the Government the priorities that it believes should be assigned to engineering objectives, proposes ways of applying engineering talents more effectively to aerospace problems of national importance, and suggests methods to improve education in aerospace engineering.

Early in 1969, the Board published six reports covering in greater detail the areas of civil aviation summarized in its report on "Civil Aviation Research and Development" (1968). These reports are "Flight Vehicles and Airbreathing Propulsion," "Aircraft Operations," "Air Traffic Control," "Airport and Support Facilities," "Economics of Civil Aviation," and "Aircraft Noise." Following its major study on civil aviation, the Board was asked by NASA and the Department of Transportation to organize an ad hoc advisory committee to assist those agencies in their joint study of civil aeronautical R&D policy. This committee was formed in late 1969 and is expected to function for approximately 15 months.

During 1969, the Board held several meetings with officials of NASA and the Department of Defense to discuss areas in which the Board might make a useful contribution to the national space program. Primary interest of the Board centered on space transportation system concepts. In this regard, the Board Chairman transmitted a letter to NASA and the Department of Defense in August 1969 presenting views of the Board on critical questions relating to the space shuttle system as an element of the national space program studied by the President's Space Task Group. The Board is continuing its plan to study engineering approaches to a space transportation system.

The House Science and Astronautics Committee has aimed to find better ways to understand and even predict the impact of technology on society. The Board was one of three groups within the National Academy of Engineering that contributed to the NAE report, "A Study of Technology Assessment" (1969), prepared at the request of the House committee. The Board convened a special panel which conducted a preliminary experimental assessment of the effect of subsonic aircraft noise on the growth of civil aviation. The assessment considered the various parties in our society who are affected by that noise and examined some alternative ways of maintaining the benefits of civil aviation while reducing the negative effects attributed to the concomitant noise.

Division of Behavioral Sciences

Committee on Hearing, Bioacoustics, and Biomechanics (Chaba)—A symposium on head injury was convened by the Committee on November 19, 1969, in Washington. Its objective was to investigate the problem of impact injury to the head, primarily in aviation; papers and discussion centered on the incidence and the physiological and behavioral effects of head injury, clinical management and rehabilitation, protection and prevention, and research underway or required. Concurrent symposia, also conducted by Chaba, were held on environmental noise hazards, and military problems in otology and audiology. The annual meeting of Chaba on November 20 included deliberations on the acoustic performance of high bypass engines and nacelle treatment, on effects of tones and tone combinations on perceived noisiness, and on the derivation of a predictive equation for estimating the level of annoyance of airport communities.

Planning is underway for the fifth annual meeting on vestibular function as related to space travel and a symposium on the effect of vibration and related forces on human performance. Both meetings, to be held in 1970, are jointly sponsored by NASA and Chaba. Final arrangements have been made for the selection and confirmation of authors and reviewers for the third revision of the "Bioastronautics Data Book."

The Committee has continued to advise NASA and the FAA on long-range research planning in aircraft noise and sonic boom as well as to evaluate the quality of current research and proposals for future work. Close working relations are maintained with the NAS–NRC Committee on SST-Sonic Boom, Office of Noise Abatement of the Department of Transportation, Task Force on Noise of the Committee on Environmental Quality of the Office of Science and Technology, and the Aeronautics and Space Engineering Board's Ad Hoc Committee on Noise.

Committee on Vision—At the request of NASA, a panel has been formed to review the NASA research program in vision with the purpose of identifying problem areas that should be investigated during the next 10 years. The Committee has also furnished advice to NASA on eye safety in the use of lasers and will continue to furnish information on this topic as new data are gathered.

At the request of FAA, a working group was formed to advise the agency on its research in collision avoidance devices. The group has reviewed research proposals for evaluating anticollision lights on the SST and will serve as a continuing advisory group for collision avoidance devices on general aviation aicraft. A major portion of the annual meeting of the Committee was concerned with visual problems in flying and air traffic control.

Division of Earth Sciences

Committee on Space Programs for Earth Observations Advisory to the Department of the Interior—The central concern of the advisory committee this year has been to help the Department prepare for use of data that will be acquired beginning in early 1972 by NASA's Earth resources technology satellite (ERTS) program. This focus lies within the broader responsibility of the Committee to advise regarding the Department's Earth resources observation satellite (EROS) program which is concerned with utilization of any available satellite data together with relevant aerial and surface surveys.

The Committee has reviewed in detail the Department's inhouse and contract projects which, at the present phase, are aimed at developing full capability of utilizing satellite data. The Committee also has helped in the evaluation of proposals for new projects in terms of their scientific merit and importance to the EROS objectives. In addition to the parent Committee, there are five subcommittees on geography, cartography, hydrology and water resources, geology and mineral resources, and oceanography and marine resources. These groups provide advice through roundtable discussions with Department personnel and letters addressed to the Director of the EROS program.

NAS–NAE Committee Advisory to ESSA—The NAS–NAE Committee Advisory to the Environmental Science Services Administration reviews and advises on ESSA programs. Such programs include applied research and development for Earth-satellite applications: The improvement of meteorological data input from satellites and satellite applications to geophysics, including hydrology, geodesy, oceanography, geomagnetism, seismology, cartography, photogrammetry, aeronomy, and ionospheric physics, as well as weather modification and data handling for weather and oceanographic needs as they are directly related to ESSA satellite programs.

Division of Engineering

Summer Study in Space Applications—The final report of the space applications study, held during the summers of 1967 and 1968, was published in 1969 as "Useful Applications of Earth-Oriented Satellites—Report of the Central Review Committee; Summaries of Panel Reports"; and 12 individual reports of panels. The Committee concluded that the potential benefits to mankind from unmanned Earth satellites is substantial enough to merit a doubling or tripling of Federal support, to an expenditure of $200 to $300 million a year. An extensive, coherent, and selective program of this magnitude would obtain these benefits within the coming decade. The evolution of booster and launcher technology, the improvement of guidance and controls, and the increasing lifetime of electronic equipment in space means that systems deemed uneconomic or even impracticable a few years ago now may be firmly within the payoff range. In meteorology and communications, satellites have already entered solidly into the area of economic usefulness.

Applications in two other broad fields are imminent. The first includes communications, navigation, and traffic control, in which the satellite's unique advantage of direct line-of-sight coverage of large geographical areas makes possible the design of communications systems of extraordinary scope and versatility. In this category, high priority was recommended for the development of three programs: (1) A multichannel distribution system for public and private network television broadcasts. (2) A multichannel system for educational broadcast use in developing countries and for programing to special interest groups such as physicians, lawyers, engineers, and educators. Immediate development of these broadcast systems was urged because they are so easy technically, so reasonable economically, and so potentially desirable. (3) a North Atlantic satellite navigation system for en route traffic control of transoceanic aircraft and ships. Its international use for shipping alone would be likely to pay for the cost of the system.

The second broad category of imminent use is Earth sensing, in which instruments aboard satellites report on thermal radiation from land, sea, clouds, and atmosphere, recording the information in photographs or on tape, or relaying it directly back to Earth by radio. The ultimate uses of such information will be diverse, ranging through agriculture, water-resources management, metropolitan planning, and geography. Practical use of these imaging sensor satellites lies in the near future, but is dependent upon research and development in sensor signatures—in the form of information provided by the instruments. The report recommended an immediate pilot program for providing information in familiar and immediately usable pictorial form, exploration into the use of side-looking radar, and the start of a 10- to 12-year development plan for more sophisticated sensors.

The study considered, and rejected, manned missions, believing the practical benefits will generally be achieved more effectively and economically with automated devices. Manned programs must be justified in their own right; they cannot be justified in terms of space applications.

One major conclusion was that organizational problems, both national and international, must be solved before the full potential can be realized of the many projects that the Committee found otherwise to be feasible.

National Materials Advisory Board—The National Materials Advisory Board, established in January 1969 has as its general purpose the advancement of materials science and engineering in the national interest. More specifically, it undertakes to define technical problems, potential solution approaches, and opportunities of national concern and relevance to government, industry, or academia, attempting thereby to stimulate appropriate action.

The problems of aerospace materials command a large part of the Board's attention and effort. Most of these problems stem from (1) the requirements for structural materials that will withstand the high heat of reentry and (2) the great premium placed on weight-saving requires space structures to be designed to utilize materials to their maximum property limits, with margins for imperfections approaching zero. This in turn creates need for nondestructive evaluation methods that are capable of providing quantitative measures of material integrity.

The following NMAB studies, completed or underway in 1969, relate directly to the materials problems of aerospace. "Coatings for High Temperature Oxidation Protection of Superalloys, Refractory Metals and Graphite" will be published by the Academy early in 1970. A report is now in preparation on the atmospheric deterioration of superalloys, particularly in aircraft turbine engines, and a report is being prepared for the Air Force on new techniques for systematic selection of optimal materials for specific applications and for definition of the materials test data necessary for screening, selection, and design. Report NMAB–252, "Nondestructive Evaluation," recommends application of advanced nondestructive testing techniques to assure integrity of structures. Studies have been initiated to assess the needs for beryllium and to define the appropriate government and industry roles in the advancement of beryllium technology; to achieve more rapid utilization of advanced materials; to explore new and more effective methods for the accelerated testing of materials to assure long-term reliability; and to develop improved methods for technological forecasting in the area of engineering materials.

Division of Physical Sciences

Committee on Atmospheric Sciences—The Committee on Atmospheric Sciences undertakes reviews and studies in research and technological areas for which particular needs or potential have emerged. Scientific fields that have received recent attention are weather and climate modification and remote atmospheric probing utilizing both ground- and space-based techniques. This latter study is fully reported in the two-volume document "Atmospheric Exploration by Remote Probes" (NAS, 1969). The study on intentional and unintentional weather and climate modification will be completed early in 1970. In addition, a report on "Educational Implications of the Global Atmospheric Research Program," dealing with key educational problems in the atmospheric sciences, was completed and widely distributed to academic centers and Federal agencies.

The Committee will coordinate with the USC-Global Atmospheric Research Program (see below) an examination of the status of monitoring of the gaseous and particulate composition of the atmosphere in light of the possible local, regional, or global effects that composition or concentration trends may have on both the short- and long-term aspects of weather and climate. It would be anticipated that any monitoring programs designed to obtain spatial and temporal quantitative information will require observations utilizing both remote and *in-situ* measurement techniques. Plans will soon be made for a major review of the entire field of atmospheric sciences to ascertain the progress, problems, and prospects that have occurred during the past decade; the present balance in research and educational programs; and the scientific, technological, and manpower requirements for addressing critical atmosphere problems and processes that impinge on the present and future environmental issues before the nation.

U.S. Committee for the Global Atmospheric Research Program—The objective of the GARP is to increase our knowledge of the dynamics of the general circulation of the terrestrial atmosphere, with the ultimate aim to develop a sound physical and mathematical basis for extended predictions of the larger scale motions of the atmosphere. The U.S. Committee for GARP, established in March 1968, is serving as the principal mechanism for developing scientific objectives, observational requirements, and initial technological feasibility evaluations; for coordination and communication between the scientific community and the Government; for review and advice on detail project design and planning; and to serve as the U.S. link to developing international scientific activities.

The Committee has submitted its first planning report to the Government which is now reviewing the planning, research and development, logistic, scheduling, and costing aspects of the plan. The report, "Plan for U.S. Participation in the Global Atmospheric Research Program" (NAS, 1969), recommends several theoretical and field research programs over a period of 5 years that will permit advances in the science and observational techniques to guide the details and plans for a global examination of the entire system of atmospheric large-scale dynamics. Observational platforms will include a judicious mixture of land and ocean surface platforms, aircraft, balloons, and polar-orbiting and geosynchronous meteorological satellites, in an observational system to which international participation will contribute.

Committee on Radio Frequency Requirements for Scientific Research—The Committee serves as a channel for coordinating the knowledge and views of the U.S. scientific community regarding the radio frequencies needed for scientific research, particularly in space research, radio and radar astronomy, and oceanography. A Subcommittee for Space Science was established in 1969 to deal with frequency matters pertaining to space research. There are two other subcommittees, one on radio astronomy and the other on Earth and life sciences. The subcommittees and committee have been active during the past year in reviewing and commenting on the proposed U.S. views for the World Administrative Radio Conference of the

International Telecommunications Union, to be held in Geneva in June 1971, on matters pertaining to the radio astronomy and space services.

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 NASA international university fellowship program has as its objective assistance to foreign nations in the peaceful exploration of space. To this end, the fellowships provide an opportunity for promising young scientists and engineers to study and participate in research in the space sciences at leading universities in the United States. The fellowships are cooperatively financed by NASA and by the foreign sponsoring agency which selects and supports foreign graduate students and postdoctoral scientists. Appointments are usually for 1 year, and may be renewed for an additional 12 months, for study and research at one of the 33 participating U.S. universities. From the start of the program in 1961 to December 1969, there have been 244 fellows from 20 countries, at 29 U.S. universities. During 1969 there were 87 fellows (72 graduate and 15 postdoctoral) from 14 countries, at 21 U.S. universities.

Through the resident research associateships, postdoctoral scientists and engineers of unusual ability and promise hold temporary appointments in NASA research centers. The purposes of the program are (1) to provide these appointees with an opportunity for research on problems largely of their choice in association with selected members of the permanent professional laboratory staff, and thus (2) to contribute to the general research effort of the laboratory. Through the associates the program provides a method for dissemination of space knowledge from NASA laboratories to university graduate training centers and enhances exchange of scientific knowledge with other countries. In addition, through associates, the program makes available to the scientific and engineering community some of the unusual or unique research facilities that exist in NASA centers.

Since the beginning of the program in 1959, appointments have been held by more than 550 postdoctoral scientists and engineers representing about 37 countries. At the end of August 1969, there were 174 associates on tenure at the participating NASA centers.

Committee on SST-Sonic Boom

During 1969, the Committee noted progress made on the national sonic boom research program. The Interagency Noise Abatement Program Organization (IANAP), in endorsing the recommendations made in earlier Committee reports, provided a basis not only for orientation of Federal sonic boom research but also for those portions of the national program placed on contract and grant to universities and other research organizations, principally by NASA, FAA, and USAF.

In response to a request from FAA, the Committee established a Subcommittee on Aircraft Noise Research to determine the research required to reduce noise from large engines such as those used in the SST. Although the Committee agreed that research underway was excellent, the members concurred in the need that it be greatly augmented. In this connection, the Subcommittee concluded that a better understanding of the basic mechanism of jet noise production was required for the class of engine to be used in the SST if more effective noise suppressors are to be evolved. Engine research, for example, should aim toward increasing engine airflow per unit weight while reducing fuel consumption, with efforts focused on high mass flow, lightweight compressors and turbines, and improved turbine cooling techniques.

With respect to jet noise and its suppression, the Subcommittee stated that the fundamental gas dynamics and acoustics of both subsonic and supersonic jets require more attention, leading toward improved quantitative understanding and noise prediction. Moreover, since the way in which present noise suppression devices work is not well understood, their mode of operation is controversial and their scaling laws are uncertain, additional research was recommended to achieve a quantitative understanding and predictive capability for more effective, practical and sound-suppression devices. Specific recommendations included studies, both theoretical and experimental, of the overall structure and turbulence levels of supersonic jets and the fluid mechanics and acoustics of multiple jets, including measurement of turbulence levels between jets and any acoustical interference effects that may occur.

XV The Smithsonian Institution

Introduction

The Smithsonian Institution is actively engaged in a variety of projects which are contributory to the national aeronautics and space program.

The space-related activities are being conducted by the Smithsonian Astrophysical Observatory (SAO), the Center for Short Lived Phenomena (CFSLP), the National Air and Space Museum, and the National Museum of Natural History.

Smithsonian Astrophysical Observatory

Since the mid-1950's SAO has been deeply engaged in space activities. During 1969 it continued to make significant contributions to space research and to develop plans and programs aimed at maintaining world leadership in its areas of competence.

SAO developed, built, and now operates the ultraviolet television instruments carried by the first successful Orbiting Astronomical Observatory (OAO–2). Gamma-ray telescopes are in advanced stages of development, and work has started toward follow-on ultraviolet astronomy and toward hydrogen-master experiments in space to test the theory of relativity. The Observatory operates ground-based facilities to define the meteoroid environment in space, to make lunar and planetary observations supplementing spacecraft missions, and to analyze samples of extraterrestrial materials. SAO is a recognized leader in geoastronomy, the study of the Earth by space and astronomical techniques. It is responsible for internationally adopted atmospheric and geodetic models. A major effort is under way to apply new laser, radio, and maser instruments and observing techniques. Accurate observations and sophisticated computer usage allow investigations of the dynamical behavior of the earth: tides, earthquakes, continental drift, polar motion, irregular earth rotation, and the interrelation of these.

Observations Supporting Space Projects—SAO operates extensive instrument networks in support of space projects. Its Baker-Nunn cameras acquired satellite-tracking data for atmospheric, geodetic, and earth physics objectives. Together with other data, these have led to the production of a new reference atmosphere model and a new set of geodetic parameters for a standard earth. Both are being prepared for publication in 1970.

During Apollo flights, certain space operations generate clouds of icy particles that follow their own orbits. The Baker-Nunn cameras photographed several of these clouds; the films were analyzed to investigate the behavior of the clouds.

Implementation of a satellite-tracking network of laser systems progressed through field tests of the first of three new systems built for the Observatory. Results from another SAO laser were compared with those from a NASA/GSFC laser system collocated at Mount Hopkins to check the accuracy of the systems. As the operational emphasis has changed from camera to laser tracking, five of the 12 Baker-Nunn instruments have been taken out of routine operation.

Very long baseline radio interferometry is a recently developed, extremely accurate technique that can be adapted to measure angles between radio stars and spacecraft. The Observatory assembled and put into operation two data-recording systems for such measurements. One is installed, with a hydrogen-maser clock, at the joint Smithsonian-Harvard radio telescope at Agassiz, Mass. The second can be transported to another radio telescope thousands of kilometers distant from Agassiz.

An optical telescope of 60-inch aperture was installed at SAO's Mount Hopkins site in Arizona. The program of planetary observations begun in Massachusetts will henceforth be continued with this new instrument under the superior observing conditions in Arizona.

Meteor observations in Illinois by radar and television techniques produced data that give new insight into the meteoroid environment around the Earth. In particular, previous estimates of the meteoroid population versus particle mass must now be revised for small particles.

The network of meteor cameras in the Great Plains of the United States collected photographs showing, ever more conclusively, the surprising fact that very large meteoroids (tons) are predominantly fragile bodies that fragment completely into tiny particles when the body hits the atmosphere. The observed number of these large masses exceeded expectations by an order of magnitude.

Project Celescope—After nearly a decade of painstaking design and development, OAO–2 was launched on December 7, 1968. It carries SAO's "Celescope." A cluster of four Schwarzchild f/2 telescopes, Celescope takes television pictures of stars in four regions of the far-ultraviolet spectrum between 3200 and 1050 angstroms. Transmitted to ground by telemetry, the pictures are analyzed to yield the brightnesses of individual stars in the four wave-lengths bands. During 1969 Celescope was in operation roughly half the time, the other half being used by the Wisconsin experiment, which shares space aboard OAO–2.

During 1969 the instrument's television photometers measured the ultraviolet brightnesses of more than 17,000 stars. Preparation of the first volumes of an extensive ultraviolet-star catalog is nearing completion.

One of the first findings from the Celescope experiment was that about half the observed stars are significantly fainter in the utlraviolet than was predicted. A study of the types and positions of these stars indicates that this is probably an inherent property of the stars rather than a result of absorption in the interstellar medium.

The shortest wavelength band, which includes the Lyman-alpha line of atomic hydrogen, had provided information on the Earth's outer atmosphere. The intensity of the Lyman-alpha radiation from the geocorona is at maximum when the Sun is near the horizon as seen by the spacecraft, and at minimum when the Sun is in the nadir.

Collection and Analysis of Extraterrestrial Materials—Through the good offices of (CFSLP) whose activities are reported in detail below, the Observatory was able to begin analyses of the Allende, Belfast, Police, Alandroal, and Murchison meteorites within a few days of their falls. This promptness is particularly important if a meteorite's radioactive constituents having short half-lives are to be accurately measured.

Of particular interest was the Pueblito de Allende meteorite since it is the largest of the 27 carbonaceous chondrites known to have fallen. Its most unusual feature is the isotopic composition of the xenon in its chondrules, tiny spherical globules of material that looks like rock once melted but now embedded in a fine-grained dust-like matrix. Measurements at SAO indicated that the xenon in the Allende chondrules was almost pure xenon-129. Since this probably came from now long-extinct radioactive iodine-1129 (which was created when the elements were formed), Allende must have been created very soon after the formation of the elements.

From the relative amounts of stable argon-38, and radioactive argon-39, SAO scientists found that Alandroal, an iron meteorite, had been exposed to cosmic rays for 33 million years, whereas most iron meteorites have been exposed between 200 million and 2 billion years.

Even more interesting are the implications of the ratio of argon-37 and argon-39, which in an iron meteorite is controlled by the changes of cosmic-ray intensity. Being only 0.50, this ratio suggests that cosmic-ray flux is greater with increasing distances from the Sun and confirms measurements made by the Mariner 4 space probe that showed a 10 percent increase per astronomical unit. These results, when compared with those on the Bogou iron meteorite that fell in 1962, show that the increase was greater in 1968 (near sunspot maximum) than it was in 1962 (near minimum).

Two laboratories at SAO that have studied meteorites are now also analyzing lunar samples returned by Apollo 11. In one, measurements of radioactive isotopes in three 10-gram samples indicate definite similarities between lunar material and chondritic meteorites. Also, the cosmic-ray exposure age of lunar rocks has been determined to be between 200 and 375 million years, 10 times older than that of most chondrites. These results have been substantiated by analyses of laboratories elsewhere. Also, there seems to be a difference between the tritium content of the soil and that of interiors of rocks.

In the other SAO laboratory, probe data on selected fragments of 16 grams of lunar samples permit distinction between highland and mare materials. In addition to broken basalt from the Tranquility base, pieces of lighter colored highland material tossed into the area by meteorite impact were found. The highland material more closely resembles terrestrial rock in density and composition than does the mare material, the latter being more dense than any normal terrestrial rock. Small droplets of iron meteorites were also found in the samples; these are apparently debris of impact by iron meteorites.

Center for Short Lived Phenomena

During 1969, the CSLP participated in a number of activities relating to the space sciences.

Meteorite Recoveries—In the 10-month period, January 2 through October 20, 1969, the CFSLP was responsible for the recovery of five freshly fallen meteorites from Portugal, Mexico, Ireland, Czechoslovakia, and Australia. Recovery time (from date of fall to arrival at the Smithsonian Astrophysical Observatory Laboratories) ranged from 4 to 31 days with the average recovery time being 17 days.

In addition, the Center coordinated a series of field expeditions to the Allende, Mexico, meteorite shower which resulted in the largest collection of stony meteorite material in history. This material is now under study at no less than 34 laboratories throughout the world.

The Transient Lunar Phenomena Observing Program—Under contract to NASA the CFSLP coordinnates communications for an international network of 216 professional and amateur astronomers located in 34 countries and 14 states for the purpose of making systematic observations of the lunar surface for transient lunar phenomena (TLP) during manned lunar landing missions.

Contacts are made with individual astronomers 6 weeks prior to the missions. Operations plans and observing schedules are sent to all observers outlining communications procedures, communications codes and cable formats to insure rapid response, data continuity, and positive identification of teletype routing codes and telephone numbers. Arrangements are made for telephone contact with 46 North American observers and the Manned Spacecraft Center on a 24-hour-a-day basis during missions. Foreign observer contacts are by commercial cable, teletype, Navy and Nascom circuits, and international telephone.

In order to make systematic observations of the lunar surface during selected time periods to insure redundant observing coverage and to obtain independent corroboration of possible TLP observations by both ground-based observers and the astronauts, a selected lunar feature observing program is scheduled. The purposes of a prescheduled observing program is to insure observation of (1) lunar areas with a known history of TLP observations; (2) lunar areas observable from the spacecraft during approach and departure from the Moon; (3) the lunar landing site area during the period that the astronauts approached the site, landed on the Moon, and departed from the Moon; and (4) selected lunar areas that the astronauts could observe during the lunar orbit phase of the mission.

The observing programs cover 10 discrete periods from liftoff to splashdown but with special emphasis placed on the 110-hour period when the astronauts approach the Moon, orbit the Moon, land on the Moon and begin their return to Earth.

It is particularly worthwhile to organize intensive global lunar observing programs during manned lunar missions for serveral reasons: they provide short time periods (8 to 10 days) when there is greater than usual interest in the Moon and during the lunar approach, lunar orbit, and lunar departure phases of the missions when there are opportunities for astronaut observation and photography of lunar areas where transient events may be reported to be taking place. Conversely, if the astronauts observe anything unusual on the lunar surface, they could communicate this information to Earth which would enable ground-based astronomers to attempt to make observations of these phenomena. Through preplanned, concentrated observing efforts, the network has the capability of keeping the lunar surface under 24-hour-a-day surveillance for short periods of time. The main objectives of these observing programs are to record the nature, magnitude, frequency, and distribution of transient lunar phenomena and possibly obtain independent corroboration of events from widely separated ground-based observatories.

The CFSLP produced 10 reports on the transient lunar phenomena observing program, seven of these contain detailed documentation of all transient lunar events reported to the Center during these missions.

Major Fireball Events—The CFSLP participated in the investigation of 17 major fireball events that occurred in 10 countries and seven states during 1969. These investigations included contact with event areas by telephone and cable, collecting eyewitness reports of magnitude, direction, duration, color, sound phenomena, and impact locations where they occurred. The reports were telephoned and cabled to interested scientists throughout the world who made on the spot investigations of nine of the 17 events.

National Air and Space Museum

The National Air and Space Museum has been the recipient, under the terms of the 1967 agreement with NASA, of significant aerospace "artifacts." Placed on public view during 1969 were: Apollo 4 Command Module, X–15 aircraft, Surveyor and Lunar Orbiter spacecraft, Saturn V–F and J–2 rocket engines, and an Apollo 8 astronaut's spacesuit. A 1-pound lunar rock from Apollo 11 flight was placed on display in September.

Such exhibits of space materiel have attracted enormous public interest, evidenced by increased annual attendance to more than 2 million visitors in 1969. Appropriate display of aerospace artifacts, however, has become increasingly difficult in the temporary exhibit areas available in the Arts and Industries Building and adjacent metal service shed.

Other spacecraft and memorabilia have been loaned to appropriate museums and organizations in the United States and abroad. Overseas loans are coordinated with U.S. Information Agency and Department of Commerce. At the request of USIA a major collection of space artifacts has been loaned for display at the U.S. Pavilion at Expo 70, Osaka, Japan.

National Museum of Natural History

Some of the activities of the National Museum of Natural History's Department of Mineral Sciences are also space related. These include investigations of meteorites; mapping and geologic studies of large terrestrial craters as analogs of lunar and martian craters; and mineralogic, petrographic, and chemical analyses of lunar material (by contract with NASA).

Specifically, in 1969, we can report the following activities. On February 8, a large meteorite fell near Parral in Mexico; Smithsonian scientists were on the scene on February 12, and spent a week investigating the circumstances of the fall, and collecting a large amount of material. It is now apparent that this is one of the largest stone meteorites ever to fall; being also of a rare type, it is in great demand for research, and we have distributed material to over forty scientists, both U.S. and foreign. Since late September most of the staff of the Department of Mineral Sciences has been actively engaged in the investigation of lunar material brought back by Apollo 11; this work will be continued on the collections of Apollo 12 and later missions.

Experiments to determine the feasibility of utilizing satellites to track the movements of large animals and to obtain related data were begun in June 1969, by the Smithsonian Institution, with the University of Montana, New York State University, and the Goddard Space Flight Center. Lightweight apparatus attached to a free-moving elk will measure the skin temperature of the animal as well as ambient environmental factors and transmit them to the Nimbus satellite upon interrogation. The orbital characteristics of the Nimbus III should enable at least two interrogation sequences per day, approximately 12 hours apart. The satellite will keep daily records of the movements of the elk and of weather and travel conditions all of which will be checked against fixes obtained from a ground tracking system. These experiments will provide a basis for perfecting the satellite tracking technique and at the same time producing useful information toward a better understanding of the behavior of elk in relationship to weather, seasonal changes, migration stimuli, herd composition, habitat requirements and range conditions.

XVI Federal Communications Commission

Introduction

The global commercial satellite communications system continued to expand. The International Telecommunications Satellite Consortium (Intelsat) membership increased by seven additional countries to a total membership, as of December 31, 1969, of 70 countries. Two additional Intelsat III satellites were put into service over the Atlantic and Pacific Oceans and Intelsat III launched in 1968 was moved to the Indian Ocean. Twenty-one additional Earth terminal stations became operational during the year, making a total of 43 stations in 27 different countries.

Regulatory Activities

The Communications Satellite Corporation (Comsat) was authorized to participate with the International Telecommunications Satellite Consortium in the construction of two Intelsat III satellites in addition to the six previously authorized. The first of the Intelsat III satellites was destroyed in a launch failure in September 1968. The fifth satellite, launched in 1969, suffered a launch failure.

The communication satellite system was expanded to provide coverage of the Indian Ocean region, so that now communications via satellite is available over the Atlantic, Pacific, and Indian Oceans, providing service to some 48 countries by the end of the year. The total circuits of the system has increased by some 815 circuits to about 1,416 circuits.

The expansion of the system was made possible through the use of the larger capacity satellites of the Intelsat III series and additional Earth stations becoming operational around the world. In the first quarter of the year, Atlantic region coverage was provided through the Intelsat III F–2 and Intelsat II F–3 satellites; Pacific region coverage was provided through the Intelsat III F–3 and Intelsat II F–2 and F–4 satellites. About midyear, the III F–3 satellite was moved to provide service in the Indian Ocean region. The system was operating in this configuration at the year's end.

Of the 19 new Earth stations put into service during the year, three were in the United States—in West Virginia, California, and Puerto Rico. A second antenna was completed and made operative at the Hawaiian Earth station complex and construction of Earth stations was authorized in Alaska and Guam. At year end there were 36 Earth stations located in 24 countries.

Additional comments were filed by various companies in the Commission's 1968 domestic satellite notice of inquiry. These are presently under consideration by the Commission.

International Radio Consultative Committee

An international interim meeting of Study Group IV (Space Systems and Radio Astronomy) of the CCIR was convened in September 1969 at Geneva. The CCIR, encompassing 14 such study groups, serves as an adviser to the ITU (International Telecommunication Union) on technical matters involving the use of radio. For the study Group IV meeting, an FCC member served as International Chairman of Working Group IV–B, dealing with problems concerning the sharing of frequencies by the space services and terrestrial services. Developments of major interest included (*a*) the continuation of an international working party (IWP) with a U.S. representative provided by the FCC, which completed its initial tasks of issuing a report on the efficient use of the geostationary orbit for satellites; (*b*) the adoption of a further refined report on satellite broadcasting; (*c*) the development of documents on the use of frequencies above 10 GHz, including sharing; (*d*) the introduction, through a report, of a discussion of the advantages of escalation of the permissible power flux density from satellites as a function of angle of arrival at the earth and (*e*) the adoption of a number of reports on the use of satellites for providing radiocommunication with aircraft and ships.

The Commission will provide participation in a special interim meeting of CCIR Study Group IV to be convened around 4 months prior to the forthcoming World Administrative Radio Conference (WARC) on Space, scheduled for June 1971. Plans for intensive preparation for this meeting have been scheduled so that the resulting documentation will be responsive to the needs of the space conference.

Maritime Mobile Service

The Commission, working with the Intergovernmental Maritime Consultative Organization (IMCO) Subcommittee 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 ATS–3 satellites between U.S. ground terminals and the merchant ship SS *Santa Lucia* en route 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 Commission is analyzing the results of these and other test programs, and study reports to determine their validity and potential for satisfaction of maritime communications requirements and to establish the parameters for the additional test and study programs that may be required. Additionally, working with the RTCM, the staff is developing a program plan for the evolutionary development and implementation of marine communication systems using space techniques.

The ITU World Administration [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.

A government-industry program has resulted in the establishment and documentation of a comprehensive statement of operational requirements which is being used as guidance in the development of the evolutionary program plan.

Commission staff representatives participated in the preparation of guidance material for and served on the U.S. delegation to, inter alia, the CCIR interim meeting, Geneva; IMCO Subcommittee on Radiocommunications, fifth session, London; CIRM Technical Committee meeting, Majorca; and the RTCM annual assembly meeting, Cleveland, at all of which system planning criteria and/or technical considerations were discussed.

The Commission has issued a notice of inquiry in docket No. 18294 in preparation for a World Administrative Radio Conference (WARC) on Radio Astronomy and Space Services to be held by the ITU in 1971. The Conference agenda will also include consideration of maritime communication needs using satellite techniques. The ITU radio regulations (para. 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.

Present efforts are directed, in particular, to the problem of feasibility of the sharing of systems and/or subsystems between aviation and marine services; feasibility of sharing of frequency bands for commonality (particularly for search and rescue); problems of terrestrial and space systems sharing frequencies; and preparation of documentation in advance of the forthcoming ITU Space WARC. Preconference coordination with other administrations is in progress.

Aeronautical Development

The Commission, in discharging its statutory responsibilities with respect to nongovernment uses of radio for aviation, prescribes the manner and conditions under which frequencies may be assigned for aeronautical telecommunications. This includes flight-test telecommunications and telemetry functions used in the development and production of missiles, rockets, and satellites as well as aircraft. In addition the Commission assigns frequencies to aircraft radio stations, aeronautical en route, 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), toward 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 assess the relative merits of AM versus FM emission techniques and normal power versus substantially higher power aboard aircraft as elements between a communication aeronautical station and aircraft via satellites. The Commission staff continued study of the results of those tests as well as the results of studies such as the Comsat contracted industry report of the program in order to determine the most suitable techniques to be used in aeronautical satellite systems.

The Commission staff representatives have participated in the preparation of 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, which treated, inter alia, aeronautical satellites. The staff is preparing documentation for the forthcoming International Telecommunication Union conference.

The Commission authorized 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 satellites, over both the Atlantic and the Pacific between ground terminals and aircraft. Continued testing and analysis of the results is in progress.

Further test programs, particularly in regard to UHF usage and technology are being prepared.

Amateur Radio Service

A group of radio amateurs, the Radio Amateur Satellite Corp. (Amsat), plans to launch the fifth OSCAR (orbiting satellite carrying amateur radio) built by Australian amateurs and dubbed Australis OSCAR–V on a NASA Thor Delta vehicle. The satellite will be placed in a circular polar orbit at an altitude of about 800 miles. Launch is currently scheduled for early in 1970.

The satellite contains a 144-MHz, 50-milliwatt beacon and a 29.4-MHz, 250-milliwatt beacon. The 29-MHz beacon may be turned on and off by a 147.8-MHz ground command signal. The operation has been authorized by the Commission.

Radio Astronomy and Space Services

The Commission has been in continuing consultation with the Office of Telecommunications Management and the Department of State in the preparatory work for the forthcoming ITU (International Telecommunication Union) World Administrative Radio Conference (WARC) on matters pertaining to radio astronomy and the space services. The ITU Administrative Council, in 1968, adopted a resolution calling for such a conference and set forth a tentative agenda for comments. The date on which it will convene has now been set for June 7, 1971, to run for 6 weeks. In response to the resolution, the FCC issued a notice of inquiry (docket 18294) in August 1968, which dealt with (*a*) the Conference agenda; (*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.

Three additional notices of inquiry were issued as the preparatory work progressed. The last of these to date, the fifth notice of inquiry released August 27, 1969, was accompanied by a comprehensive document entitled "Preliminary Views of the United States of America for the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971)." The latter document has also been transmitted abroad by the Department of State to elicit the comments and reactions of other member countries of the ITU.

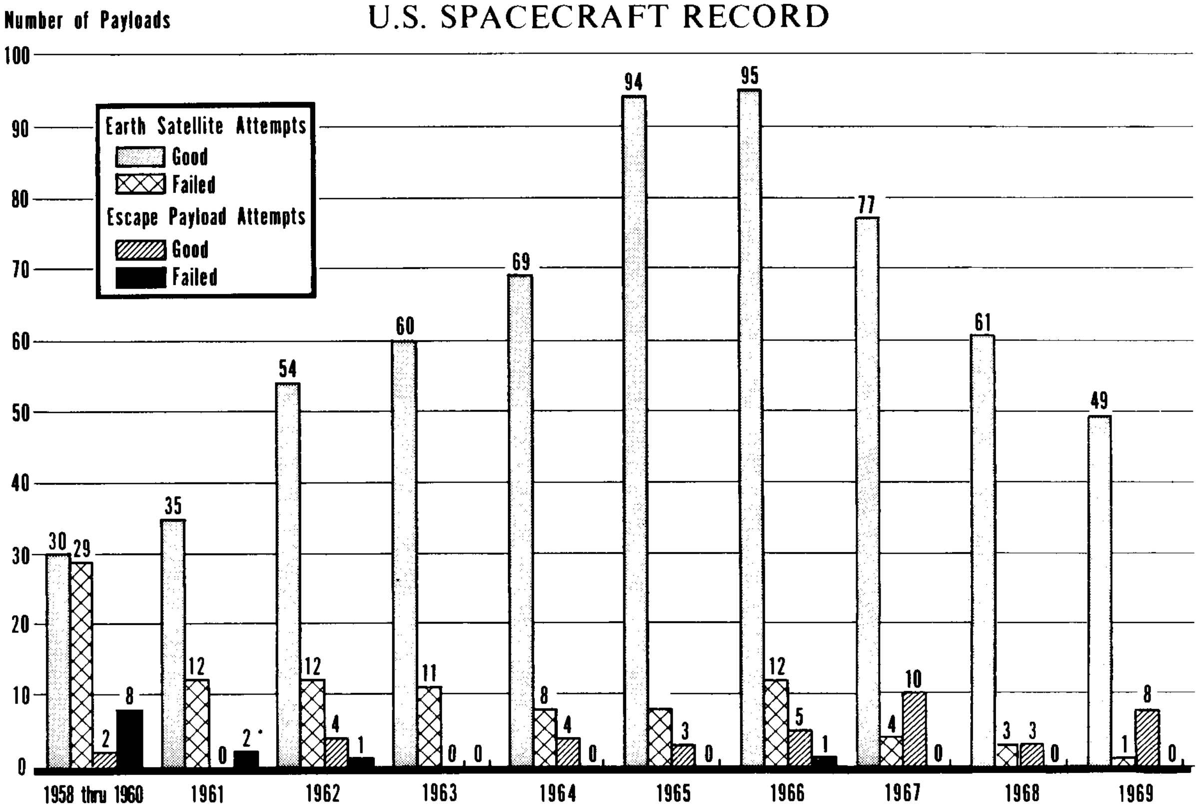
Broadcasting Policy Coordination

The FCC provided an adviser on the U.S. delegation to the United Nations Working Group on Direct Broadcast Satellites, second session, which was convened in Geneva in July 1969. A report of this session, among other things, urged continuing international cooperation in the area of direct satellite broadcasting in recognition of its important potential role in providing improved education and health benefits, greater flow of news and information, including cultural programs, and the development of closer ties between people, nationally and internationally. It was recommended that the U.N. Outer Space Committee should consider, in particular, technical aspects, international legal questions, contents of broadcasts and organizational matters.

FCC participation is also being provided on Panel 1, Ad Hoc Intragovernmental Communication Satellite Policy Coordinating Committee, under the aegis of the Office of Telecommunications Management (OTM). The Panel considers matters such as satellite broadcasting from the standpoint of national policy. In addition, the Commission coordinates closely with the OTM and other agencies on aeronautics and space matters of mutual concern, on a continuing basis.

Appendix A–1

U.S. SPACECRAFT RECORD



* INCLUDED IN EARTH SUCCESSES

NASC STAFF

Appendix A–2

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
1969	50	1	8	0
Total	625	101	39	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	'69	Total
Spacecraft	2	1	3	3	7	21	18	38	73	51	67	74	70	428

Notes: U.S.S.R. tabulation combines successfully launched Earth-orbit and Earth-escape spacecraft. In the total of 428 are included 25 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—1969

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. 22 OSO–V Thor-Delta	Objective: To obtain high-spectral resolution data from pointed experiments from approximately 1 to 1,250 Angstrom during at least 1 solar rotation period including roster scans of the solar disk in selected wave lengths; to obtain extended observation data from the nonpointed experiments of single lines and solar flares. Spacecraft: Revolving 9-sided polyhedron 44-in. diameter and 15-in. high with sun-pointing 22-in. radius semicircular sail; spin stabilized; 26-watt solar cell power supply; weight: 636 lbs.	353 338 95. 8 33. 0	Continues OSO I, II, III and IV investigations of the Sun. Spacecraft carried 8 experiments. All functioned normally.
Jan. 22 Defense 7A Titan IIIB/Agena	Objective: Development of space flight techniques and technologies. Spacecraft: Not announced.	672. 5 92. 0 96. 9 106. 1	Decayed Feb. 3, 1969.
Jan. 30 ISIS–I 9A Thrust-augmented Thor-Delta	Objective: To obtain information about the ionosphere in the region above the F-layer maximum; the distribution of free electrons and the various species of ions as a function of time and position; the composition and fluxes of the energetic particles which interact with the ionosphere; and the velocity distribution of thermal electrons and ions. Spacecraft: 8-sided oblate spheriod with diameter of 50-in and height of 42-in.; spin stabilized; 90 watt solar cell power supply; weight: 520 lbs.	2, 186 356 128. 3 88. 4	This is the third in a series of 5 spacecraft in a joint United States-Canadian ionospheric research program. Nine of ten experiments functioned normally; 10th experiment functioned partially. Mission judged successful.
Feb. 5 Defense 10A Thor/Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	171. 0 91. 7 88. 7 81. 6	Decayed Feb. 24, 1969.
Feb. 5 Defense 10B Thor/Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	894. 9 866. 4 114. 1 80. 4	Still in orbit.
Feb. 6 Intelsat III (F–3) 11A Thrust-augmented Thor-Delta	Objective: To provide equivalent of 1,200 two-way voice circuits or 4 color TV channels to carry commercial communications traffic between the United States, Hawaii, and the Western Pacific. Spacecraft: Cylindrical 56-in. diameter and 78-in. high; spin-stabilized; 300-watt solar cell power supply; weight: 303 lbs.	22, 200 22, 190 1, 436. 4 1. 3	Launched by NASA for Comsat Corp., the manager of Intelsat. F–3 spacecraft initially positioned over Pacific. Component failure reduced capacity. After F–4 was launched. F–3 was moved to Indian Ocean to carry lighter traffic load. Currently operating satisfactorily.
Feb. 9 Tacsat I 13A Titan IIIC	Objectives: To explore and demonstrate the feasibility of using a spaceborne repeater to satisfy selected communications needs of the DOD mobile tactical forces. Spacecraft: Weight 1,600 lbs.	22, 387 22, 332 1, 446. 6 00. 6	Still in orbit.
Feb. 25 Mariner-Mars VI 14A Atlas Centaur	Objective: To conduct a 1,800-mile Mars fly-by mission to make exploratory investigations of Mars which will set the basis for future experiments, particularly those relevant to search for extraterrestrial life. Spacecraft: Octagonal boxshape structure 54-in. wide and 18-in. high, 4 extended solar cell panels; overall width 19 feet; cold gas jet stabilization; solar cell power supply—800 watts near Earth and 449 watts near Mars; weight: 908 lbs.	In helio-centric orbit	Successfully passed by Mars at 2,130 miles on July 31. Transmitted 74 television pictures and investigated Martian atmosphere.

Successful U.S. Launches—1969—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)—Period (minutes)—Inclination to Equator (degrees)	Remarks
Feb. 26 ESSA IX 16A Thor-Delta	Objective: To operate two advanced vidicon camera systems in a sun-synchronous orbit having a local equator crossing time between 2:15 and 2:35 p.m. local time so that daily AVCS cloud cover pictures of the entire globe can be obtained regularly and dependably; and to make measurements of net radiation of the earth from which the heat balance of the atmospere can be derived. Spacecraft: Cylindrical 42-in. diameter and 22.5 in. high; spin stabilized, solar cell power supply; weight: 347 lbs.	997 935 115.2 101.71	All systems functioning normally.
Mar. 3 Apollo 9 18A command module 18C lunar module Saturn V	Objective: To demonstrate crew/space vehicle/mission support facilities performance during a manned Saturn V mission with service module (CSM) and lunar module (LM); to demonstrate LM/crew performance; to assess consumables; to demonstrate performance of nominal and selected backup lunar orbit rendezvous mission activities, including: Transposition, docking, LM withdrawal, Intervehicular crew transfer, Extravehicular capability, Service propulsion and descent propulsion system burns, and LM active rendezvous and docking. Spacecraft: Carried full lunar landing configuration, including command module (CM), service module, and lunar module. Three 31-cell, Bacon-type, hydrogen-oxygen fuel cells plus batteries in command module and 6 batteries in the LM. Total weight at initial earth orbit insertion: 289,970 lbs.	Varied.	Crew consisted of J. A. McDivitt, commander; D. R. Scott, command module pilot; and R. L. Schweickart, lunar module pilot. All objectives of the flight successfully accomplished. Length of flight: 241 hours, 01 minute. Also 46 minutes EVA by Schweickart.
Mar. 4 Defense 19A Titan IIIB	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	279.6 96.3 90.3 92.0	Decayed Mar. 18, 1969.
Mar. 18 OV 1-17 25A Atlas	Objective: To perform 12 solar radiation experiments. Spacecraft: Weight 312 lbs.	287.7 246.7 93.1 99.1	Still in orbit.
Mar. 18 OV 1-18 25B Atlas	Objective: To gather information on the ionosphere, radio interference, electrical fields and radiation. Spacecraft: Weight 275 lbs.	362.3 288.3 95.0 98.8	Still in orbit.
Mar. 18 OV 1-19 25C Atlas	Objective: To perform 7 experiments studying trapped radiation and 5 studying radiation hazards. Spacecraft: Weight 273 lbs.	3,592.9 288.0 153.5 104.7	Still in orbit.
Mar. 18 OV 1-17A 25D Atlas	Objective: To operate 2 radio beacons mounted on the OV 1-17 propulsion module. Spacecraft: Weight 487 lbs.	233.0 106.9 89.8 99.0	Decayed Mar. 24, 1969.
Mar. 19 Defense 26A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	156.6 102 5 86.6 82.9	Decayed Mar. 24, 1969.

Successful U.S. Launches—1969—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)—Period (minutes)—Inclination to Equator (degrees)	Remarks
Mar. 19 Defense 26B Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	318.8 312.8 94.7 83.0	Still in orbit.
Mar. 27 Mariner-Mars VII 30A Atlas Centaur	Objective: To conduct a 1,800-mile Mars fly-by mission to make exploratory investigations of Mars which will set the basis for future experiments, particularly those relevant to search for extraterrestrial life. Spacecraft: Octagonal boxshape structure 54 in. wide and 18 in. high, 4 extended solar cell panels; overall width 19 ft.; cold gas jet stabilization; solar cell power supply—800 watts near earth and 449 watts near Mars; weight: 908 lbs.	In heliocentric orbit	Successfully passed by Mars at 2,190 miles on Aug 5. Transmitted 91 TV pictures to Earth and investigated Mars atmosphere. Mariner VI and VII made following preliminary observations: Nothing new to encourage existence of earthlike life, but does not preclude unknown forms which may have evolved in the Martian environment; night temperature: -150 to $-190°$ F; day temperature: -60 to $+60°$ F; atmospheric pressure 4 to 7 millibars, silica or silicates (sand) in equatorial regions; terrain varied from crater, featureless, to chaotic.
Apr. 13 Defense 36A Atlas-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	24,391 20,302 1,436.0 10.2	Still in orbit.
Apr. 14 Nimbus III 37A Thorad-Agena	Objective: to make IR measurements from which a vertical temperature profile of the atmosphere can be determined; to conduct global mapping of radiative energy balance of earth atmosphere; to demonstrate feasibility of surface pressure and tropospheric wind measurements, to conduct global mapping of the earth and its cloud cover day and night; and to demonstrate SNAP 19 power supply. Spacecraft: Torus ring structure 56-in. diameter with pyramidal frame structure 120-in. high. Active 3 axis stabilization; 415 watt solar cell plus two 25-watt SNAP–19 power supply; weight: 1,360 lbs.	704 667 107.3	The following experiments were carried out: high resolution IR radiometer; image dissector camera; monitor of UV solar energy; IR interferometer spectrometer; interrogation recording, and location subsystem; and two SNAP 19 radioisotope thermoelectric generators.
Apr. 14 Secor XIII 37B Thorad-Agena	Objective: To continue geodetic measurements program. Spacecraft: Rectangular box-shaped structure 9 in. by 11 in. by 13 in.; solar cell power supply; weight: 46 lbs.	704 667 107.3 99.9	Launched by NASA for the Department of Defense (Army) as a secondary payload. Spacecraft functioning normally.
Apr. 15 Defense 39A Titan IIIB/Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	292.7 78.9 89.9 108.7	Decayed Apr. 20, 1969.
May 2 Defense 41A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	202.1 104.6 89.5 64.9	Decayed May 23, 1969.

Successful U.S. Launches—1969—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)—Period (minutes)—Inclination to Equator (degrees)	Remarks
May 2 Defense 41B Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	283.2 255.9 93.2 65.7	Still in orbit.
May 18 Apollo 10 43A command module 43C lunar module Saturn V	Objective: To demonstrate crew/space vehicle/mission support facilities performance during a manned lunar mission with the command service module and the lunar module; to evaluate the lunar module performance in the cis-lunar and lunar environment. Spacecraft: Carried full lunar landing configuration, including command module, service module, and lunar module. Three 31-cell, Bacon-type, hydrogen-oxygen fuel cells plus batteries in command module and 6 batteries in the LM. Total weight at initial Earth orbit insertion: 289,970 lbs.		Crew consisted of E. A. Cernan, commander; J. W. Young, command module pilot; and T. P. Stafford, lunar module pilot. The lunar module successfully made two 47,000-foot, low-altitude passes over the prospective Apollo 11 landing area. Length of flight: 192 hours and 3 minutes.
May 22 Intelsat III (F-4) 45A Thrust-augmented Thor-Delta	Objective: To provide equivalent of 1,200 2-way voice circuits or 4 color TV channels to carry commercial communications traffic between the United States, Hawaii, and the Western Pacific. Spacecraft: Cylindrical 56-in. diameter and 78-in. high; spin-stabilized; 300-watt solar cell power supply; weight: 303 lbs.	22,205 22,190 1,436.0 .54	Launched by NASA for Comsat Corp., the manager of Intelsat. Stationed at 170° east longitude. Spacecraft operating normally.
May 23 OV 5-5 46A Titan IIIC	Objective: To measure the power spectrum of magnetic and electrical field fluctuations at the magnetospheric boundary. Spacecraft: 11-in. side octahedral research satellite weighing 25 lbs.	69,427 10,480 3,119.6 32.9	Still in orbit.
May 23 OV 5-6 46B Titan IIIC	Objective: To provide research data about the solar processes which influence the near Earth environment. Spacecraft: 11-in. side octahedral research satellite weighing 25 lbs.	69,427 10,480 3,119.6 32.9	Still in orbit.
May 23 OV 5-9 46C Titan IIIC	Objective: To measure the energetic particles emitted by the Sun and study the trapped electrons and protons at near-synchronous altitude. Spacecraft: 11-in. side octahedral research satellite weighing 25 lbs.	69,427 10,480 3,119.6 32.9	Still in orbit.
May 23 Vela 9 46D Titan IIIC	Objective: To orbit nuclear detection sensors capable of monitoring X-ray, gamma ray, neutron, optical, electromagnetic pulse, and air fluorescence emissions. Spacecraft: Weight: 571 lbs.	69,387 68,653 6,718.5 32.7	Still in orbit.
May 23 Vela 10 46E Titan IIIC	Objective: Same as Vela 9 located in similar orbit, satellites separated by 180°. Spacecraft: Weight: 571 lbs.	69,614 68,774 6,707.6 32.8	Still in orbit.
June 3 Defense 50A Titan IIIB/Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	265.3 86.4 89.8 110.0	Decayed June 14, 1969.

Successful U.S. Launches—1969—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
June 5 OGO VI 51A Thorad-Agena D	Objective: To make detailed measurements near solar maximum of the near-Earth environment, including the global composition and density of the neutral atmosphere; the composition and structure of the ionosphere: the solar radiation producing ionization; the auroral and polar cap phenomena of the polar regions; the structure and variability of terrestrial fields, the propagation and form of VLF emissions; the trapping and precipitation of particles; and air glow emissions related to photochemical dissociative or recombination interactions. Spacecraft: Rectangular boxlike structure 67 in. by 32 in. by 31 in. with 2 shaft-mounted rotatable solar cell arrays, 2 22-ft.-long booms, and 4 4-ft. booms; active 3 axis and spin stabilization; 560-watt solar cell power supply; weight 1,394 lbs.	682 246 99. 8 82. 0	Spacecraft and experiments are functioning normally.
June 21 Explorer XLI (IMP-G) 53A Thrust-augmented Thor-Delta	Objective: To obtain measurements of plasma and energetic particle during period of solar maximum at distances of 100,000 miles and at an angle in excess of 80° to the equator. Spacecraft: Octagonal box structure 27 in. wide and 10 in. high with 4 solar cell paddles and 2 6-ft. booms for magnetometer and balance; spin stabilized; 70-watt solar cell power supply; weight: 174 lbs.	130, 640 210 4, 906 87	This is the seventh of a series of 10 Interplanetary Monitoring Platform spacecraft. Carries 12 experiments. All functioned normally.
June 29 Bios-III 56A Thor-Delta	Objective: To make detailed measurements on a 14-lb pigtailed monkey during a 30-day orbiting flight, to include measurements of wave patterns from 10 areas in the brain; record heart action and respiration; take measurements at 4 circulatory system sites; make 3 urinary measurements; and provide observation of performance on 2 selected behavioral tasks. Spacecraft: Combined a blunt nose cone reentry capsule mounted on cylindrical section. Total length 84 in.; maximum diameter 57 in. 135-watt hydrogen/oxygen fuel cell plus batteries power. Active stabilization. Weight: 1,536 lbs.	245 224 92. 1 33. 6	Flight was terminated after 8 days. Monkey successfully recovered but died about a day later from apparent heart failure. Results are still being analyzed.
July 16 Apollo 11 59A Command Module 59C Lunar Module Saturn V	Objective: To perform a manned lunar landing in the southwest corner of the Sea of Tranquility, to conduct limited geological exploration in the vicinity of the touchdown point, deploy passive seismic experiment, laser ranging retroreflector, and solar wind experiment, and return to earth. Spacecraft: Carried full lunar landing configuration including command module, service module, and lunar module. Three 31-cell Bacon-type hydrogen-oxygen fuel cells plus batteries in command module and 6 batteries in the LM. Total weight at initial Earth orbit insertion: 292,865 lbs.	N.A.	Crew consisted of Neil A. Armstrong, commander; Michael Collins, command module pilot; Edwin E. Aldrin, Jr., lunar module pilot. The mission was successfully accomplished. Touchdown occurred at 20:17:43 Gmt, July 20 and Armstrong stepped on to the lunar surface at 02:56:15 and Aldrin at 04:11:00 Gmt on July 21. The Lunar Module lifted off from the lunar surface 17:50:00 Gmt, July 21, for a total stay time of 21 hours, 36 minutes, 17 seconds. Total flight time: 195 hours, 19 minutes.
July 23 Defense 62A Thor/Burner II	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	531. 5 488. 4 101. 3 98. 8	Still in orbit.

Successful U.S. Launches—1969—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)—Period (minutes)—Inclination to Equator (degrees)	Remarks
July 24 Defense 63A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	136. 1 110. 6 88. 4 74. 9	Decayed Aug. 23, 1969.
July 26 Intelsat III (F–5) 64A Thor-Delta	Objective: To provide equivalent of 1,200 2-way voice circuits or 4 color TV channels to carry commercial communications traffic between North America, Europe, South America, and Africa. Spacecraft: Cylindrical 56-in. diameter and 78 in. high; spin stabilized; 300-watt solar cell power supply; weight: 303 lbs.	3, 325 168 146. 2 30. 2	Intended as replacement for F–2 launched in December 1968 which was having antenna difficulties. Due to third-stage failure, the spacecraft did not achieve a usable orbit. F–2 appears to have overcome its difficulties.
July 31 Defense 65A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	333. 1 288. 9 94. 6 75. 0	Still in orbit.
Aug 9 OSO–VI 68A Thrust-augmented Thor-Delta	Objective: To obtain high spectral resolution data within the range of 10 to 20 Kev and 1–1,300 Angstrom; to detect the zodiacal light, hard solar X-rays, and the Earth's x-ray albedo, high energy neutron fluxes, and solar helium emissions. Spacecraft: Revolving 9-sided polyhedron 44-in. diameter, and 22-in. radius semicircular sail; spin stabilized; 26-watt solar cell power supply; weight: 610 lbs.	348 308 95. 2 33. 0	To continue OSO I, II, III, IV, and V investigations of the Sun. All experiments are functioning normally.
Aug 9 PAC 68B Thrust-augmented Thor-Delta	Objective: To test an experimental spacecraft control system which can be used to convert the 3d stage of the Thor-Delta to a 3-axis Earth stabilized platform for various future piggyback payloads. Spacecraft: Not applicable.	340 300 94. 2 32. 9	Experiment functioned as planned.
Aug. 12 ATS–5 69A	Objectives: To conduct a carefully instrumented gravity gradient orientation experiment directed toward providing the basic design information for stabilization and control of long-lived spacecraft in synchronous orbit, to conduct millimeter wave and L-band aeronautical communications experiments, and to make environmental measurements. Spacecraft: Cylindrical 56-in. diameter and 72-in. long; gravity gradient stabilization; 148-watt solar all power supply; weight: 951 lbs.	23, 500 23, 500 1, 435. 9 2. 5	The spacecraft arrived at a synchronous geostationary orbit but with an abnormally high spin rate about the yaw axis. This prevented the principal spacecraft experiments to function and therefore the mission is assessed as a failure.
Aug. 23 DEFENSE 74A Titan IIIB/Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	234. 3 85. 8 89. 6 108. 1	Decayed Sep. 7, 1969.
Sep. 22 Defense 79A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	157. 2 110. 0 88. 7 85. 0	Decayed Oct. 12, 1969.
Sep. 22 Defense 79B Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	308. 2 305. 1 94. 4 85. 1	Still in orbit.

Successful U.S. Launches—1969—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Sep. 30 Defense 82A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not applicable.	303. 2 299. 5 93. 8 69. 6	Still in orbit.
Sep. 30 Defense 82B Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	586. 0 574. 8 103. 7 70. 7	Still in orbit.
Oct. 1 ESRO-1B (Borealis) 83A Scout	Objective: To perform an integrated study of high latitude ionosphere and particles and associated effects. Spacecraft: Cylindrical 30-in. diameter and 40-in. high; spin stabilized; 23-watt solar cell power supply; weight 189 lbs.	237 181 91. 2 85. 1	All experiments functioned normally.
Oct. 24 Defense 95A Titan IIIB/Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	395. 8 78. 3 92. 1 108. 1	Decayed Nov. 8, 1969.
Nov. 8 Azur (GRS-A) 97A Scout	Objective: To make measurements of the inner Van Allen belt, the auroral zones of the Northern Hemisphere, and the spectral variations of solar particles versus time during solar flares. Spacecraft: Cylindrical section with conical top, 30-in. diameter and 44-in. high. Spin stabilized, 29-watt solar cell power supply; weight: 159 lbs.	1, 952 239 121. 6 103. 0	This is the first of a series of cooperative missions between the German Ministry for Scientific Research and NASA under a memorandum of understanding dated 17 July 1965. Seven scientific experiments are carried. All experiments functioning normally.
Nov. 14 Apollo 12 99A command module 99C lunar module Saturn V	Objective: To perform a manned lunar landing in the Ocean of Storms, to develop techniques for a point landing capability, to perform selenological inspection, survey, and sampling in a mare area, to deploy and activate an Apollo lunar surface experiments package, to develop man's capability to work in lunar environment, and obtain photographs of candidate exploration sites. Spacecraft: Carried full lunar landing configuration, including command module, service module, and lunar module. Three 31-cell, Bacon-type, hydrogen-oxygen fuel cells plus batteries in command module and 6 batteries in the LM. Total weight at initial Earth orbit insertion: 289,970 lbs.	N.A.	Crew consisted of Charles Conrad, Jr., commander; Richard F. Gordon, command module pilot, and Alan L. Bean, lunar module pilot. All mission objectives were successfully accomplished. Lunar module landed at 06:54:35 (Gmt) on Nov. 19 and lifted off again at 14:26:00 (Gmt) on Nov. 20. Total lunar stay time: 31 hours, 31 minutes. Total flight time: 244 hours, 36 minutes, 25 seconds.
Nov. 22 Skynet A 101A Thrust-augmented Thor-Delta	Objective: To place into synchronous orbit over the Indian Ocean a United Kingdom communications spacecraft as part of the initial defense communications satellite program (augmented) in response to a United States/United Kingdom agreement. Spacecraft: Cylinder 54-in. diameter and 32-in. high; spin stabilized; solar cell power supply; weight: 535 lbs.	22, 777 20, 546 1, 431. 0 2. 4	Spacecraft is functioning normally.
Dec. 4 Defense 105A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	155. 3 105. 6 88. 4 81. 4	Still in orbit.

Aeronautical Events of 1969

Jan. 8	U.S.S.R.'s supersonic transport, the Tu 144, successfully made its second test flight.
Jan. 10	Japan approved a licensing agreement with a U.S. company to produce 104 F–4E jet fighters in Japan by fiscal year 1977.
Jan. 15	A new SST configuration was submitted to the FAA for approval. The new design incorporated a delta wing platform with a horizontal tail.
Feb. 4	The U.S. Navy announced the award of a $40,000,000 contract for the engineering development phase of the F–14A supersonic fighter.
Feb. 7	The XB–70 research airplane was flown from the NASA's Flight Research Center, Edwards, Calif., to Wright Patterson AFB, Ohio, to be placed in the Air Force Museum.
Feb. 9	The 747 Jumbo Jet made its successful 1 hour and 15 minute maiden flight from Paine Field, Everett, Wash.
Feb. 9	NASA announced that it would flight test the Whitcomb-designed supercritical wing on a U.S. Navy F–8 fighter at NASA's Flight Research Center.
Feb. 10	President Nixon appointed a 12-member interdepartmental ad hoc committee to review the supersonic transport program.
Mar. 2	The Anglo-French supersonic transport aircraft, the Concorde, made its successful maiden flight from Toulouse-Blagnac Airport, France.
Apr. 17	NASA's X–24A lifting body research vehicle successfully completed its first glide flight, launched from a B–52 carrier aircraft at 45,000 feet over Rogers Dry Lake, Calif.
Apr. 27	NASA announced the retirement of the 2 remaining active X–15 research aircraft to the Smithsonian Institution and the Air Force Museum.
May 9	The NASA HL–10 lifting body vehicle made its first supersonic flight, reaching 54,000 feet and mach 1.1, after a 45,000-foot air launch from a B–52.
May 21	U.S.S.R. publicly demonstrated its TU–144 supersonic airliner in a 90-minute test flight from Sheremetyevo Airport.
May 23	FAA announced allocations of nearly $35,000,000 to construct and improve 177 U.S. airports under the fiscal year 1970 Federal aid to airports plan.
May 29	The 28th Salon Internationale de l'Aeronautique et de l'Espace (Paris Air Show) opened, featuring nearly 550 exhibitors from 14 nations. In the United States, the C–5A "Galaxy" took off at a gross weight of 728,000 pounds, the heaviest airplane ever flown.
June 5	U.S.S.R.'s TU–144 supersonic airliner exceeded mach 1 for the first time during flight tests.
Sept. 23	President Nixon recommended proceeding with the construction of 2 U.S. supersonic transport prototypes, asking Congress for $96,000,000 to finance the program in fiscal year 1970.
Oct. 8	The Air Force received its first new bomber in almost a decade with the delivery of the first FB–111 to the Strategic Air Command.
Nov. 3	The Air Force issued requests for proposals to airframe and engine manufacturers asking for their plans for the development of the B–1 strategic bomber.
Nov. 12	A regulation was announced by FAA which established noise standards and maximum noise levels for all new subsonic transport turbojet airplanes.
Nov. 28	Japan successfully flew its first VTOL research test bed vehicle.

APPENDIX B

U.S. Applications Satellites 1958–1969

GEODESY

Date	Name	Launch vehicle	Remarks
Oct. 31, 1962	Anna 1B	Thor-Able Star	Used 3 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	Spacecraft is a 100-foot-diameter balloon used as a photographic target to make geodetic measurements.
Aug. 19, 1966	Secor VII	Atlas-Agena D	
Oct. 5, 1956	Secor VIII	Atlas-Agena D	
June 29, 1967	Secor IX	Thor-Burner II	
Jan. 11, 1968	GEOS II	Thor-Delta	
Apr. 14, 1969	Secor XIII	Thor-Agena D	

U.S. Applications Satellites 1958–1969

DEFENSE SUPPORT

Date	Number	Launch vehicle used	Remarks
Apr. 13, 1959 to Dec. 31, 1969.	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	
	118	Thor-Agena D	
	4	Thor-Able Star	
	5	Thor-Altair	
	7	Thor-Burner II	
	4	Atlas-Agena A	
	12	Atlas-Agena B	
	68	Atlas-Agena D	
	23	Titan IIIB-Agena D	
	9	Titan IIIC	
	4	Atlas	

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 2-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 (IDCSP). Active-repeater spacecraft in near-synchronous orbit, random-spaced.
Oct. 26, 1966	Intelsat II–F1	Thor-Delta	First in Intelsat II series spacecraft; 240 2-way voice circuits or 1 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 (F–2)	Thor-Delta	First in Intelsat III series of spacecraft. 1,200 2-way voice circuits or 4 color TV channels. Positioned over Atlantic to carry traffic between North America, South America, Africa, and Europe. Entered commercial service on Dec. 24, 1968.
Feb. 6, 1969	Intelsat III(F–3)	Thor-Delta (TAT)	Stationed over Pacific to carry commercial traffic between the United States, Far East, and Australia.
Feb. 9, 1969	Tacsat I	Titan IIIC	Demonstrated feasibility of using a spaceborne repeater to satisfy selected communications needs of DOD mobile forces.
May 22, 1969	Intelsat III(F–4)	Thor-Delta(TAT)	Stationed over Pacific to replace F–3 which was moved westward to the Indian Ocean. Completes global coverage.
July 26, 1969	Intelsat III(F–5)	Thor-Delta(TAT)	Spacecraft failed to achieve the proper orbit. Not usable.
Nov. 22, 1969	Skynet A (IDCSP–A)	Thor-Delta	Launched for the United Kingdom in response to an agreement to augment the IDCSP program.

U.S. Applications Satellites 1958–1969—Continued

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 2 wide-angle TV camera systems.
Feb. 28, 1966	ESSA II	Thor-Delta	Complemented ESSA I with 2 wide-angle APT cameras.
May 15, 1966	Nimbus II	Thor-Agena B	
Oct. 2, 1966	ESSA III	Thor-Delta	Odd-numbered ESSA spacecraft carry 2 advanced videcon camera systems. Even-numbered spacecraft carry 2 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 Suomi camera system.
Jan. 26, 1967	ESSA IV	Thor-Delta	
Apr. 20, 1967	ESSA V	Thor-Delta	
Nov. 5, 1967	ATS–3	Atlas-Agena	Provided continuous color cloud-cover pictures from a synchronous orbit, using 3 Suomi camera systems.
Nov. 10, 1967	ESSA VI	Thor-Delta	
Aug. 16, 1968	ESSA VII	Thor-Delta	
Dec. 15, 1968	ESSA VII	Thor-Delta	
Feb. 26, 1969	ESSA IXI	Thor-Delta	
Apr. 14, 1969	Nimbus III	Thor-Agena	Provided first vertical temperature profile on a global basis of the atmosphere from the spacecraft to the Earth's surface.

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 16, 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. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgi Beregovoy	94 hrs. 51 mins.	Maneuvered near unmanned Soyuz 2.
Appollo 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.
Soyuz 4	Jan. 14, 1969	Vladimir Shatalov	71 hrs. 22 mins.	Soyuz 4 and 5 docked and transferred 2 Cosmonauts fron Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris Volynov Alecksey Yeliseyev Yevgeniv Khrunov	72 hrs. 40 mins.	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	241 hrs. 1 min.	Successfully simulated in Earth orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	192 hrs. 3 mins.	Successfully demonstrated complete system, including lunar module descent to 47,000 ft. from the lunar surface.
Apollo 11	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	195 hrs. 19 mins.	First manned landing on lunar surface and safe return to Earth. First return of rock and soil samples to Earth, and manned deployment of experiments on lunar surface.

History of U.S. and Soviet Manned Space Flights—Continued

Spacecraft	Launch date	Crew	Flight time	Highlights
Soyuz 6	Oct. 11, 1969	Georgiv Shonin Valeriy Kubasov	118 hrs. 21 mins.	Soyuz 6, 7 and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and Earth and celestial observations.
Soyuz 7	Oct. 12, 1969	Anatoliy Filipchencko Vladislav Volkov Viktor Gorbatko	118 hrs. 43 mins.	
Soyuz 8	Oct. 13, 1969	Vladimir Shatalov Aleksey Yeliseyev	118 hrs. 51 mins.	
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	244 hrs. 36 mins.	Second manned lunar landing. Continued manned exploration and retrieved parts of Surveyor III spacecraft which landed in Ocean of Storms on Apr. 19, 1967.

APPENDIX D

U.S. 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 Thorad-Delta.	1. Thor (SLV-2J) plus	LOX/RP	[3] 170	11	109	2,000	525	1968 (60)
	three TX 354-5	Solid	[2] 52					
	2. Delta (DSV-3)	IRFNA/UDMH	7.8					
	3. FW-4D/TE 364	Solid	5.9/10.0					
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-Burner II	1. Atlas booster and sustainer (SLV-3A).	LOX/RP	400	10	84	4,950	700	1968
	2. Burner II	Solid	10					
Atlas-Agena	1. Atlas booster and sustainer (SLV-3A).	LOX/RP	400	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	400	10	100	9100	2,700	1967 (62)
	2. Centaur (Two RL-10).	LOX/LH	30					
Uprated Saturn IB	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	[3] 281	285,000@ 105 NM	100,000	1967
	2. S-II (Five J-2)	LOX/LH	1,150					
	3. S-IVB (One J-2)	LOX/LH	230					

[1] The date of first launch applies to this latest modification with a date in parentheses for the initial version.
[2] Each motor.
[3] 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.

Appendix E

Nuclear Power Systems for Space Application

Designation	Application	Status
SNAP-3	Navigation satellites (DOD)	Units launched in June and November 1961. Unit still operating at reduced power levels.
SNAP-9A	Navigation satellites (DOD)	Units launched in September and December 1963. Units still operating at reduced power level. Third satellite failed to orbit in April 1964.
SNAP-19	Nimbus B weather satellite (NASA)	First Nimbus B launch aborted; Pu-238 fuel recovered from offshore waters. Replacement unit launched in April 1969 and has operated continuously at gradually reducing power levels since that time.
SNAP-27	Apollo lunar surface experiment package (NASA)	First SNAP-27 placed on lunar surface by Apollo 12 astronaut in November 1969. System is supplying total power for ALSEP.
SNAP-10A	Unmanned missions	Tested in orbit in 1965.
Transit [1]	Navigation satellites (DOD)	Development program underway.
Pioneer [1]	Jupiter flyby mission (NASA)	Modified SNAP-19 generator system will be used.
Viking [1]	Mars lander mission (NASA)	Modified SNAP-19 generator system will be used.

[1] Planned missions.

Appendix F-1

Space Activities of the U.S. Government

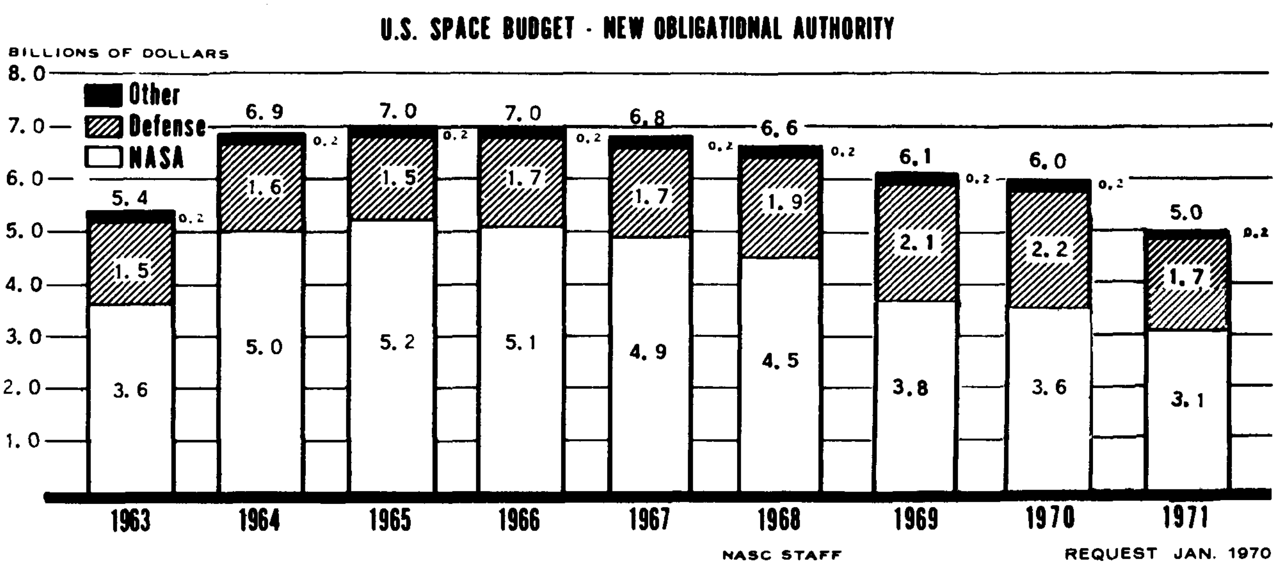
Ten-Year Summary and 1971 Budget Recommendations January 1970—New Obligational Authority

[In millions of dollars (may not add due to rounding)]

	NASA		Department of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total space
	Total	Space [1]							
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
1969	3,990.9	3,822.0	2,013.0	118.0	20.0	2.0	0.7	1.9	5,977.6
1971 budget:									
1970	3,734.9	3,548.6	1,756.0	102.0	7.0	3.0	0.9	2.4	5,419.9
1971	3,330.0	3,144.5	1,674.0	98.7	26.0	4.0	1.5	2.2	4,950.9

[1] Excludes amounts for aviation technology.

Source: Bureau of the Budget.



APPENDIX F–2

Space Activities Budget, January 1970

[In millions of dollars]

	New obligational authority			Expenditures		
	1969 actual	1970 estimate	1971 estimate	1969 actual	1970 estimate	1971 estimate
Federal space programs:						
NASA [1]	3, 822. 0	3, 548. 6	3, 144. 5	4, 078. 0	3, 706. 6	3, 215. 9
Defense	2, 013. 0	1, 756. 0	1, 674. 0	2, 095. 0	1, 820. 0	1, 690. 0
AEC	118. 0	102. 0	98. 7	117. 5	102. 5	103. 7
Commerce	20. 0	7. 0	26. 0	31. 0	27. 0	24. 0
Interior	2. 0	3. 0	4. 0	2. 0	3. 0	4. 0
NSF	1. 9	2. 4	2. 2	1. 9	2. 3	2. 1
Agriculture	0. 7	0. 9	1. 5	0. 7	0. 9	1. 5
Total	5, 977. 6	5, 419. 9	4, 950. 9	6, 326. 1	5, 662. 3	5, 041. 2
NASA:						
Manned space flight	2, 625. 8	2, 257. 5	1, 810. 3	2, 781. 4	2, 354. 7	1, 936. 8
Space science and applications	543. 4	632. 3	682. 6	569. 1	633. 8	612. 3
Space technology	308. 5	300. 8	292. 1	344. 3	337. 3	305. 8
Aviation technology	168. 9	186. 3	185. 5	168. 5	179. 8	184. 1
Supporting activities	350. 5	364. 0	374. 1	389. 4	386. 8	375. 6
Less receipts	−6. 2	−6. 0	−14. 6	−6. 2	−6. 0	−14. 6
Total NASA	3, 990. 9	3, 734. 9	3, 330. 0	4, 246. 5	3, 886. 4	3, 400. 0

[1] Excludes amounts for aviation technology.

Source: Bureau of the Budget.

Aeronautics Budget

[In millions of dollars]

	New obligational authority		
	1969	1970 estimate	1971 estimate
Federal aeronautics programs:			
NASA [1]	168. 9	186. 3	185. 5
Department of Defense [2]	1, 160. 9	1, 597. 9	1, 624. 4
Department of Transportation [3]	−30. 0	96. 0	290. 0
Total	1, 299. 8	1, 880. 2	2, 099. 9

[1] R. & D., R. & P.M., C. of F.
[2] R.D.T. & E. aircraft and related equipment.
[3] R. & D., SST. Unobligated balances rescinded in 1969.

Source: Bureau of the Budget.

U.S. GOVERNMENT PRINTING OFFICE: 1970 O—371-775