



Aeronautics and Space Report  
of the President *1971 Activities*

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# Aeronautics and Space Report of the President *1971 Activities*



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:*

I am pleased to transmit herewith a report of our national progress in aeronautics and space activities during 1971.

This report shows that we have made forward strides toward each of the six objectives which I set forth for a balanced space program in my statement of March 7, 1970.

Aided by the improvements we have made in mobility, our explorers on the moon last summer produced new, exciting and useful evidence on the structure and origin of the moon. Several phenomena which they uncovered are now under study. Our unmanned nearby observation of Mars is similarly valuable and significant for the advancement of science.

During 1971, we gave added emphasis to aeronautics activities which contribute substantially to improved travel conditions, safety and security, and we gained increasing recognition that space and aeronautical research serves in many ways to keep us in the forefront of man's technological achievements.

There can be little doubt that the investments we are now making in explorations of the unknown are but a prelude to the accomplishments of mankind in future generations.

THE WHITE HOUSE,  
March 1972



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# I



# Progress Toward U.S. Aeronautics and Space Goals in 1971

## Introduction

The United States has traditionally been, and continues to be, a leader in the world's aeronautics and space activities. In large part, this leadership derives from the fact that those activities manifest some very basic American characteristics. Americans are pioneers and explorers, and space offers the most exciting and most challenging frontier yet left to explore. Americans are competitive people, but people who prefer to compete by being successful in activities which benefit mankind, not threaten it. Space competition in the sixties resulted in achievements and capabilities which reflected U.S. preeminence, but which also have provided benefits, both tangible and intangible, to many throughout the world. Continued US efforts to develop the most advanced air transports and aeronautical vehicles represents a similar pattern of beneficial competition which contributes to the quality of life we need and enjoy. Americans are practical people, and increasingly they are coming to realize that their national investment in space and aeronautics has already produced payoffs, in terms of national security, economic growth, and an increased quality of life, which justify the costs of obtaining them.

The past year saw many successes for the United States in its aeronautics and space activities—perhaps most dramatically, the continuation of manned exploration of the moon after a 14-month interim and the unmanned reconnaissance of the planet Mars. International involvement in the U.S. space program increased substantially. The year also saw a national decision to discontinue support for the development of an American supersonic transport.

The United States is proceeding into this decade with clearly-defined goals and objectives for its civilian space program, a program characterized by its balance and by its attempt to utilize existing capabilities while at the same time developing the new ones required to continue the exploration and exploitation of outer space. These goals and objectives were first enunciated in March, 1970, and they remain the guidelines for determining national space policy. There are three general reasons why the United States continues to

invest substantial resources in space activity: the national thrust to explore the unknown, the desire to acquire new knowledge, and the realization that space activity has practical and widely-beneficial applications. Space is increasingly coming to be seen as an arena of human activity, rather than national activity, and therefore a particularly congenial focus for cooperative undertakings that bring the peoples of the world together.

Six specific objectives for the U.S. space program, derived from these purposes, have been established. These are:

1. continued exploration of the moon;
2. exploration of the planets and the universe;
3. substantial reductions in the cost of space operations;
4. extension of man's capability to live and work in space;
5. expansion of the practical applications of space technology;
6. greater international cooperation.

This chapter reviews activity in the United States space program in 1971 in terms of progress towards achieving these six objectives.

In aeronautics, the most important event of the year was probably the decision to discontinue support for the supersonic transport. Other elements of aeronautical activity during the year included the completion of a broad study delineating the needs of future civil air transport systems and increasing emphasis on the development of an efficient and environmentally sound air transport system for short distance flights. Military aeronautics programs aimed at providing modern strategic and tactical capabilities continued.

Involvement of many nations in U.S. space activities and the application of those activities to many problems and opportunities throughout this planet are symbolic of the realization, first dramatized by photographs from space, of the finite boundaries of man's common home. It is particularly appropriate that space activity, which has been so influential in creating the perception of Spaceship Earth, is now being used to help manage that spaceship for the benefit of all mankind.

## Continued Exploration of the Moon

With the success of the Apollo 14 and Apollo 15 missions during 1971, seven crews of American astronauts have now travelled to the moon and four teams have explored, in full view of millions around the world, the lunar surface.

Almost four hundred pounds of lunar rocks and soil have now been returned for analysis by over 200 scientists. Sixty-four of the Principal Investigators operate in foreign laboratories. Geophysical research stations of increasing complexity have been established on the moon; the stations set up by the Apollo 12, 14, and 15 lunar explorers and powered by long-lived nuclear units continue to return valuable data.

In addition, the lunar missions have brought back thousands of photographs for study and analysis not only of the moon, but of earth.

The combination of direct and remotely-controlled instruments is providing the data for a coordinated and comprehensive analysis aimed at answering major questions, not only about the origin and nature of the earth and moon, but also related to the origin of our solar system. This data may provide some of the missing links required for understanding not only our solar system but the universe. For example, within the returned lunar samples there are traces of matter interpreted to be 4.6 billion years old. If, as most scientists now agree, the moon and the earth are approximately the same age, then these lunar samples fill a gap in our knowledge of the earth's first billion years of existence. Later natural processes on this planet have obliterated or obscured any record of what happened on earth prior to approximately 3.5 billion years ago. The Apollo 15 mission returned two other lunar samples of intense scientific value. One was the so-called "genesis rock," which is believed to be 4.15 billion or more years old and to represent a chunk of the original lunar crust. The other is an eight-foot deep core sample which contains solar particles captured by the lunar soil and thus provides a record of the last billion years or so of the sun's activity.

The capabilities of Apollo missions have increased dramatically since the Apollo 11 landing in July 1969. Mission duration has increased from eight to twelve days. The Apollo 11 astronauts were on the surface 21.6 hours and made one extravehicular excursion lasting 2.5 hours, staying within 200 feet of the lunar module. The Apollo 14 astronauts, during their 33 hours on the moon, spent 9 hours outside the lunar module going out a little over half a mile. The Apollo 15 mission represented a quantum jump in exploratory capabilities. The astronauts spent 67 hours on the moon and made three trips, totalling over 18 hours, and covering 17 miles, within a three mile radius, along the Apennine Front and the Hadley Rille. The Apollo

15 mission was the first to employ the Lunar Roving Vehicle, which allowed astronauts to journey away from their landing site and to preserve their energies for the demanding tasks of manned lunar exploration. Because the Lunar Rover was equipped with a remotely-controlled television camera, those watching on earth had a deep sense of sharing the fascination of pioneering exploration, as the Apollo 15 team roamed the spectacular lunar surface in the Hadley-Apennine region.

No lunar samples returned by the Apollo missions or the Soviet Luna 16 spacecraft to date have contained evidence of viable organisms. As a result the strict quarantine requirements of earlier lunar landing missions were cancelled for Apollo 15 and subsequent flights.

Apollo 15 was a concrete demonstration of the many ways in which the presence of men during lunar exploration is a decided asset. The Apollo crews are called upon to act as scientific observers or field geologists, to collect samples, to carry out specific experiments in real-time communication and cooperation with scientists on earth, and to deploy and activate scientific stations. Apollo has exploited man's unique capabilities for collecting data, for adapting to the unexpected, and for contributing critical elements of judgment and discrimination. The scientific success of the Apollo missions to date can be attributed directly to the resourcefulness and skill of the astronauts in carrying out their tasks of lunar exploration. The combination of the extended capability of the later Apollo hardware and the continued excellence of Apollo crews promise to make the last Apollo missions, 16 and 17, two more chapters in the chronicle of man's most challenging and potentially most rewarding exploratory undertaking, Project Apollo.

## Exploration of the Planets and the Universe

As the year ended, the Mariner 9 spacecraft was orbiting Mars and was half-way through its mission of sending photographs and other scientific data about that planet back to earth. The results of this mission, the first in which a spacecraft orbited another planet in the solar system, are expected to provide scientists with significantly more data on the characteristics of the Martian surface and atmosphere than were previously available. The Mariner 9 mission is a follow-up to earlier U.S. exploration of Mars in 1964 and 1969, and is part of a concentrated plan for the study of the one body in the solar system which most scientists agree should have highest priority for exhaustive investigation. The initial stages of this plan will culminate with the 1975 Viking mission to land scientific

instruments with emphasis on the search for life on the Martian surface.

Mariner 9 was one of two Mars exploration missions launched during May 1971. The other mission, Mariner 8, failed to reach earth escape velocity due to a malfunction of the launch vehicle second stage guidance system. Mariner 9 was placed in orbit about Mars on November 13. The Mariner 9 spacecraft carried television cameras and other instruments to provide data for mapping at least 70 percent of the Martian surface, for establishing the atmospheric and surface characteristics of the planet, and for the study of the dynamic elements of those characteristics. Early results of the mission include the first photographs of the two Martian moons. Due to an extensive dust storm on Mars, not as much of the planet had been mapped by the end of the year as had been planned. Complete visual coverage of the polar cap and coverage of other areas of interest was obtained.

Although Mars is a major focus of the U.S. program for planetary exploration, missions to each of the other planets in this solar system will be launched during the 1970's. The Pioneer F spacecraft scheduled for launch on a mission to Jupiter during the first quarter of 1972 was undergoing final integration and testing at the end of the year. The Pioneer mission will examine the interplanetary medium beyond Mars, determine the size, density, and velocity of asteroids, and measure, during a close fly-by, the environmental and atmospheric conditions of Jupiter. SNAP-19 generators which will power this and several later planetary missions were delivered to NASA by the Atomic Energy Commission in December.

Significant progress was made during 1971 on the design of and the selection of a contractor to develop a Mariner spacecraft scheduled for a 1973 launch to Mercury, with a fly-by of Venus enroute. This mission will be the first closeup examination of the nearest planet to the sun.

During the late 1970's, Mariner or Pioneer class spacecraft will be sent to explore Jupiter and Saturn.

During the year a seventh Orbiting Solar Observatory (OSO-7) was launched. The primary mission of the OSO program is to obtain scientific information on the sun and its influence on the rest of the solar system. The OSO-7 mission is studying explosive solar flares and the solar corona. Data from OSO-7 has already revealed extended "polar caps" on the sun-regions in which the temperature of the solar corona is about one million degrees less than that of the equatorial corona. The National Oceanic and Atmospheric Administration (NOAA) is using information from OSO-7 to predict solar flares likely to cause electromagnetic disturbances.

As part of a cooperative U.S.-Federal Republic of Germany program called Helios two spacecraft will be launched to the vicinity of the sun in the mid-1970's. Germany is responsible for spacecraft and experiment development and for mission operations. The United States is providing additional experiments, will launch the spacecraft, and will assist Germany in other elements of the project. During 1971, spacecraft design was completed and construction and testing of an engineering model begun.

Seven Explorer-class missions, including four involving cooperation with another country, were launched during 1971. These missions increase our knowledge of space physics and astronomy. A number of spacecraft launched prior to 1971 continue to operate and to provide valuable information about the solar system and the universe.

### **Substantial Reduction in the Cost of Space Transportation**

Further design studies and economic analysis during 1971 reinforced the conclusion that the key to reducing the costs of space operation for the foreseeable future is the development of some form of reusable transportation to space. The basic element will be a reusable space shuttle capable of placing payloads in orbit. With its use man can repair and service existing satellites or return them to earth for refurbishment, and it can be used to support scientific investigators during "sortie" missions in orbit. Major emphasis in the year was given to investigating in detail alternate configurations for a two-stage, fully reusable shuttle and for several versions of a partially reusable system to determine the trade-offs between capabilities and costs. Through close interagency coordination, NASA and the Air Force agreed on performance characteristics for the shuttle in order that it could meet both civilian and military needs for future space operations. The prime characteristics concern: payload size (up to 15 ft. dia. x 60 ft. long); payload weight (up to 65,000 lbs. for a due east launch); and range of the re-entering orbiter, lateral to the orbit plane (1100 n. mi.). Benefit-cost studies suggested that system development was a desirable investment for the United States if a moderate level of space activity was to be maintained in the 1980's.

### **Extension of Man's Capability to Live and Work in Space**

In 1973 three Americans will embark on the first of a series of earth orbiting missions using Skylab, the first United States vehicle created specifically to en-



able man to live and work in space for extended periods. This program is dedicated to the use of space and its unique environment and vantage point to increase our knowledge and understanding of the earth's importance to man's well-being and man's influence on earth's ecology. Skylab will also be a major step in manned space flight. Habitation by the first crew will double our previous man-in-space duration for a single mission; the second crew's visit will double that duration. Skylab, in effect, creates a bridge between the development flights of the 60's and the long duration operational space flights of the future.

To accomplish its mission, Skylab will be placed in earth orbit and will be visited by three different crews during an eight-month period. While successfully inhabiting and operating the vehicle for one- and two-month continuous periods, these crews will obtain data in areas pertinent to the man/Earth relationship and to the biomedical aspects of space flight.

Investigations conducted aboard the orbiting laboratory and data acquired from Skylab experiments and returned to earth will permit us to: (1) increase man's knowledge of the Sun and its importance to earth's and man's existence; (2) increase man's knowledge of the biomedical functions of living organisms, human and other, by making observations under conditions different from those on Earth to determine the influence of Earth conditions to those functions; (3) develop techniques for observing from space Earth phenomena in the areas of agriculture, forestry, geology, geography, air and water pollution, land use and meteorology, and the influence man has on these ecological elements; (4) develop improved techniques for space operations in the areas of crew habitability, crew/vehicle interrelationships, and space vehicle structure and materials, and evaluate various equipments necessary for successful habitation of the unique environment of space.

During the past year, considerable progress has been made in the development phase of the Skylab program. Flight hardware has been delivered, new features such as rescue capability and an extensive earth resources survey project have been added, qualification testing is well advanced, and astronaut training has been initiated. Activities in the coming year will concentrate on final validation of all systems, pointing to the Skylab launch in 1973.

In addition to preparations specifically related to the Skylab program, NASA life sciences specialists are carefully investigating recent U.S. and Soviet manned missions to determine whether any heretofore unanticipated biomedical obstacles related to long-duration flights in a zero-gravity environment exist.

## Practical Applications of Space Technology

There has been increasing attention given to deriving the maximum tangible returns from our national investment in space capabilities. The most direct form of return is the use of space techniques to provide needed services such as communications, resource management, weather forecasting, and the like. These practical applications of space technology have already provided significant benefits to the nation and to the world, and future applications programs promise substantial additional benefits.

**Earth Resources Survey (ERS).**—This program represents an attempt to combine aerospace technology and interdisciplinary science in developing a new capability for rational management of the limited resources of the earth. The major emphases of the program are two: to learn how to gather data about earth accurately and efficiently from a variety of surface, airborne, and space platforms, and to learn how to extract from these data new information to support environmental decisionmaking. The goal of the current experimental ERS program is to move to a point at which a national decision on the advisability of developing an integrated operational earth survey system can be made.

During 1971, the ERS program continued to use airborne platforms to develop remote sensing techniques and prototype systems, in anticipation of the launch of the initial Earth Resources Technology Satellite (ERTS) in the first half of 1972. Until that launch, the aircraft program also serves as the principal data source for research and the application of remote-sensing techniques. Three major events marked the progress of the ERS aircraft program during the year. Several new remote sensing systems which will provide new capabilities for exploring environmental problems became operational. The practical application of remote sensing were demonstrated in relation to several actual environmental problems. There was a major effort to extend the 1970 study of corn blight; in addition, remotely-sensing data were used to investigate public health and agricultural problems. NASA acquired two surplus U-2 aircraft for high-altitude simulation of the ERTS-A mission. These aircraft are flown over test sites in California, Arizona, and the Chesapeake Bay area every 18 days to collect ERTS-like data in advance of the first space ERTS mission.

Work continued on the development of two ERTS spacecraft, one for launch in 1972 and the other in 1973. NASA selected experiment proposals for the use of data from the ERTS-A mission and Earth Resources Experiment Package aboard Skylab. That experiment package was further defined during 1971.

The ERS program involves the cooperation of a number of government agencies. An interagency Earth

Resources Survey Program Review Committee is responsible for coordinating ERS-related activities in the agencies. During the year, the National Aeronautics and Space Council completed a study of the management aspects of the ERS program.

**Communications.**—The Applications Technology Satellites (ATS)–1, 3, and 5, all of which continue in operation far beyond their design lifetimes, were utilized to provide communications services to government agencies, both state and federal, university and commercial organizations, and foreign governments. In one instance, in which emergency medical care was provided for remote villages in Alaska by transmitting treatment instructions via the ATS–1 satellite.

During the year experiments in communications, meteorology, traffic management, spacecraft technology and science were selected to be carried aboard the ATS–F spacecraft. NASA also agreed to support, with this spacecraft, an experiment proposed jointly by the Department of Health, Education, and Welfare and the Corporation for Public Broadcasting to transmit educational and health programs to the Rocky Mountain region and to Alaska. Under a similar cooperative agreement, about one year after launch, ATS–F will be made available for use by the Government of India.

Cooperation in the international field continued with the launch of the CAS–1 (EOLE) satellite for the French. This satellite will collect wind velocity and air temperature and pressure in the southern hemisphere from about 500 balloons fabricated by the French and launched from stations in Argentina.

In April a Memorandum of Understanding was reached with the Department of Communications of Canada to develop cooperatively the CAS–3, a communications technology satellite. The U.S. will provide the launch vehicle and the transmitter output stage while Canada will provide the balance of the spacecraft.

The Defense Satellite Communications System (DSCS) is designed to provide secure long distance military communications via satellite. Phase I of the DSCS, consisting of 21 operational satellites and 29 earth terminals, continues to perform satisfactorily. The first two satellites will be moved to geo-stationary positions over the Atlantic and Pacific at the equator. The research and development phase of the Tactical Satellite Communications Program (TACSATCOM) was completed in 1970. Satellites launched as part of this phase of the program were used during 1971 in both test and interim operational modes. Development of the Navy's Fleet Satellite Communications System, an outgrowth of the TACSATCOM program, was initiated in 1971. This system is intended to provide improved communications for Navy ships worldwide

while also fulfilling certain Air Force requirements. The second NATO Phase II communications satellite was launched successfully by the United States in February.

**Meteorology.**—Use of Applications Technology Satellites (ATS)–1 and –3 to acquire daytime cloud cover imagery continued during the year. The ATS–3 spacecraft is used by the National Hurricane Center and the National Severe Storms Forecast Center; during the spring, the spacecraft is placed at the most favorable position for viewing mid-continent severe storms and then moved to look at hurricane areas in the western Atlantic Ocean during the summer and fall.

After more than 18 months in orbit, data from the Nimbus-4 spacecraft continues to be used by the National Oceanic and Atmospheric Administration to derive atmospheric vertical temperature profiles for use in operational analysis. Advanced Nimbus satellites will be launched in 1972 and 1974, and will include devices for remote sensing of the atmosphere in cloudy regions, at higher temperatures, and in new regions of the electromagnetic spectrum.

Two second-generation operational environmental satellites launched in 1970, ITOS–F and NOAA–1, were deactivated during 1971 due to problems in their stabilization control systems. The launch of a third such satellite in October was unsuccessful due to launch vehicle failure. The next launch in the ITOS series is scheduled for the first half of 1972.

Work continued on the development of a Synchronous Meteorological Satellite, with the goal of a late 1972 launch for the first such spacecraft. This satellite will provide day and night cloud cover imagery from synchronous orbit, among other capabilities.

**Geodesy.**—Emphasis is being given to the application of space technology and related precision metric measurement techniques to investigations related to areas such as the understanding of earthquake mechanisms required for earthquake warnings and for development of earthquake-prone areas and the discovery of new mineral deposits. In conducting these investigations, use will be made of the radio and laser satellite tracking techniques developed in NASA's Geodetic Satellite Program; the very long baseline interferometry technique originally developed for radio astronomy studies; satellite altimetry techniques; and a special class of satellites designed to support measurements of the earth's gravity and magnetic fields and of the geometry of the ocean surface.

During 1971 new information about the mechanical properties of the earth was derived from analysis of the orbital perturbations of the Beacon-C satellite caused by the earth's tidal bulge. The Apollo tracking ship Vanguard participated in an experiment to measure

large ocean surface geoidal undulations. Geodetic satellite tracking data was used to improve the representation of the earth's gravity field.

The military services initiated procurement of a man-portable satellite tracking system designated Geociever; this system will provide a cost-effective and highly accurate mobile station.

### **International Cooperation**

During 1971 international cooperative activity related to space may have been more extensive than during any previous year. The General Assembly of the United Nations endorsed a convention on liability for damage caused by objects launched into space. The 81 members of the International Telecommunications Satellite Organization (INTELSAT) completed negotiations regarding Definitive Agreements for the organization. The United States and the Soviet Union conducted expanded discussions on a variety of possible cooperative undertakings. At the end of the year, these two nations reached tentative agreement on certain technical aspects of a possible future joint U.S.-U.S.S.R. manned mission to test compatible docking systems. There was a continuing dialogue with European nations regarding their participation in the U.S. post-Apollo planning, and with Atlantic and Pacific countries regarding the use of satellites for air traffic control and related civil aviation purposes. Both through direct cooperation with the U.S. and through increasing United Nations involvement in the program, many developing countries demonstrated their awareness of the potential benefits of the U.S. Earth Resources Survey programs.

During the year, six spacecraft which involved foreign participation were launched, and agreements for several future cooperative projects or launches were signed. Scientists from 15 countries outside the US received lunar samples from the Apollo 14 or 15 mission for analysis. NASA increased its efforts to provide opportunities for foreign scientists to participate in the planning of future scientific missions such as the High Energy Astronomical Observatory.

Representatives of the United States and the Soviet Union met several times during the year to discuss aspects of expanded cooperation in space sciences and applications. A January meeting in Moscow produced an agreement under which there was an exchange of lunar surface samples in June. The agreement also specified four other areas of potential cooperation and coordination: space exploration, meteorological applications, surveying of ocean and vegetation resources, and space biology and medicine. Ways of implementing this agreement were explored in later working sessions.

The United States continued its effort to solicit significant foreign involvement in the major space programs of the 1970's and after. There was European participation in design studies for the space transportation system. A potential obstacle to European participation in programs after Apollo was removed in September when the United States assured the European Space Conference that U.S. launch vehicles or services will be available for purchase for projects which are for peaceful purposes and which are consistent with obligations under relevant international agreements and arrangements.

In May, a number of federal agencies sponsored an International Workshop on Earth Resources Survey Systems at the University of Michigan. Representatives from 40 countries and 16 international organizations attended. Thirty-seven proposals from 22 countries for the analysis of data acquired by the initial ERTS mission and the Earth Resources Experiment Package aboard Skylab have been tentatively accepted; other acceptances of non-US proposals are anticipated.

The United Nations Committee on the Peaceful Uses of Outer Space, reflecting the increased international attention being given the ERS program, established a Working Group on the Remote Sensing of the Earth by Satellites.

### **Aeronautics**

Issues related to the nation's progress in aeronautics were the focus of much public and Congressional interest during 1971. After extensive Congressional debate, a federal guarantee to permit the Lockheed Corporation to secure sufficient funding to continue its L-1011 "airbus" program was approved. Also after extensive debate, continued federal support for the development of two prototypes of a supersonic transport was discontinued; therefore, the program to develop an American SST was concluded.

Issues of aeronautical policy were the focus of the Civil Aviation Research and Development (CARD) study, which was completed in 1971. This study was a joint effort of NASA and the Department of Transportation (DOT) with support from other agencies. It outlined the benefits of civil aviation, the value of a sound R&D base for this important field, and delineated the needs of future R&D. Emphasis was placed on reducing the environmental impact of aviation, easing congestion, and improving low density short haul systems. Attention was focused on system-wide activities necessary to maintain U.S. leadership in civil aviation. It was recommended that the government re-examine its regulatory posture with respect to civil aviation to insure the necessary development of this field. Aircraft noise and engine emissions were

designated as priority problems for further research. Recommendations resulting from this intensive study have been evaluated and will serve as basic guidelines for NASA and DOT, working with the National Aeronautics and Space Council and the Office of Management and Budget, in the establishment of priorities and support for future federal programs in aeronautics.

During the past year NASA has intensified efforts to assure technology readiness for the successful development and operation of short takeoff and landing (STOL) transports. It is believed that the use of such aircraft will reduce community noise and pollution, relieve airport and airways congestion, and shorten total city-to-city travel time. There also appear to be significant benefits related to military short-haul and tactical requirements that might be derived from the use of STOL aircraft. Basic analytical and wind tunnel studies of turbofan powered lift concepts with emphasis on externally blown flap (EBF) and augmentor-wing (AW) configurations have provided the necessary research base for an experimental STOL airplane program. Contracts have been let for competitive design and proposals leading to the development of two experimental STOL transport research aircraft.

Research on the reduction of jet transport noise continues on several fronts. Studies on takeoff and landing flight profiles have shown that significant noise abatement may be realized through new flight procedures. Programs are under way to insure that the necessary aircraft avionics equipment will be available to implement these new flight procedures. NASA is finding that substantial noise reduction is also possible within the engine design with little performance loss. A new engine test stand is nearing completion at Lewis Research Center where an experimental Quiet Engine will be tested in an acoustically treated nacelle.

DOT completed and implemented a noise certification regulation for civil aircraft. Similar noise regulations are being developed for older aircraft, supersonic transports, and other special category aircraft. Research and development programs for clean, quiet jet transport engines were initiated. Also, contracts have been awarded and demonstration tests will be conducted next year on noise suppression designs for some existing jet engines. A joint NASA/DOT Noise Abatement Office has been established to provide leadership and focus for the solution of these problems associated with civil aviation. Environmental planning guides for airports have been prepared by DOT and several areas of legislation have been developed. Also, modernization of air traffic control centers, airport control towers, and landing and navigation aids continues.

As a result of the national decision to discontinue government funding of the supersonic transport prototypes, certain research efforts of basic value to supersonic and transonic flight and to aeronautical science are being sponsored by various government agencies.

Emphasis has been given to the problem of aircraft hijacking. Equipment has been installed both on the ground and in aircraft to deter hijacking attempts. Effort has also been continued in programs to improve air and ground safety. To minimize the number of deaths from crashes, experiments have been conducted relative to crashworthiness of aircraft. A study concerning general aviation safety was completed. Its recommendations are in the process of being implemented.

Aeronautical programs continued to grow in 1971 within the Department of Defense. Flight tests of the second test aircraft of the advanced carrier-based tactical fighter (F14A) began this year and are proceeding satisfactorily. Development of carrier-based aircraft with the capability of an improved airborne warning system (E-2C) has taken place with a first flight of a prototype occurring early this year. The development aircraft is leading to an improved readiness of the Navy to operate in the modern warfare environment. The Air Force's advanced tactical fighter (F-15) program continues on schedule and the first flight test aircraft is being fabricated. Development of the B-1 bomber is proceeding on schedule. Completion of the preliminary design review and full-scale mock-up were important steps leading toward manufacture of the first test aircraft. The Air Force initiated development of the AX, a close air support aircraft, to be optimized for effective support of friendly ground forces. Two contractors are involved in this program and a competitive fly-off will occur. Programs to develop a heavy lift helicopter (HLH) and the utility tactical transport aircraft system (UTTAS) were begun. Further advanced systems evaluation of the AH-56A (Cheyenne) prototype attack helicopter is progressing satisfactorily.

In 1971, many joint agency programs highlighted the cooperative efforts leading to more cost effective aeronautical research. NASA and the DOT have joined in a program which reflects common interests in the development and investigation of aircraft and electronic technologies, operational procedures, and system concepts which can improve the operational efficiency, public acceptance, safety, and reliability of a STOL short haul system. A joint Army/NASA program for the procurement and flight test of a V/STOL tilt-rotor research aircraft includes investigations of tilt-rotor handling and control characteristics, noise, and near terminal operational techniques. A joint USAF/NASA

program for the procurement and flight test of a supercritical wing on an F-111 fighter aircraft is being developed to provide "proof-of-concept" of the application of supercritical wing technology for military and civil system advancements. A joint NASA/USAF research program investigated the transonic regime with a YF-12 aircraft from subsonic to supersonic cruise speed conditions and a stability and control investigation was completed during 66 flights in 1971.

## II



# National Aeronautics and Space Council

### Introduction

The National Aeronautics and Space Council was established by the National Aeronautics and Space Act of 1958 to advise and assist the President on matters pertaining to aeronautics and space activities conducted by the departments and agencies of the United States. That same Act also established the National Aeronautics and Space Administration.

The Vice President of the United States is the Chairman of the Council; its members are the Secretary of State, the Secretary of Defense, the Secretary of Transportation, the Administrator of the National Aeronautics and Space Administration, and the Chairman of the Atomic Energy Commission.

The Executive Secretary and Council staff act in an advisory capacity throughout the year in providing technical inputs to the Executive Office of the President regarding aeronautics and space programs. In this respect the relative priorities of various U.S. aeronautics and space programs with respect to national goals are examined and the effects of proposed program funding revisions and projections evaluated. The Council staff continually reviews the aeronautics and space policies and programs of all governmental agencies with a view toward sponsoring interchange of technical information, avoiding duplication of effort, and assuring that programs are consistent with national goals. Where problems arise which transcend the jurisdiction of individual organizations they are brought to the attention of the affected Council members through the Executive Secretary. Affected Council members frequently meet to consider important issues which do not require the involvement of the full Council. The Council staff also provides a means for interchange of ideas

### Conclusion

This summary shows that 1971 was a year of both accomplishment and challenge in space and aeronautics. Further challenges lie ahead. Soundly-based research and development, bold and innovative programs, and a strong national commitment to excellence are required if we are to continue to meet these challenges and maintain our position of leadership and accrue its benefits

between industry and government on aeronautics and space matters involving several agencies.

### Studies and Reports

Typical of the activities of the Executive Secretary and Council staff are the reviews conducted at the request of the President or his staff. During 1971 emphasis was placed on studies relating to the problems of the aerospace manufacturing and air transport industries caused by the nation's transition from a wartime to a peacetime economy. The magnitude of these problems, their short and long term impact on the national economy and security were examined and policy options developed for Executive and Council consideration.

The Council staff also supports studies conducted by other government agencies. During 1971 the Council staff supported a joint DOT/NASA study to examine the options for national policy with respect to civil aviation research and development (CARD). The effects of past government R & D expenditures on the rapid growth of the U.S. aerospace manufacturing and air transport industries and the problems attendant to this growth, such as airport congestion, noise and smoke pollution, air traffic control and safety were examined. A general plan was formulated by Council member agencies to direct future government aeronautical R & D activities to the solution of these problems. Council member agencies in cooperation with OMB will establish priorities and implement programs responsive to CARD guidance.

In 1971 the Council staff supported a review of our international competitive posture with respect to high technology aerospace equipment sales. The dominant position which the U.S. has held for many years in the area of international sales of commercial and military

aircraft is being challenged by a coalition of foreign competitors supported by their respective governments. This challenge was examined and key technology initiatives are being identified as candidates for increased R & D activity.

Interagency coordination was undertaken to define meaningful environmental research programs related to the supersonic transport after the halt of the SST, the staff was active in encouraging member agencies to continue vital technology programs having general value to aeronautics and to the nation.

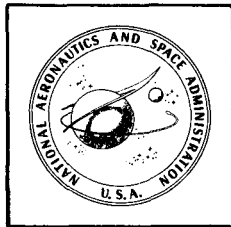
Last year an Interagency Ad Hoc Study Group chaired by the Executive Secretary was convened to examine the overall earth resources survey effort of the Federal Government and to make recommendations to insure that the sum of individual agency activities is an integrated and productive program. In 1971 the NASC staff prepared the final report of this group; its recommendations are currently in the process of being implemented.

## Other Activities

The Council is represented by its staff on interagency subcommittees of the National Security Council which discuss and advise on international cooperation in space. The Executive Secretary participated as a member of the U.S. delegation which discussed possible post-Apollo cooperation with the European space community and as a member of the delegation which went to Moscow to develop procedures for space cooperation and data exchange with the USSR.

The Council staff reviews and approves proposals for use of radioisotopes in space and prepares the President's Annual Report on Aeronautics and Space to the Congress. Staff members also participate in many interagency panels and committee meetings such as the NASA/DOD Aviation and Astronautics Coordinating Board (AACB) and its panels, as well as the Space Transportation Committee.

## III



# National Aeronautics and Space Administration

## Introduction

Two highly successful Apollo missions were completed this year—Apollo 14 and Apollo 15. In addition, planning was underway for the Apollo 16 and 17 flights; the manufacture of flight hardware for Skylab neared completion; and studies were extended to provide additional data on alternative concepts for the Space Shuttle.

Both Apollo missions were highly productive scientifically. Apollo 15 added as much new data as the three previous missions combined, its crew had the longest stay on the lunar surface—67 hours, and they were able to explore a greater area by using the Lunar Rover. Both missions left a number of experiments on the Moon which continue to transmit data back to Earth. The Apollo 15 team brought back an eight foot core sample believed to contain records of the Sun's activity for a billion years.

Unmanned programs to carry out scientific investigations in space were wide ranging. Spacecraft launched in previous years continued to provide useful data; Explorer 42 discovered X-ray sources previously unknown; and the OAO-2, after three years in orbit, was still serving astronomers as an observer of celestial

bodies. OSO-7, launched in September, discovered low temperature polar regions of the Sun.

The Mariner Mars spacecraft launched in May (Mariner 9) went in orbit about Mars in November. It has returned hundreds of high quality pictures of Mars as well as scientific data indicating that Mars is warmer than expected at the south polar cap and colder over the rest of the planet. Work continued on the Mariner Venus Mercury spacecraft scheduled for launch in 1973 for a Mercury flyby early in 1974. Viking, the 1975 orbiter/lander mission to Mars underwent preliminary design reviews, and breadboard models of instruments were tested. For the outer planets missions, spacecraft and mission design studies were continued with emphasis on making the mission and spacecraft design compatible with maximum scientific returns.

NASA launched two Intelsat IV commercial communications satellites for the Communications Satellite Corporation. Applications Technology Satellites previously launched provided meteorological data and were used for experiments by a number of organizations. Fabrication of the ATS F and G spacecraft was underway, with ATS F scheduled for early 1973 launch.

The Nimbus 4 meteorological satellite continued to furnish data to the NOAA, and good progress was made in manufacture and testing of the Nimbus E spacecraft and experiments. ITOS-1 and NOAA-1 (formerly ITOS-A) operated as part of the National Operational Meteorological Satellite System until about midyear, when both were deactivated because of problems with the stabilization control subsystem. ESSA 8 and ESSA 9 remained fully operational. The Earth Resources Technology Satellite made satisfactory progress towards its scheduled 1972 launch date.

The advanced research and technology program continued work on a large number of varied aeronautical and space projects. In the experimental STOL transport research airplane program, the definition stage was completed and contractors were selected to design the airplanes for NASA flight research. Supporting technology activities were directed toward defining and building a low pollution, quiet experimental engine for STOL applications. Progress was made in work on noise reduction in jet transport airplanes with indications that a change in flight profile could help achieve this objective.

The design of a device for detecting clear air turbulence was completed and a test instrument installed on an aircraft; final flight tests of an optical pilot warning indicator demonstrated its feasibility. In support of the Space Shuttle, extensive studies were made of aerothermodynamic phenomena affecting shuttle configuration and materials. In addition, studies were made of nuclear rocket-powered stages for shuttle applications.

Other research efforts were concerned with increasing the efficiency of solar cells, testing a fully automatic electric propulsion system for interplanetary spacecraft, and developing an inexpensive high performance laser gyro for a three-axis strapdown system.

### **Manned Space Flight**

**Continued Exploration of the Moon.**—Seven crews of Apollo astronauts have journeyed to the moon and returned safely to earth. Eight Americans have descended to the lunar surface and planted the American flag at four landing sites. They have erected experimental equipment, explored craters, and provided guided tours of the landing site through world wide live television coverage. Thousands of photographs, both panoramic and mapping, have been returned to earth with many photos of earth itself from space. These are being studied and analyzed for benefit to all mankind.

Some 385 pounds of lunar rocks and soil have been returned to Earth for laboratory analysis and scientific stations have been established on the Moon. More detailed information about the Moon has been acquired in the last two years than in previous history, and the

Apollo 15 mission provided more new data than the three previous missions combined.

The capabilities of Apollo have increased dramatically since the Apollo 11 landing in July 1969. Mission duration has been increased from 8 to 12 days and surface stay-time has tripled from 21.5 hours for Apollo 11 to 67 hours for Apollo 15. The Lunar Roving Vehicle (LRV) that Astronauts Scott and Irwin drove around their landing site along the Apennine Front and the Hadley Rille demonstrated that man can explore and operate on the Moon as far as three miles from the landing craft. Orbital science capability was improved by the addition of the Scientific Instrument Module (SIM) instrument package and other scientific experiments. The subsatellite which was left in lunar orbit was carried in the SIM bay along with the Panoramic and Mapping cameras.

**Apollo Program.**—Two manned lunar landing missions were accomplished in 1971: Apollo 14, in January, and Apollo 15 in July. The next missions, Apollo 16 and 17, planned for launch in April and December of 1972 respectively, will raise the total number of manned lunar landings to six. Phase-out of Apollo is planned for 1973 with transfer of such resources as are appropriate to follow-on programs.

**Apollo 14.**—The Apollo 14 mission landed the third American lunar exploration team. It explored the Fra Mauro formation and continued the scientific investigation of the Moon begun with Apollo 11 and 12.

The space vehicle with the crew of Alan B. Shepard, Commander; Stuart A. Roosa, Command Module Pilot; and Edgar D. Mitchell, Lunar Module Pilot, was launched on January 31, 1971.

Earth-orbital checkout and translunar injection were accomplished without difficulty, but a problem was encountered when attempting to dock the Command and Service Module (CSM) with the LM. A hard dock was accomplished on the sixth attempt, approximately five hours after launch. Inspection of the docking mechanism by the astronauts revealed that it was functioning properly and the mission continued as planned.

A midcourse correction placed the spacecraft in the planned trajectory for lunar orbit, and the spacecraft was inserted into lunar orbit on February 4. During prelanding checkout and lunar descent, minor problems were encountered, but coordination between ground-support personnel and the crew overcame the difficulties. Touchdown took place on February 5, within 50 meters (164 feet) of the target point in the Fra Mauro highlands.

The first planned period of extravehicular activity (EVA) began 5½ hours after touchdown. A color television camera mounted on the descent stage provided live coverage of the descent of both astronauts

to the lunar surface. The crew deployed the U.S. flag and the solar-wind composition experiment, erected the S-band antenna, and off-loaded the Modularized Equipment Transporter (MET), the Laser Ranging Retro-reflector (LRRR), and the Apollo Lunar Surface Experiments Package (ALSEP). The ALSEP and the LRRR were deployed and the MET was used to carry the required equipment and geological samples collected. Total EVA time was just under 5 hours.

The second EVA had a traverse to Cone Crater as its objective and, at the crew's request, it was begun 2½ hours earlier than planned. Equipment required for the traverse, including the Lunar Portable Magnetometer (LPM), was carried on the MET, and the trip up the side of Cone Crater provided good experience in climbing and working in hilly terrain in the reduced gravity of the Moon. The samples collected and the area traversed were documented photographically and two LPM measurements were made. This second EVA lasted 4½ hours, and the astronauts traveled approximately 3 km (1.86 miles).

The crew then stowed its gear and 43.2 kilos (96 pounds) of samples and prepared the LM ascent stage for launch and rendezvous with the orbiting CSM. Liftoff occurred on February 6, after 33 hours on the lunar surface. Rendezvous and docking were achieved without incident. After crew transfer, the ascent stage was separated and impacted on the lunar surface on February 6 between the Apollo 12 and 14 seismometers resulting in seismic signals lasting 1½ hours.

Orbital-science experiments and science photography were performed in lunar orbit and during the long return to Earth. During transearth coast, the crew conducted demonstrations of electrophoretic separation, heat flow and convection, liquid transfer, and composite casting. The entry sequence was normal and the command module splashed down in the Pacific Ocean approximately 1 km (.62 miles) from the target point on February 9.

Total time for the Apollo 14 mission was 216 hours. All primary objectives were accomplished.

**Apollo 15.**—The Apollo 15 mission was the fourth manned lunar landing. Major objective of this mission was detailed exploration of the Hadley-Apennine region. It also continued scientific studies from Apollo 11, 12, and 14, using equipment that provided significant increases in performance. The LRV and improved spacesuits gave increased range, mobility, and stay time on the lunar surface; the landed scientific payload weight was doubled; an experiment package in the service module (SM) was used in lunar orbit to supplement the experiments on the lunar surface, and a small subsatellite was left in lunar orbit.

Crew members were David R. Scott, Commander; Alfred M. Worden, Command Module Pilot; and James B. Irwin, Lunar Module Pilot; launch took

place on July 26, 1971. Translunar insertion, separation, and docking were all satisfactory; during translunar coast minor problems with ground and flight equipment occurred and were resolved expeditiously.

During the 12th lunar revolution on the far side of the Moon (July 30) the undocking and separation maneuver was initiated; however, undocking did not occur. The crewmen and ground control suspected that an umbilical connector was loose or disconnected. Al Worden went into the tunnel, and confirmed that a connector was loose and tightened it. Undocking and separation were then achieved. LM landing took place on July 30, about 600 meters (656 yards) north, northeast of the planned touchdown point.

EVA-1 commenced on July 31. The commander deployed the Modularized Equipment Stowage Assembly (MESA). The TV in the MESA was activated and excellent pictures were obtained. The TV camera was then placed on the tripod for further coverage of crew activities. The LRV was deployed and during checkout it was found that the front steering mechanism was inoperative. After minor troubleshooting, a decision was made to perform EVA-1 without front wheel steering. The crew then proceeded on the planned traverse, obtaining rock samples and photographs at various stations. TV transmission from the LRV, another first for this mission, was excellent. At the end of the traverse, the ALSEP was deployed; however, the second boring operation for the heat flow experiment was not completed and this portion of ALSEP deployment was rescheduled for EVA-2. EVA-1 duration was 6 hours, 42 minutes.

EVA-2 took place on August 1. The LRV was powered up and the front steering was found to function. The trip included stops at Spur Crater, Dune Crater, Hadley Plains, and between Spur and Window Craters. Numerous samples and photographs were obtained and TV transmission was again very good. The heat flow experiment which was initiated on EVA-1 was completed, and a drill coring was started but the drill core stems were left at the ALSEP site for retrieval during EVA-3. The crew returned to the LM, deployed the U.S. flag, and stored the sample container and film in the LM. Duration of EVA-2 was 7 hours, 12 minutes.

For EVA-3 (August 2) the traverse was made in a westerly direction from the LM to Hadley Rille. The first stop was near the ALSEP site to retrieve the EVA-2 drill core stem samples. Two sections of the drill core stem were removed and stowed in the LRV. The drill and the four remaining sections of the drill core stem could not be separated and were left for later retrieval. The remaining stops were Scarp Crater, "The Terrace" near Rim Crater, and Rim Crater. The return route was generally the same as the outbound route. Samples were obtained and documented and



photographs were taken of various lunar surface features.

Upon reaching the ALSEP area, the crew again attempted to disassemble the drill core stem. They managed to separate another section, but the remaining three sections were returned assembled.

The crew then returned to the LM, unloaded the LRV and stationed it for TV coverage of the LM lift-off. They also emplaced a commemorative plaque for all deceased astronauts and cosmonauts. Total duration of EVA-3 was 4 hours, 49 minutes.

The televised lift-off from the lunar surface occurred August 2. The ascent stage was inserted into a nominal lunar orbit, and after CSM/LM docking, the samples and other equipment were transferred to the CM for return to earth. CSM/LM separation was accomplished and the spent LM ascent stage impacted the lunar surface 93 km (58 miles) west of the Apollo 15 ALSEP site. The impact was recorded on the Apollo 12, 14, and 15 passive seismometers.

On August 4, the subsatellite was launched into lunar orbit and the transearth injection maneuver was performed. Astronaut Worden performed an in-flight EVA on August 5 making three trips to the SIM bay to retrieve the panoramic and mapping camera film cassettes. The film cassettes were retrieved during trips one and two and on the third trip, the contents of the SIM Bay were inspected to determine their condition.

The CM was separated from the SM on August 7 at 400,000 feet. Drogue and main parachutes deployed normally. However, one of the three main parachutes partially collapsed during descent causing a harder landing than planned. The CM landed 10 km (6.3 miles) from the prime recovery ship, the *USS Okinawa*, about 1.8 km (1.15 miles) from the planned landing point. Total mission time was 295 hours.

**Lunar Exploration.**—The Apollo missions have provided increasing amounts of revealing data about the Moon. Scientists in laboratories all over the world are studying samples from the Moon's surface, chemical maps of large areas, detailed photographs of its geologic and topographic features, and data telemetered to Earth from instruments left on the lunar surface and in lunar orbit. This comprehensive and coordinated analysis is providing substantive answers to major questions about the Moon. The implications and consequences of these answers are forcing scientists to reexamine long held theories about the Earth and Sun as well as the Moon.

Within returned lunar samples there are traces of matter interpreted to be 4.6 billion years old. Scientists now generally agree that the Moon is approximately the age of the Earth. The Moon underwent an extensive early period of melting and differentiation which lasted at least 1.5 billion years. The Earth may have undergone a similar period; however, the earliest his-

tory of the Earth (i.e., before 3.5 billion years) has been obscured or obliterated by later processes. The lunar samples fill the information gap in our knowledge of the Earth's earliest history.

The lunar materials returned are of igneous origin (i.e., crystallized from molten material) or are a product of meteorite bombardment. Although some lunar materials greatly resemble terrestrial volcanic rocks, they have their own distinctive concentrations of chemical elements. Investigations of lunar material, including a Luna 16 sample obtained from the USSR, indicate that the Moon is not like the meteorites in composition, as was earlier postulated by scientists. One particularly spectacular sample, the so-called "Genesis Rock" collected on Apollo 15, is believed to represent a chunk of the original lunar crust formed very shortly after the formation of the Moon. This sample has extremely low amounts of radioactive elements and is the oldest whole lunar rock yet returned (4.15 billion years or perhaps older). Its age is significantly older than a terrestrial counterpart and forces a re-examination and further study of the processes which formed the Earth's crust.

A deep core sample collected on Apollo 15 is believed to contain a record of the last billion years or so of the Sun's activity preserved by the capture of solar particles in the soil. No viable organism has been found in the lunar samples and no evidence of fossil material. Because of the absence of lunar organisms, bioscientists are now emphasizing investigations germane to the mode of occurrence and geochemical characteristics of carbon and hydrogen in a lifeless environment (the Moon), as compared with an environment teeming with life (the Earth). This is expected to open up new interdisciplinary research opportunities for physical and life scientists.

The astronaut-deployed geophysical stations (ALSEPs) positioned at three locations on the lunar surface are essential in solving the major questions concerning the Moon. The instrument complement and spacing of the ALSEPs are such that the data are continually telemetered to Earth and are mutually supporting. Data from several of the ALSEP instruments, the seismometers, the magnetometers, the laser ranging retroreflectors, and the heat flow experiments are confirming and adding details to the story which the lunar rocks are unfolding. With the analysis of these new geophysical data, we now know that the Moon, like the Earth, is layered. Deep moonquakes, deeper than any recorded earthquakes, require the Moon to have a thick crust. Swarms of small moonquakes may indicate that volcanic activity is taking place even now. Several hundred seismic events generated by moonquakes and meteorite impacts have now been monitored. The moonquakes may possibly be triggered by the tidal effects of the Earth, but the specific processes operating

deep within the Moon causing the stresses are yet unknown.

The impact of a meteorite onto the lunar surface gives a seismic signal similar to those observed for the Lunar Module and S-IVB impacts. The data indicate that the Moon gets several grapefruit size meteorite impacts and one impact with an approximate force of 11.5 tons of TNT every year—fewer than previously estimated.

The surface of the Moon at the landing sites consists of a regolith of fine particulate material and rocks of varying sizes. The sculpturing or “erosion” of the surface features of the Moon is caused primarily by impact phenomena related to bombardment by meteorites, ranging in size from microscopic to quite enormous (tens of kilometers or more) as well as small particles emanating from the Sun.

The Heat Flow Experiment deployed by Apollo 15 shows that the heat flow from the center of the Moon outward is about half the average of the Earth’s heat flow. This result differs from a predicted value (one-fifth of the terrestrial heat flow) based on relative volumes and surface areas. Data on returned samples and from the orbital-gamma-ray experiment suggest that the overall radioactivity of the Moon is less than that of the common Earth materials.

Magnetometer measurements of the Moon, as it passes through the Sun’s magnetic fields, also point to a change in composition, or layering, at some depth. The orbital magnetometer launched on Apollo 15 is mapping detailed magnetic patterns of the lunar surface. As additional data become available, models of the Moon’s internal structure will be refined.

The Moon’s farside is markedly different from the nearside. Not only does it consist almost entirely of highlands terrain, but the Apollo 15 mission showed it to be different in composition and elevation. The highlands are rich in alumina and low in magnesium, a characteristic of anorthositic rocks.

Measurements made from orbit also show that over the ground track, the average farside topography is 2 km higher than average frontside topography relative to the Moon’s center of mass. This information, together with an extended sequence of high precision measurements of Earth-Moon distance, now being accumulated by the laser retroreflector arrays, provides additional data for better understanding the orbital configurations of the Moon and of the Earth (e.g. the wobbles in the Earth’s rotational axis), vital to understanding the formation of the Earth-Moon system. Moreover, highly precise determinations of Earth-Moon distances make possible the monitoring of the dynamic motions and relative displacements of large plates of the Earth’s crust (e.g., continental drift, seafloor spreading).

**Forthcoming Launches.**—Two Apollo lunar landing missions are scheduled for 1972—Apollo 16 in April

and Apollo 17 in December. The primary scientific objectives of the Apollo 16 mission are to land at Descartes and study the lunar highlands, emplace a carefully selected group of surface experiments, and continue the orbital surveys and experiments initiated during Apollo 15.

A highlands site was selected for the first time to permit study of that portion of the Moon which constitutes the major topographical unit of the frontside and almost the entire surface of the farside. A portion of the Moon’s crust which has apparently undergone modification at some time in the Moon’s early history will be studied and sampled. During the lunar surface phase of the mission, a fourth ALSEP will be deployed as well as several other significant new surface experiments. The ALSEP experiments will extend the instrument network onto the topographically highest region on the lunar frontside.

Besides the ALSEP, two new experiments are intended to provide data about the cosmos: A *Cosmic Ray Detector* will measure very low energy particles outside the Earth’s magnetosphere. The second experiment, the *Far UV Camera/Spectroscope*, will measure the diffuse clouds of gas which cause the UV (ultraviolet) background in space. Additionally, this experiment will show the interaction of the solar wind and the Earth’s magnetosphere and atmosphere.

Although the orbital science payload is identical to that of Apollo 15, a new area of the Moon is being surveyed because the landing site is in the southern hemisphere almost due south of the Apollo 11 landing site. The remote sensing geochemical instruments, consisting of gamma ray, X-ray, and alpha particle spectrometers, are designed to provide a map of the chemical composition of the lunar surface. Information gathered from orbit is necessary to extrapolate the knowledge gathered at the landing sites to large areas of the Moon which we cannot visit at this time. The orbital track of Apollo 16 will provide geochemical information about the southern highlands, the major highlands feature of the lunar nearside.

The lunar atmosphere, already monitored by cold cathode ion gages emplaced on the lunar surface by Apollos 14 and 15 and extended to orbital altitude on Apollo 15, will be further studied by means of a modified mass spectrometer. The data gathered will refine our understanding of the lunar atmosphere.

The Panoramic Camera and the Mapping Camera System are extremely powerful data collection tools capable of covering large areas of the lunar surface. The high quality photographic information about surface materials and landforms permits the extension of knowledge gained from the landing sites to all of the areas of the Moon photographed at high resolution.

During this mission three life sciences experiments will be undertaken. The crews of Apollo 11 through 15 have reported seeing light flashes. The Apollo

Light Flash Moving Emulsion Detector will seek to correlate the characteristics of the particles and types of flashes reported by the crew. BIOSTACK is an experiment designed to study the effects of individual particles of galactic cosmic radiation during space flight outside the Earth's magnetic field. The third experiment, Microbial Ecology Evaluation Device, is an experiment to subject a variety of microbial test systems to all or part of the space and/or spacecraft environment, i.e., vacuum, weightlessness and ultraviolet radiation. These experiments will be useful in planning for future manned space flight activities.

For Apollo 17, now scheduled as the final mission in the Apollo series, a special effort has been made to include as many as possible new, significant experiments. With the schedule extension brought about by the cancelling of Apollos 18 and 19, all of the new experiments originally planned for the cancelled Apollo 18 and 19 missions will be included on Apollo 17.

Several highly desirable candidate sites are under consideration for Apollo 17. Final selection will be made after analyzing the data and photographs returned by the Apollo 15 mission for the site that offers the greatest potential or the largest payoff from the standpoint of both surface and orbital science.

The final ALSEP to be deployed during this mission is being redesigned to increase its inherent quality and reliability. This design should provide for a long-lived geophysical station on Apollo 17.

The *Tidal Gravimeter* is perhaps the most comprehensive experiment planned yet. It will elucidate the intrinsic nature of gravity and test the hypothesis that gravity is propagated in wave form.

Three additional surface experiments will be carried for the first time on Apollo 17. The *Lunar Mass Spectrometer* will determine the constituents of the tenuous lunar atmosphere and the findings will be correlated with the mass spectrometers carried in lunar orbit. The *Lunar Ejecta and Meteorites Experiment* will determine the frequency and energy of the small meteorites which constantly impact the Moon. The *Lunar Seismic Profiling Experiment* will deploy large explosive charges at distances of several kilometers from the landing site in order to extend seismic knowledge of the upper structure and layering in the lunar subsurface.

Experiments to be carried by the Apollo 17 will also be new. The *Surface Electrical Properties Experiment* will search the subsurface for traces of water. The *Traverse Gravimeter* is expected to provide additional key data to increase understanding of the Moon's subsurface structure.

The Apollo 17 camera systems are required to support the interpretation of results from the other experiments on board. In addition to the cameras flown, a new complement of three advanced orbital experiments has been assigned to Apollo 17.

The *Lunar Sounder* can identify subsurface layering and will study the variation in physical properties of such layers, which may include water. This experiment will provide the opportunity to study detailed physical structure beneath several complete orbits to depths up to one kilometer. The *Infrared Scanning Radiometer* will provide a high resolution thermal map of the shadowed parts of the Moon. The location of lunar hot spots and their relationship to geological features may isolate regions of possible volcanism and concentrated radiogenic heating. The *Far UV Spectrometer* will measure the compositional and density variation of the lunar atmosphere.

**Skylab Program.**—The Skylab Program, the Nation's next step in manned space exploration, will carry out the most extensive experiment program ever conducted in Earth orbit. The 28-ton Skylab, as large as a 5-room house, will allow astronauts to remain in space longer in comfortable surroundings while carrying out important Earth-oriented applications, astronomical, and technological experiments.

The design and essentially all phases of development testing have been completed on the Skylab program. Qualification testing is in the late stages and systems are being installed in flight hardware. About 26,000 persons are engaged on various phases of the work in the NASA Centers and at contractor plants across the country. They are building and testing the flight modules and experiment equipment, developing flight plans, training crews, and performing other necessary development support tasks.

The first major piece of flight hardware to be completed, the 26,000-pound payload shroud, was accepted by NASA in September and placed in storage pending delivery to Kennedy Space Center (KSC). The shroud, which protects the Skylab workshop during the launch and atmospheric flight phases, will be the largest payload shroud ever launched on a space mission.

Five Skylab trainers were shipped to the Manned Spacecraft Center (MSC) for use in the astronaut training program. They included the Orbital Workshop, the Apollo Telescope Mount, the Multiple Docking Adapter (MDA), the Airlock trainer and CSM one-g trainer.

Skylab astronauts started extravehicular training in the Neutral Buoyancy Space Simulator at Marshall Space Flight Center (MSFC). Mockups of Skylab space laboratory modules were submerged in this very large water tank to permit simulation of weightless conditions encountered in manned space flight missions.

Of the 43 items of flight hardware required to perform the more than 50 Skylab experiments, some 37 units have already been delivered with most of the remainder scheduled for delivery in early 1972.

A significant program milestone was achieved in late October with the completion of integrated systems testing of the Experiment Support System and interfacing medical experiments. A live subject was used to verify the experiment, employing mission operational procedures and timelines.

The Earth Resources Experiment Package (EREP), which was added to the Skylab program in late 1970, progressed favorably through the development phase. This experiment facility offers an opportunity to expand investigations of remote sensing of the Earth from orbit by carrying relatively large, flexible and high-performance sensors and by utilizing the crew to operate them in laboratory fashion.

A minimum of 45 selected orbits or EREP operations are expected to be available, during the three Skylab missions, to overfly instrumented ground sites and to coordinate with aircraft and satellites which support the investigations. Since EREP operations will extend over the inhabited operational life of Skylab covering the four seasons of the year, studies can be made of seasonal variations on Earth by remote sensing from orbit.

The information obtained by EREP instruments will be provided to scientists who have proposed specific investigations based on the Skylab Earth survey data. In December 1970, an invitation was extended to potential U.S. and foreign participants in the form of an Announcement of Opportunities for Participation in Space Flight Investigations. Over 300 proposals were received from potential EREP investigators including scientists from U.S. government agencies, U.S. and foreign universities, public and private research institutes, corporate users and 11 foreign countries.

Representatives of 40 countries and 16 international organizations attended the first International Workshop on Earth Resources Survey Systems sponsored by agencies of the United States Government at the University of Michigan. The workshop provided foreign experts with information on the latest techniques for interpreting earth resources data acquired by space and airborne remote sensing systems. The sessions included papers on remote sensing as related to agriculture, forestry, cartography, geography, environmental quality, geology, hydrology and oceanography.

During the year, a ground-based rescue capability was developed for the Skylab program. A modification kit was designed which converts a Skylab CSM into a rescue vehicle which can accommodate five crewmen instead of three.

The conversion is accomplished by removal and relocation of stowage lockers and substitution of two additional crew couches. Immediately after each manned launch, preparations for the next normal manned launch are started. Under the plan, if a CSM docked with the Skylab cluster becomes disabled, the next scheduled revisit CSM will be converted and launched

with a reduced two-man crew to retrieve the three stranded crewmen who have been able to remain in the orbiting cluster until rescued. The backup Saturn IB launch vehicle and spacecraft will be readied to provide a rescue capability for the last scheduled revisit mission.

A Skylab student project was added to program activity this year. Its purpose is to stimulate the interest of secondary school students in science and technology by directly relating students to a space research program. The student is given an opportunity to participate in the Skylab program by proposing experiments to be conducted aboard the space laboratory.

NASA and the National Science Teachers Association are jointly sponsoring and conducting the project. Twenty-five regional winners will be selected by a national committee and NASA will then make a final selection of the experiments to be flown. The national winners and their teachers will be invited to attend the Skylab Educational Conference and the awards presentation at KSC at the time of Skylab launch.

*Space Shuttle.*—The Space Shuttle—a two-stage, reusable space transportation system—will reduce operational cost and lead to lower payload cost through the capability of satellite placement and return, and the repair and servicing of satellites.

It will also deliver propulsive stages to low earth orbit for synchronous or escape missions, support short duration science applications with a Sortie Module installed in the payload compartment for either applications or research, provide a rescue capability, deliver propellants for exploration, and eventually support a Space Station. The Shuttle will be configured for vertical launch and horizontal landing.

Concurrent design studies were awarded two contractors to define the Shuttle and the requirement for the main engine; complete a preliminary design of the orbiter and booster; demonstrate the feasibility of the design to meet the technical requirements; refine estimates of scope, timing and cost; and provide information and data for use in selecting configurations to be pursued in later phases. Supplemental feasibility studies of alternate vehicle concepts were conducted by three other corporations.

In parallel with the preliminary design, NASA investigated projected national space traffic models, and the effects of weight, volume, and reuse on payload design and cost. Design verification of technology data and study results included wind tunnel tests, structural heat load tests, and full scale thermal protection system testing.

The original concept envisioned a completely self contained orbiter with internal fuel and oxidizer (liquid hydrogen and liquid oxygen) tanks for complete orbiter reusability. However, during 1971, the concept of external hydrogen tanks was developed. This resulted in

an increase in the efficiency of the orbiter so that staging velocities were reduced, which in turn reduced the size of the booster required. This concept permitted a significant reduction in the estimated cost to first manned orbital flight, and resulted in a baseline configuration using a booster which does not require special thermal protection and an orbiter with external hydrogen tanks capable of relatively long range flights in earth atmosphere for return to the landing site.

NASA also explored the feasibility of removing the oxygen from the inside of the orbiter and using an external hydrogen-oxygen tank. This permitted a considerable further reduction in the size of the orbiter vehicle which again improves the efficiency of the total system. The increased efficiency reduced staging velocities to the point where boosters with conventional fuels begin to be competitive.

The European Launcher Development Organization sponsored studies to examine whether Europe might develop the Space Tug as an integral part of the space transportation system. Such a tug would be used to deliver payloads to and retrieve them from orbits unattainable by the Shuttle orbiter. Industrial concerns in eight countries participated. European groups have also been involved with basic technology programs and have participated in working sessions in such areas as aerothermodynamics and configurations, structures and materials, propulsion, and integrated electronics.

**Life Sciences Reorganization.**—In the Spring of 1970, at the request of NASA, the Space Science Board of the National Academy of Science—National Research Council convened a panel to review the NASA Life Sciences programs. This committee recommended combining the several life sciences discipline offices into a single administration to reduce overlapping authority and improve internal communications.

In 1971 NASA created the position of NASA Director for Life Sciences responsible to the Administrator of NASA, for guidance, review and recommendations regarding the integrated Life Sciences research program for all of NASA. At the same time, elements of the space program covering the disciplines of biology, medicine, man-machine, human factors, and life support and protective systems were combined into a single NASA Life Sciences Office, as part of the Office of Manned Space Flight.

**Support of Manned Space Programs.**—The Life Sciences Program continued to actively support the ongoing Apollo missions, the Skylab development, Space Shuttle and Station planning.

Following Apollo 13 crew pre-flight exposure to rubella, the existing preventive medicine plan for Apollo missions was reviewed and augmented for

Apollo 14 by the establishment of the Flight Crew Health Stabilization Program. Increased emphasis was placed on immunological and epidemiological surveillance of the crews, their families, and their primary contacts supporting the Apollo Flight Program.

An extensive review of the results of the lunar sample biological assessment tests and analysis from the Apollo 11, 12 and 14 missions confirmed the basically total sterility of the moon. No evidence of viable organisms or precursors to life were found in all the tests conducted. The Interagency Committee on Back Contamination reviewed and concurred in a proposed recommendation to discontinue quarantine for Apollo 15. The NASA Administrator approved the recommendation on April 26, 1971, to discontinue quarantine for Apollo 15 and all subsequent missions.

The Advanced Development Program, which fosters the development of technology and hardware for advanced manned missions, concentrated on continuing work begun in previous years on shuttle requirements. New development activities were coordinated with the Shuttle Office and the Office of Advanced Research and Technology. Emphasis is shifting to advanced systems for missions employing the shuttle and for other advanced spacecraft.

Because the early requirement for a space tug, or comparable capability, created an added financial burden at a time when shuttle costs were projected to be near a peak demand, several different means of acquiring this capability were explored. Studies were initiated to define and evaluate the utilization of existing Centaur and Agena stages which could be inexpensively modified to inject payloads into high energy orbits. At the same time discussions began with the European space community, which was exploring ways for Europe to join with the U.S. in post-Apollo space activities and where space tug studies were underway. The results of U.S. and European tug studies were exchanged and planning for future work was coordinated for maximum return. In an additional study, a major analysis of the comparative economics of a broad range of tug concepts was initiated to provide data to help select the optimum configuration for development.

**Advanced Missions.**—Advanced Missions activities focused primarily upon system and mission studies which supported the definition of the space shuttle, its requirements, and its utilization. The study of payloads to be placed into space over the next two decades was a major activity which formed the basis of a NASA payload model supporting shuttle planning. The analysis of interfaces and interactions between the payloads and the shuttle was important to both payload and shuttle definitions. The studies of space tugs made it

clear that approximately half of all payloads in the NASA mission model involved high energy orbits necessitating more emphasis in shuttle planning for operations requiring tug support.

Limited activity is continuing in the definition of long-lead systems which were shown by the definition studies to be critical to program accomplishment. Verification test activities on the design, performance and man/machine interface of these systems were undertaken and will concentrate initially on systems and concepts applicable to shuttle payload carriers but will also consider their possible evolution into future space stations.

With the main future focus of manned space flight on the space shuttle, definition studies were started of space payload carrier modules. The shuttle together with its payload modules will provide a new and unique opportunity for space research in either its sortie or free flying modes. The definition studies will consider the use of modules attached to future space stations to take maximum advantage of commonality in the design and development of these modules.

**Space Station.**—Due to budgetary constraints, NASA decided to forego, for the next several years, proposing the development of a space station. In keeping with this decision, contracted program definition studies underway since 1969 were brought to completion. These studies furnished candidate space station concepts, their design characteristics, operational sequences, shuttle interfaces, experiment support capability, development schedules and funding requirements for both large Saturn V-launched and space shuttle-launched modular stations. The studies of different station concepts are being reviewed and program plans for future station development are being formulated.

**Applications.**—Results of Advanced Research and Technology Development in the NASA Life Science areas continued to find earth applications. For example: A mass spectrometer for sensing and measuring oxygen, carbon dioxide, water vapor and humidity in closed environments developed and being utilized by NASA in controlling the atmosphere in manned space cabin simulator operations has proven of value in hospitals where monitoring patients' respiration is required.

In the area of water use and recovery, the Life Sciences advanced technology program is investigating alternate methods of providing a reliable source of clean water to support man in space without the need for carrying huge reservoirs.

Some of these techniques show promise in the solution of similar problems here on earth. For this reason, the Office of Saline Water in the Department of Com-

merce is jointly supporting selected investigative efforts.

To meet the cooling requirements for pilots of experimental flight vehicles, NASA developed a self-contained cooling garment using circulating water cooled by an ice pack. The total weight of the integrated garment is 19 pounds. Recognizing the fact that similar cooling requirements exist for fire fighters, the USAF Fire Department at Edwards Air Force Base is evaluating the cooling garment for application to fire fighting procedures.

Results of Apollo 14 medical tests provided the first indication of the primary source of body fluid loss that all astronauts have experienced in space flight. Fluid volume assessments revealed that fluid inside the cells accounted for the greater part of the total body water deficit rather than the previously suspected fluid outside the walls of cells.

Additionally, a new device called a "hydrogen depolarized carbon dioxide concentrator" was developed by NASA for the removal of carbon dioxide from the spacecraft habitable atmosphere. This technology promises lighter weight and simpler life support systems for future space missions.

## Space Science and Applications

**Orbiting Observatories.**—NASA's Orbiting Observatories, whose mission is to obtain scientific information on the Sun, its energy and mass transfer mechanisms, and its influence on the Earth and the rest of solar system, have made major contributions to scientific knowledge. They have discovered that the temperature in solar flares is at least 30 million degrees and that the density in flares is 100 to 10,000 times higher than in their vicinity. OSO-5 discovered long duration and impulsive hard X-ray emission indicating extended storage of energetic particles produced in flares.

On September 29, NASA launched an Orbiting Solar Observatory (OSO-7) to continue studies of explosive solar flares and the solar corona. OSO-7 discovered extended "polar caps" of the Sun, regions in which coronal temperature is depressed by about one million degrees compared to the equatorial corona. OSO-7 predicts the appearance of solar active regions several days before they appear at the limb and can recognize active regions which are about to produce flares. This information is being used by the National Oceanic and Atmospheric Administration in space disturbance forecasting.

**High Energy Astronomy Observatories (HEAO).**—The purpose of HEAO is to extend our knowledge of celestial X-rays, gamma rays, and cosmic ray flux.

Although Small Astronomy Satellite (SAS) payload capabilities suffice for initial investigations of low energy X-rays and gamma rays, follow-on work and the higher energy cosmic rays require that much larger

and heavier instruments be used for their detection. HEAO will provide this capability.

HEAO is planned as a series of four missions. The first two missions, HEAO-A and B, are fully approved and are expected to be under contract for design and fabrication early in 1972. The prime spacecraft contractor for HEAO was selected in November. The experiment payloads for HEAO-A and B have also been selected. Studies are underway on missions C and D, with a partial study payload for HEAO-C selected. Launches for the first two missions are being planned for 1975 and 1976, on Titan launch vehicles.

Scientific objectives for the first two HEAO missions are as follows:

**HEAO-A.**—To investigate specific regions of X-ray, gamma ray and cosmic ray emission by performing an all-sky survey. Emphasis will be placed on obtaining a complete map of the X-ray sky.

**HEAO-B.**—To continue investigation of X-ray, gamma ray and cosmic ray emissions. Emphasis will be placed on obtaining spectra of lines and studying primary cosmic rays.

**Explorer and International Satellites.**—Seven explorer class missions, including four cooperative missions with foreign countries, were launched this year. An Interplanetary Monitoring Platform (IMP), designated Explorer 43, was launched on March 13. The IMP series was established to make long term observations of Earth-Sun relationships, particularly the outer magnetosphere, the magnetosheath and the interplanetary medium. Earlier IMP's have mapped in broad detail the interplanetary region, the Earth's magnetosphere, solar and galactic cosmic rays, and other complex solar-terrestrial relationships. They have also provided the basis for improvements in sensor and spacecraft technology, making possible studies of the Earth/Sun environment in far greater detail than before.

A cooperative mission with Canada, ISIS-2, was launched on March 31 to study the physics of the Earth's ionosphere. San Marco-3, a cooperative mission with Italy, was launched on April 24 to study the Earth's equatorial atmosphere at altitudes between 200 and 800 km (124 and 497 miles). On July 8, a satellite, SOLRAD-10, was launched for the U.S. Naval Research Laboratory to monitor the Sun's X-ray and ultraviolet emissions, to search for other X-ray sources, and to provide real-time X-ray flux monitoring for the ESSA/AF solar flare network.

On September 20 a cloud of barium was released from a cannister aboard a Scout launch vehicle at an altitude of 36,000 km (22,300 miles) giving ground observers a means of visually studying the features of the electric and magnetic fields in the Earth's outer

radiation belts. This mission was a cooperative effort with West Germany.

A small Scientific Satellite (SSS), designated Explorer 45, was launched on November 15 to investigate the dynamic processes which occur in the inner magnetosphere. UK-4, launched December 11 in a cooperative project with the United Kingdom, was the last Explorer mission of the year. Its mission objective is to investigate interactions among the plasma, charged particle streams, and electromagnetic waves in the upper ionosphere.

A number of spacecraft launched in previous years continued to provide valuable scientific information. Explorer 42, SAS-A, has discovered a number of X-ray sources, including some X-ray pulsars, which appear to differ in some respects from the more commonly known radio pulsars. The working telescopes of OAO-2, launched December 1, 1968, provide astronomers with a means of observing celestial bodies undistorted by the Earth's atmosphere.

**Sounding Rockets, Balloons, and Aircraft.**—The NASA Sounding Rocket and Balloon program launched 85 rockets of which about 39 were from White Sands Missile Range, New Mexico, six from Fairbanks, Alaska, seven from Ft. Churchill, Canada, 16 from Wallops Station, Virginia, and 14 from foreign launch sites. The program supported about 50 research teams from universities, private industry, NASA field centers, and other Federal Government agencies, and several foreign countries. The payloads represented a wide range of scientific disciplines and included engineering tests of advanced instruments, some of which will be used later on satellite missions.

About 45 balloons were launched (including 13 under the Skyhook Program). These balloons ranged in size from about 5 million cubic feet to 30 million cubic feet and carried a variety of scientific payloads. University, NASA, and other Federal Government research teams were supported. One balloon, launched from Huntsville, Alabama, in September, carried a Stratoscope II telescope to an altitude of 82,800 feet. The 36-inch astronomical telescope photographed the Andromeda Galaxy, another galaxy (M-32), and a planetary nebula (NGC 7662).

In March, NASA acquired a C-141 aircraft which is being modified to carry a 91 cm (36-inch) infrared telescope. The telescope, operating at altitudes near 15 kilometers (50,000 feet), where the atmosphere is virtually free of water vapor, will make it possible to study the universe in the infrared region of the electromagnetic spectrum, much of which can be observed only from above the water vapor in the Earth's atmosphere.

**Mariner Mars 1971.**—The two Mariner Mars 1971 spacecraft were launched in May 1971. Mariner 8 was launched May 8 and Mariner 9 was launched

May 30. Due to a failure in the guidance system of the Centaur stage of the Atlas/Centaur launch vehicle, Mariner 8 failed to reach earth escape velocity and fell into the Atlantic Ocean. Mariner 9 was successfully placed in orbit about Mars November 13, 1971 and has been sending photographs and other scientific data about Mars back to Earth since several days prior to arrival at Mars. The basic 90-day orbital mission reached the half-way mark at the end of this year.

The science instrumentation aboard Mariner 9 consists of two television cameras (wide and narrow angle), an ultraviolet spectrometer, an infrared spectrometer, and an infrared radiometer. These instruments will provide data for mapping at least 70 per cent of the Martian surface, for more clearly defining the planets atmospheric and surface characteristics, and for study of the dynamic characteristics and time variable features of Mars surface and atmosphere.

As of December 7, after 24 days in orbit, Mariner 9 had taken approximately 1,600 pictures, collected a large amount of infrared and ultraviolet information, and obtained data from the celestial mechanics and S-band occultation experiments.

An extensive dust storm on Mars made it impossible to start mapping the planet as originally planned. However, complete visual coverage of the polar cap was obtained, and many pictures of four "dark spots" (Nix Olympica, a peak near Ascaraeus Lacus, a peak near Pavonis Lacus, and a peak near Nodus Gordii) were taken. These pictures show the south polar cap considerably smaller than seen in 1969 (as was expected). Detailed pictures of three of the four "dark spots" indicate that their general formation suggests volcanic activity. Excellent photographs of the two moons of Mars, Phobos and Deimos, show them to be irregular in shape. Mars has bulges at the equator and is much more irregular in its gravitational field than expected. The irregularity causes a variation in the Mariner 9 orbital period of about 34 seconds. Eight surface pressure measurements were analyzed, with seven clustering around the same pressure. The eighth measurement, taken in the region at Hellas, showed a higher surface pressure indicating that this region is some nine km below that of the other seven measurements.

The infrared measurements showed Mars to be warmer than expected at the south polar cap and colder than expected over the rest of the planet. This is believed to be the result of the dust suspended in the atmosphere. The dust particles were identified as silicate material rather high in silicon content.

The ultraviolet measurements confirmed the 1969 measurements as to the composition of the upper atmosphere, identifying carbon, atomic oxygen, and atomic hydrogen. The aeronomy portion of the ultraviolet spectrometer objectives was met, but the pressure

mapping objectives cannot be met (except at the polar cap) until the dust has settled.

**Mariner Venus Mercury 1973.**—The launch of a single spacecraft to Mercury in October 1973 will begin the first close-up investigation of the planet nearest the Sun. The spacecraft's primary mission is to investigate Mercury's atmosphere, environment, body and surface characteristics during the late March 1974 flyby. In order to reach Mercury, the spacecraft receives a gravity assist trajectory-deflection at Venus, in early February 1974. During this flyby of Venus, science instruments aboard will make measurements of the environment, investigate the atmospheric pressures and temperatures, and search the visible yellow cloud cover for "holes" through which to photograph the Venusian surface. For the first time, high resolution TV pictures will be taken of the two planets,—2500 of Mercury and 5500 of Venus.

The science instrumentation comprising the flight payload includes two high resolution cameras, two ultraviolet detectors (photometer and spectrometer), two magnetometers, a charged particle telescope, a scanning electrostatic analyzer, and an infrared radiometer.

Major progress was made during the year in the selection of the spacecraft systems contractor, negotiations of all spacecraft subsystem contracts, final configuration design, and completion of all spacecraft functional design requirements. Additionally, the mission operations and science investigator teams completed plans for conducting encounter operations at both Venus and Mercury.

**Viking.**—Effort continued on the upswing for the largest of the current planetary exploration programs—the Viking 1975 mission to Mars. Scientific emphasis for the mission will be placed on obtaining data relevant to the search for life on Mars. Two spacecraft will be placed in orbit about the planet, then each will separate into two parts: an Orbiter which will conduct visual, thermal, and water-vapor mapping of the planetary surface; and a Lander which will analyze the atmosphere as it descends to a selected landing site on the surface and then will conduct surface experiments. The Lander surface experiments will include: biological and organic analyses of the soil; detailed imaging of the surface in color and stereo; meteorology and seismology measurements; and physical and magnetic property measurements of the soil.

Preliminary design reviews were completed for the initial mission, Orbiter, Lander, and many of the spacecraft subsystems designs. Breadboard models of the most complex Lander science instruments—for biology, imaging, and molecular analysis—were completed and tested. An earlier problem of landing site alteration caused by the rocket exhaust of the Lander



was solved through extensive analysis and testing, leading to an unusual rocket nozzle design. The first full-scale tests of the Lander parachute were conducted by dropping test vehicles from a jet aircraft.

During the year, it was decided that some program readjustments were necessary to hold total runaway costs within the predicted target levels. Therefore, some changes were made in schedules, test plans, and science objectives. These actions did not lessen significantly the high scientific value of the Viking program.

**Pioneer.**—The Pioneer F and G spacecraft will be launched on a mission to Jupiter, one in late February or early March 1972 and the other about 13 months later. These spacecraft each carry eleven separate scientific instruments to explore the interplanetary medium beyond the orbit of Mars, to determine the size, density and velocity of meteoroids and asteroids in the Asteroid Belt and to examine, during a close flyby, the environmental and atmospheric characteristics of the planet Jupiter. Two other investigations concerning celestial mechanics and radio propagation will be carried out using the spacecraft radio signals and ground-based tracking equipment. A valuable dividend from these two missions will be the information and technology derived that will improve the operational capability for long duration flights to the outer planets.

During this year excellent progress was achieved with the environmental tests of the prototype spacecraft which were successfully completed in August. The spacecraft, instruments and ground equipment for the Pioneer F spacecraft were delivered and are being integrated as a system. The four flight model radioisotope thermal electric generators were delivered by the Atomic Energy Commission in December for their final testing with the other systems prior to shipment of the spacecraft flight system to Kennedy Space Center.

Pioneers 6 through 9—launched between 1965 and 1968—continued to provide data on the interplanetary medium, solar activity, and their influences on the earth's environment.

**Helois.**—This program, first conceived in 1966 as a cooperative endeavor between the United States and the Federal Republic of Germany, is planned for one mission in 1974 and a second in 1975 to investigate the properties and processes in interplanetary space in the direction of and close to the Sun (within approximately 0.25 of the distance from the Sun to the Earth). The United States will provide three scientific experiments to complement the seven German experiments; will launch the spacecraft; provide tracking and data acquisition facilities and personnel; and will provide technical assistance to the German personnel in testing the spacecraft and in the review of the spacecraft design and the spacecraft test program. The

Federal Republic of Germany will design, develop and fabricate the spacecraft (as well as the seven experiments), and will operate it during each 130-day mission.

During the year, the design was completed and work was started on construction and testing of the engineering model.

**Outer Planets Missions.**—These consist of a series of multiplanet flyby missions to accomplish early exploration of all the outer planets of the solar system, many of their natural satellites, their environments, and the interplanetary and galactic medium. These missions may be accomplished with a minimum number of flights, relatively short flight times, and modest launch vehicle capability by using the gravity-assist "swingby" technique, taking advantage of the uniquely favorable planetary alignment that occurs in the latter half of the 1970's. The planned program consisted of launches of two spacecraft in the 1976–77 time period each of which would fly by Jupiter, Saturn, and Pluto and another two in 1979 which would fly by Jupiter, Uranus, and Neptune.

Mission and spacecraft design studies were continued in an effort to maximize the science return per dollar for these missions. Since April more than 100 scientists, representing 13 different scientific disciplines, were employed in a Mission Definition Phase, with leaders for each of the disciplines forming a Science Steering Group (SSG) for the program. The SSG worked with the mission and spacecraft design teams to assure designs compatible with maximum scientific return. An "Announcement of Flight Opportunity" (AFO) was planned for issue early in 1972 to solicit experiments for the early outer planets missions.

Effort was also focused on long-lead time development and qualification of electronics and other specialized components required for a long-life outer planets spacecraft.

At the end of the year, because of budget constraints and projections, the effort on the three-planet flyby missions was terminated. New studies were initiated to develop a much more modest outer planets exploration program in accordance with suggestions made by the National Academy of Sciences. Such a program would explore Jupiter and Saturn using Mariner-type spacecraft.

**Advanced Studies and Technology.**—Spacecraft conceptual designs were developed for probe and orbiter missions to Jupiter. These missions are the logical follow-ons to the Pioneer F and G and the Grand Tour Survey missions to the outer solar system. Key technology areas were identified and efforts were initiated in scientific instrumentation, communications and heat shielding during entry. The Jupiter probe missions studied included a family of probes to survive at pressure levels ranging to 100 atmospheres. Pre-

liminary feasibility studies were also completed for Uranus and Neptune atmospheric entry missions and a Saturn rings mission. In support of these study efforts, a science advisory group was established to determine the most effective program of outer planet exploration.

The design of a low-cost Delta-class spacecraft, able to serve as an orbiter or a delivery system for a multiple set of probes was continued. Preliminary mission design and spacecraft system and subsystem designs were completed. Technology activity continued in the subsystem areas. This system is initially planned for use in exploring Venus.

Preliminary mission feasibility analyses were completed for several comet and asteroid rendezvous and docking missions. Studies have also been initiated to define scientific objectives and rationale for small body exploration and to develop the key technology required.

Studies were continued of other possible future missions, including post-Viking Mars exploration, and the development of supporting mission technology.

***Applications Technology Satellites (ATS).***—ATS 1, 3 and 5, which have far exceeded their design lifetime, continued to provide important applications and scientific data and to serve as a facility for experiments conducted by many non-NASA organizations. ATS 1 and 3 provided meteorological data in the form of spin scan cloud cover pictures to the National Oceanic and Atmospheric Administration (NOAA) on a near operational basis. During the year, the following organizations conducted experiments using one or more of these first generation ATS satellites: Maritime Administration, U.S. Air Force, Netherlands Coast Guard, Royal Norwegian Council for Scientific and Industrial Research, University of Hawaii, Alaska, Federal Aviation Administration (FAA) and commercial airlines, National Bureau of Standards, and the National Library of Medicine of the National Institutes of Health.

Progress continued on ATS F and G, which are being fabricated under contract, and prospects for launch of ATS F in the first half of 1973 are good. The basic experiments to be carried on ATS F are the 30-foot diameter parabolic antenna, an RF interferometer for measuring the direction in which the antenna is pointing, and a stabilization and pointing system able to point the transmitted radio beam toward any position on Earth or in near Earth space to an accuracy of 0.1 degree.

Additional experiments selected and contracted for included five communications experiments, one traffic management experiment, one meteorology experiment, four spacecraft technology experiments, and four scientific experiments. The thermal and structural model of the ATS F spacecraft was fabricated and satisfactorily passed environmental testing in December.

In June, NASA agreed to support with ATS F an experiment proposed jointly by the Department of

Health, Education, and Welfare and the Corporation for Public Broadcasting. The experiment will begin shortly after launch with transmission of educational and health programs to a number of ground receivers in the Rocky Mountain region and Alaska. NASA contracted for the inclusion of the necessary transmitter in ATS F and agreed to make that transmission capability available to HEW/CPB on a part time basis for the first year after launch. HEW/CPB agreed to pay for and develop all other aspects of the experimental program, including the necessary ground stations, program development, educational software, and experiment analysis.

Progress was also made on a somewhat similar cooperative experiment planned with the Government of India. Under the Memorandum of Understanding between the U.S. and India, NASA will move ATS F to a position over 35°E longitude about a year after launch and then make a special transmitter on the satellite available four to six hours per day for Indian government use.

The Indian government is responsible for provision of all ground portions of the experiment, including programming and post-experiment analysis and evaluation. During this year, the Indian government designed and tested prototype 10-foot community receiving antennas and initiated development and planning for production of television receivers and front-end converters.

***Cooperative Applications Satellites (CAS).***—On August 16, CAS-1 (EOLE) was successfully launched by a Scout vehicle from Wallops Station. The satellite, whose purpose is to obtain data on wind velocity and air temperature and pressure in the southern hemisphere by tracking and collecting data from hundreds of balloons, was developed and fabricated by the French Centre Nationale d'Etudes Spatiales (CNES). France also developed and launched the 500 instrumented balloons. NASA provided technical advice to CNES and provided the launch vehicle and launch services. The meteorological data resulting from this cooperative program is being made fully available to U.S. and French scientists.

In April, NASA signed a Memorandum of Understanding with the Department of Communications of Canada calling for the cooperative development of CAS-C, the so-called Communications Technology Satellite, which will pioneer the use of the newly allocated frequency band for satellite broadcasting at 12 GHz.

Under the terms of the Memorandum, NASA will provide the Delta launch vehicle and the 200-watt, 50-percent efficient transmitter output stage; Canada will provide the balance of the spacecraft including extendable, 1kW solar arrays, attitude control systems, ion engine thrusters for station keeping, and liquid

metal slip rings. A number of design reviews were conducted, and NASA initiated procurement of the 200-watt tube and associated power systems.

**Navigation/Traffic Control Satellites.**—In January, the Office of Telecommunications Policy set forth a government policy on satellite telecommunications for international civil aviation operations. Under the policy, the FAA was given principal responsibility for establishing such systems, with NASA providing technical support and continuing to conduct independent research in this area. NASA worked closely with Department of Transportation (DOT)/FAA in developing technical and management plans for such a satellite system.

In November, NASA reached formal understanding with the Maritime Administration (MARAD) of the Department of Commerce, regarding the implementation of a cooperative technological development program leading to the effective utilization of space technology in commercial maritime shipping system applications. This agreement formalized cooperative activities of NASA and MARAD, such as the cooperative L-band experiments using ATS 5 for communicating with and measuring lines of position of a number of merchant ships.

**Communications Satellites.**—On January 25, NASA launched Intelsat IV, F-2, for the Communications Satellite Corporation, for which it was fully reimbursed by COMSAT. Intelsat IV, with several times the capacity of earlier generations of Intelsat satellites, was placed in operational service over the Atlantic in March. On December 19, NASA launched Intelsat IV, F-3 for COMSAT. It is also for operational service over the Atlantic.

During most of the year, NASA, as requested by the Federal Communications Commission, conducted an extensive technical analysis and review of the various domestic satellite filings proposed by American industry. A final report of the NASA findings was provided to the FCC in December.

NASA continued to work closely with the U.S. delegation to the International Telecommunications Union (ITU) which is affiliated with the United Nations. The work concentrated on the technical sharing and interference criteria for space radio communications services using frequency bands in common with other terrestrial services. The results of the studies were accepted by the ITU and provided a technical basis for many of the new frequency allocations that were made at the World Administrative Radio Conference in Geneva during June and July.

**Geodetic Satellites.**—During 1971, the flashing lights on GEOS-2 and the laser retroreflectors on it and on GEOS-1 were used in the International Satellite Geodesy Experiment (ISAGEX), a cooperative interna-

tional program in geodesy sponsored by the Committee on Space Research (COSPAR) and initiated by the French. The tracking campaign, involving some 22 countries including the USSR and Eastern Bloc Nations, was concluded in August. Twelve laser stations belonging to NASA, the Smithsonian Astrophysical Observatory (SAO), and the French produced the largest block of precision satellite ranging data yet collected. This data and the photographic data collected by the other ISAGEX participants is being analyzed.

Work was initiated on GEOS-C the third and last of NASA's planned active geodetic satellites. In addition to the precision tracking and flashing light system carried in GEOS-1 and 2, GEOS-C will incorporate a radar altimeter operating at 13.9 GHz and a satellite-to-satellite tracking system, so that the GEOS-C spacecraft can be tracked by ATS F. The radar altimeter will demonstrate the feasibility of using radar altimetry to determine the geometry of the ocean surface, which is related to the geoid, ocean currents, tides, tsunamis, and storm surges.

**Ecological Sciences.**—In studies of remote sensing in public health applications, NASA discussed theoretical evaluations and practical applications of remote-sensor data with representatives of universities; municipal, county, and state governments; the U.S. Public Health Service; the World Health Organization; and the Food and Agriculture Organization of the United Nations.

Remote sensing was applied in studying the endemic strains of Venezuelan encephalitis virus along the southern coast of Florida and in an epidemic of Venezuelan equine encephalitis which crossed the Mexican border and spread through Texas counties in July and August 1971. NASA provided low- and high-altitude aerial photography to health experts trained in remote sensing. The results are being used in a concentrated study of the environmental conditions included in the epidemic and of morbidity information. Data are still being received and analyzed.

Another application was in a screwworm eradication program for Puerto Rico and the Virgin Islands. Data obtained by remote sensing were used to provide detailed thematic maps showing waterways important in the life cycle of this insect. Remote sensing technology was the basis for reliable and intelligent planning.

In addition, work is underway to determine the habitat of *Culex quinquefasciatus*, the vector of St. Louis encephalitis in the Houston, Texas area. In many cases, the habitat of this mosquito can be associated with effluent from septic tank overflow into collection ditches common in the Houston area. NASA aircraft have provided thermal scanner data, color infrared, color and multiband camera coverage over

approximately 12 miles of ditches containing septic water. Ten test sites were surveyed for ground truth (physical, chemical, microbiological and entomological characteristics) at the time of the flight. The results of this mission are now being processed by several advanced interpretive means.

**Meteorological Satellites.**—After more than a year and a half in orbit, Nimbus 4 data continue to be used by the National Oceanic and Atmospheric Administration to derive vertical temperature profiles for use in operational analyses. Objectives for the Nimbus E and F missions, planned for launch in November 1972 and June 1974, respectively, will include testing instrumentation to expand atmospheric remote sensing to cloudy regions, higher altitudes, and to new regions of the electromagnetic spectrum.

Extending atmospheric soundings to cloudy regions and to higher altitudes is needed to improve the accuracy and time extension of weather forecasts. Nimbus E will carry the feasibility demonstration experiments utilizing new infrared techniques and, for the first time, microwave radiometers.

The bench integration and test of the Nimbus E, including these experiments, was completed during the year, the flight models of the instruments were received, and fabrication and assembly of the spacecraft structure neared completion. The Nimbus F flight payload was selected and most of the payload procurement actions were completed. Nimbus F will provide continuation and improvement for the most critical Nimbus E experiments; important support for the Global Atmospheric Research Program in a critical time period; and a valuable set of new experiments vital as a mission in themselves.

This year, ITOS-1 (formerly TIROS-M) and NOAA-1 (formerly ITOS-A), operated as part of the National Operational Meteorological Satellite System (NOMSS), partially satisfying the System's requirement for direct readout and stored daytime and nighttime meteorological data.

The primary sensors of the two satellites are identical: two advanced vidicon camera systems (AVCS), two automatic picture transmission (APT) cameras, and two scanning radiometers (SR). They provided daytime and nighttime coverage in the visible and infrared regions in local and remote readout modes of operation. The identical secondary sensors—a flat-plate radiometer (FPR) and a solar proton monitor (SPM)—provided terrestrial and solar radiation data. Because of anomalies in the essential stabilization control subsystem in each spacecraft, ITOS-1 and NOAA-1 were deactivated on June 17 and August 19 respectively. The two TOS-series satellites—ESSA-VIII and ESSA-IX—were fully operational and provided data which partially fulfilled the requirements of NOMSS for daytime cloud imagery.

ITOS-B, launched on October 21, did not achieve orbit because of launch vehicle failure. Preparations were underway for the launch of the next operational member of the ITOS series in the first half of 1972.

The real-time acquisition and use of daytime cloud cover imagery from the Applications Technology Satellites (ATS)-1 and -3 were continued. The two satellites positioned in geostationary orbits over the eastern Pacific and western Atlantic Oceans, respectively, have provided data used by the National Weather Service severe storm advisory program and hurricane surveillance and advisory programs. The data were also used in the routine extraction of high level winds employed in numerical weather prediction programs.

Work continued on the development of the spacecraft, spacecraft subsystems, and associated ground equipment for the Synchronous Meteorological Satellite (SMS), the research and development forerunner of the Geostationary Operational Environmental Satellite (GOES). GOES will satisfy the second NOMSS objective of continuous viewing and data collection and relay. When SMS-A is launched, it will establish the initial capability to meet this requirement; launch is scheduled for late 1972. Present plans call for a second prototype spacecraft, SMS-B, and one follow-on operational spacecraft, GOES-A. The primary sensor of the SMS satellites will be the Visual and Infrared Spin-Scan Radiometer (VISSR) system, which will provide nearly continuous observation of cloud cover day and night. Data on cloud-top and surface temperatures will be available and wind information will be derivable from cloud motions. A data collection-and-relay capability will be included for acquisition of raw environmental data from surface platforms and for the relay of processed data from analysis centers to remote receiver stations. A Space Environment Monitor (SEM) package will also be carried.

**Meteorological Sounding Rockets.**—NASA launched 56 of the large research-type rockets, such as Nike Cajun, to explore the structure and characteristics of the atmosphere in the 30 to 100 km (20 to 60 miles) altitude region. Data were applied to the design, test, and operation of aerospace vehicles as well as to research in the meteorology and climatology of the upper atmosphere.

A series of launches was completed from Kourou, French Guiana, to determine tidal oscillations, their variation in amplitude with altitude, and relation to the atmospheric structure. One hundred and thirty-six of the Arcas and Boosted-Dart class of rockets were launched from Wallops Station and from Bermuda. These launches were in support of range operations, sounding rocket development, and international cooperative programs. Observation indicated that the differences between satellite and rocket measurements

were the same order as those between the satellite sounder measurements and between the rocket sounding observations.

The cooperative rocket programs with Argentina, Brazil, and Spain were enlarged with the conclusion of an agreement between U.S. and U.S.S.R. to develop a Western Hemisphere and an Eastern Hemisphere meridional rocket network and to exchange the data from the networks to improve understanding of the physical state and dynamics of the stratosphere and mesosphere.

**Earth Resources Survey Program.**—This program continued to use the Earth Resources Aircraft Program to develop remote sensing techniques and prototype systems. The aircraft program was also the principal source of remote sensing data for NASA-sponsored research activity. Several new remote-sensing systems became operational, and remote sensing was applied to actual environmental problems. The major effort here was an extension of the 1970 study of corn leaf blight. This year a full-scale prototype remote sensing system was applied to the problem and other agencies and several universities participated.

In addition, two surplus U-2 aircraft were obtained from the USAF to support expanded program activity generated by ERTS and Skylab. The aircraft were used to conduct a simulation of the data output of ERTS-A. Five test sites in California, Arizona, and the Chesapeake Bay area are overflowed every 18 days to collect data for selected ERTS investigators and for agencies participating in the NASA-sponsored Interagency Cooperative Research Program.

The Earth Resources Technology Satellite series (ERTS-A and B) will acquire repetitive multispectral images and radiometric Earth data from space. They will also conduct definitive experiments to verify the value of such data.

During the year, investigations were selected in agriculture, forestry, geology, hydrology, cartography, geography, environmental quality, and oceanography. These investigations will provide practical experience and engineering and management data to help determine whether operational Earth resource survey systems should be developed. As a result of an Announcement of Opportunities for participation in Space Flight Investigations over 730 proposals were received from investigators, including 34 foreign countries and the United Nations, who wished to participate in the ERTS or EREP programs. Good progress was made towards the launch of ERTS-A, now scheduled for May 1972, and for ERTS-B in November 1973. Investigations using the data from ERTS-A will begin with the launch of the satellite and will be extended by ERTS-B in order to observe seasonal changes of phenomena relating to agriculture, hydrology, and ecology and to acquire maps of surface temperature

distribution by using the ERTS-B thermal infrared capability.

Proposals also were received from investigators who plan to use data acquired by the Earth Resources Experiment Package (EREP) to be flown on Skylab. NASA selected proposals in the ERTS discipline areas designed to use the unique data from the EREP sensors. Potential investigators expressed requirements for multiband photography to be acquired with a six-camera array and imagery from the 13-channel multi-spectral scanner. Proposals were also made for the crew-operated viewfinder and tracking system which is boresighted with an infrared spectrometer, for the 13.9 GHz and 1.4 GHz microwave systems, and for the radar altimeter.

**Earth Physics and Physical Oceanography Program.**—This program emphasized investigations to enlarge understanding of earthquake mechanisms; to discover new mineral deposits; to produce accurate maps of mineral desposits on and beneath the ocean floor; to monitor and control pollution dispersal in the oceans; and to oversee and forecast maritime hazards.

New information about the mechanical properties of the Earth was derived by analyzing measured perturbations of the orbital inclination of the Beacon-C satellite caused by the Earth's tidal bulge. Geodetic satellite tracking data were used to improve the map representation of the Earth's gravity field.

Several very long baseline radio interferometer technique (VLBI) experiments were carried out to obtain a preliminary quantitative assessment of the technique. NASA spacecraft tracking networks facilities were used in the experiments, and preliminary results indicated the need to improve the instrumentation to achieve the required measurement accuracies.

The Apollo tracking ship *Vanguard* participated in an experiment to demonstrate its utility in measuring large ocean surface geoidal undulations. During a traverse of a deep ocean trench off the coast of Puerto Rico, the ship's C-band radar system tracked the GEOS-2 satellite.

Analysis of the tracking data led to an independent verification of the existence of a 10-meter (32-foot) depression on the ocean surface above the trench which had been previously measured by shipboard astronomic and gravity measurements.

Plans were made to monitor strain buildup across the San Andreas Fault in California by measuring the differential movement of the ground on each side of the fault. The upgraded five-centimeter accuracy laser satellite tracking systems will be used to monitor the changes in the distance between observation sites for a few years.

**Global Atmospheric Research Program.**—In support of GARP, NASA conducted numerical simulations experiments at the Goddard Institute for Space Studies

to optimize the GARP satellite observing systems and to extract the maximum meteorological information from space-borne sensors. Results, indicating that usefully accurate wind and pressure data for the extratropical regions of the global atmosphere might be determined from global temperature data obtained by meteorological satellite radiance measurements, may influence the design of the GARP observing systems and the requirements for observational accuracies. Goddard Space Flight Center initiated studies on the need for development of special space-related observing systems for GARP.

Plans were made for continued numerical experiments and for U.S. participation in the first GARP Global Experiment.

**Launch Vehicle and Propulsion Programs.**—Seven missions were successfully flown on the Scout launch vehicle. Two missions, SM-C and SSS-A, were orbited from the San Marco Range in Africa under a cooperative reimbursable launch services contract with the Italian Centro Ricerche Aerospaziali; four missions, including the PAET-A re-entry experiment, the SOLRAD-C and EOLE satellites, and the Barium Ion Cloud (GRS-B) probe were launched from Wallops Station, Virginia; and the UK-4 satellite was orbited from the WTR. The successful completion of these launches brought the Scout reliability record to 23 consecutive successes, and 49 successes out of the last 51 launches.

The development of the Algol III first stage motor, which increases the Scout performance by approximately 30 percent, was successfully completed, and the first production procurement of operational motors was initiated with delivery commencing in the 4th quarter of 1971.

The increased diameter 42-inch heat shield entered operational use with its first flight on the PAET mission. This heat shield provides the spacecraft with twice the volume ahead of the fourth stage motor previously available with the 34-inch heat shield.

The Delta launch vehicle system was used to launch five missions during this period: NATO B, IMP I, ISIS B, OSO H, and ITOS B. Four launches were successful. Other significant achievements were the completion of the adaptation of an inertial guidance system to the Delta vehicle, the adaptation of the Titan IIIC transtage engine to the Delta second stage, and the development of the TE-364-4 motor for use with the Delta and Centaur vehicles. Each of these systems will be first flown in 1972.

New effort was initiated in 1971 to adapt an eight-foot fairing to the Delta system and to adapt the Saturn S-1B H-1 engine to the Thor booster. These changes will be first flown in 1972 and 1973, respectively.

An agreement was completed with the Telesat Canada Corporation for the launch of domestic communications satellites. Discussions were continued with the Italian government for launches using the Delta system. Discussions were initiated with several proposers for the U.S. domestic communications satellite systems. Each of these launches will be conducted on a reimbursable basis.

The Centaur program conducted four launches in support of NASA and commercial space missions. Two launches of the Communications Satellite Corporation Intelsat IV were successfully accomplished. The first of two Mariner Mars spacecraft failed to achieve orbit as a result of an electronic failure in the Centaur stage autopilot rate gyro; the second Mariner Mars spacecraft was successfully injected into a Mars transfer trajectory. At the end of 1971, the operational Centaur record stood at 14 successful launches in 17 attempts.

### Advanced Research and Technology

**General Aviation Aircraft.**—During the past 3 years, NASA has utilized a typical light twin engined aircraft as a flying test bed with which to evaluate various levels of control and display system sophistication. The approach has been to use system and component technology that has been developed for large commercial transports or military applications, but because of cost not feasible for wide use in general aviation. The objective of the program has been to demonstrate the improvements in handling qualities and precision of flight possible, using modern control and display technology as a means of identifying goals for future general aviation aircraft system capabilities.

Results to date have been impressive. When incorporating a direct attitude command control system with a standard flight director display system, pilot ratings have improved to the near perfect level. This has been consistently demonstrated during simulated instrument approaches in moderate to severe atmospheric turbulence.

Continued effort in this area will concentrate on developing methods for achieving this system capability by techniques that have the potential for economic implementation.

**STOL Aircraft.**—Short takeoff and landing (STOL) aircraft offer important potential improvement for both civil and military short-haul (in the 500-mile range) air transportation. STOL technology can be applied to reduce community noise and pollution, to reduce congestion of the Nation's airways and airports, and to improve the quality of both civil transport and military tactical airlift. In the past year, the growing urgency of the need led to an intensification of the effort to assure technology readiness for the successful development and operation of STOL transports.

The most important step taken in STOL technology this year was the issuance in August of a Request for Proposals for the design and development of quiet experimental STOL transport research airplanes for use by NASA in flight research essential to development of propulsive-lift technology. Industry responses were received and contractors selected for Phase I, a competitive design and proposal phase. This will be followed by a single contract for Phase II, a final design and fabrication phase. The two research aircraft to be built will be utilized for development of design, operation, and certification criteria, and for evaluation of promising propulsive-lift concepts. The flight research programs will be developed in cooperation with other Government agencies and industry.

In preparation for the experimental airplane program, the technology activity this year has included basic analytical and wind-tunnel studies of turbofan powered-lift concepts with emphasis on externally-blown-flap (EBF) configurations. In the EBF concept primary and by-pass engine air are both directed against the wing flap system. Internally-blown-flap (IBF) or augmentor-wing (AW) configurations which use by-pass air ejected through special ducts in the wing over or through special flap systems to generate high lift and thrust were also being studied. In addition, the technology program encompasses studies of general STOL design arrangements and studies pertinent to the special problems of flight control, ride qualities, noise and propulsion. The propulsive-lift technology will permit development of quiet, clean, safe, and efficient turbofan transports capable of operation from runways 2,000 feet or less in length.

Quiet, low-pollutant-emission propulsion is of particular importance. In the past year, the technology being generated in the NASA Quiet Engine program was utilized in establishing a basis for meeting the particular requirements of STOL transport. Investigations were conducted at the component level, on fans, turbines, combustion, inlets, exhaust nozzles and materials. A study will be initiated shortly to identify the engine configurations and thrust levels of greatest potential interest for the civil STOL market. This work will lead to the definition and construction of low-polluting, quiet STOL experimental engines for ground-based research. Current plans are to have quiet, clean experimental engines available for research in late 1974 or early 1975.

In parallel with the technology programs, related analytical studies were initiated and coordinated with DOT and FAA to establish a better understanding of short-haul STOL transport operation and economics, implementation requirements, and the relationship between technical development and practical transport system design.

**V/STOL Aircraft.**—Major progress was made in largely completing the modification of a propeller-driven C-8A transport to an augmentor wing short take-off and landing jet (STOL) research aircraft. The fan air from the turbofan engines is ducted to "ejector type" flaps which pull air from over the wing to augment lift. This provides a STOL capability permitting the aircraft to operate from 1500-foot runways at touch down speeds of about 60 knots and slightly higher lift-off speeds. Flight tests are scheduled to begin in the spring of 1972. This is a joint program with the Canadian Department of Industry, Trade and Commerce.

Although the modified C-8A is a straight-wing research aircraft, two series of large-scale model tests completed this year in the Ames Research Center 40- by 80-foot wind tunnel confirmed that comparable STOL performance can be achieved by swept wing configurations representative of modern high-speed transports.

The large amount of high pressure air ejected through the augmentor flap creates a noise which has to be alleviated to meet desired operational-STOL noise limits. Preliminary results from two-dimensional tests started this year at Ames and under contract indicated that exit nozzles which break up the flow and acoustic lining can reduce sound emission appreciably.

The new V/STOL wind tunnel at the Langley Research Center became operational this year. It provides greatly improved capability for scaled model testing. A program was initiated to test four STOL lift augmentation concepts on a common transport model. Using simulated turbofan engines, the concepts of internally blowing air over deflected flaps, and externally blowing air onto deflected flaps were tested.

A propeller driven OV-10 airplane was delivered to Ames modified with a high rpm rotating cylinder ahead of its flap to promote flow attachment at very high flap deflections and making possible landing speeds and runway lengths of about 50 knots and 500 feet respectively. The airplane was tested in a wind tunnel and in flight to evaluate the concept, conduct handling qualities research, and investigate noise measuring techniques.

In vertical take-off and landing (VTOL) aircraft research, progress was made on lift fan and advanced rotor-craft concepts. Two series of tests were completed in the Ames 40- by 80-foot wind tunnel of a large swept wing transport model having lift fans with vectorable thrust to provide cruise propulsion. The favorable outcome of these and earlier tests together with control system and flight simulation tests led to the initiation this year of three contracts with aircraft companies to study lift-fan commercial transports for the 1980's and to define a research aircraft program for investigating the per-

formance, propulsion, handling qualities, and operational characteristics, including noise, in the real flight environment.

Investigations continued at the Langley and Ames Research Centers and under contract to gain a better understanding of helicopter rotor wakes, tip vortex generation and break up, and dynamic loads. These investigations show considerable promise for design of rotor systems with improved performance, vibration, and noise characteristics. Research on the tilt rotor concepts having higher speed capability than conventional helicopters indicated the likelihood of improved performance. Tests were completed of a full-scale flightworthy rotor in the Ames 40- by 80-foot wind tunnel, and preparations initiated for similar tests with a different rotor control system with provision to fold the rotor for cruise flight. NASA/Army definition studies are underway to define a flight research aircraft.

Variable stability capability has been incorporated in the X-14B direct lift VTOL research aircraft to permit a broader spectrum of V/STOL handling qualities flight research. V/STOL handling qualities research also continued using ground-based simulators, the variable stability CH-46 helicopter, and the variable stability tilt ducted-fan X-22 research aircraft. The latter is a joint program with the Navy, Air Force, and FAA.

**Military Support Programs.**—During the past year, steps were taken to better coordinate NASA's aeronautical research efforts to assist the military. A Military Aircraft Programs Office was formed within the Office of Advanced Research and Technology in NASA Headquarters to serve as a focus and be responsible for NASA programs in direct support of the military.

Specifically, this office is responsible for the direction from the Headquarters level, of the ongoing support to the USAF on the F-15 and B-1 programs, the ongoing support to the USN on the F-14 program, the direction of the USAF/NASA TACT Program, the direction of the planned U.S. Army/NASA Rotor Test Vehicle and the Army/NASA Tilt Rotor Research Aircraft Programs, and other ongoing and possible joint research, experimental and prototype aircraft programs.

Other actions were also initiated in these areas. An experienced NASA aeronautical engineer was assigned to the F-15 System Program Office at Wright Field and the B-1 System Program Office Operating Location No. 1 located at a contractor's Los Angeles division. These two NASA representatives report to the Military Aircraft Programs Office. The operation of the Army station at the Ames Research Center continues to be extremely successful. Similar NASA-based Army R&D groups are being built up at the Langley and Lewis Research Centers. The new differential

maneuvering simulator at the Langley Research Center was used in a cooperative NASA/Navy program in support of the F-14 program. In mid-1971 NASA assembled an intercenter study team that participated in the DDR&E prototype study. As a result of NASA's participation in the prototype study, the need for cooperative NASA/USAF efforts in the STOL experimental aircraft program was brought out clearly and a cooperative program was being prepared.

**Tilt/Rotor Research Aircraft.**—An agreement between the U.S. Army and NASA for a joint Army/NASA program for the procurement and flight test of a V/STOL tilt-rotor research aircraft for research on the tilt-rotor concept was consummated on November 1, 1971. The program will include investigations of tilt-rotor handling and control characteristics, noise, and near-terminal operational techniques. The flight research vehicle will be used also for general research of V/STOL instrumentation and automatic landing systems and of advanced rotor concepts. The program will be conducted over a two-year period and the costs will be shared equably by the Army and NASA.

**Rotor Systems Test Vehicle.**—An agreement between the U.S. Army and NASA for a joint program for the procurement of Rotor Systems Test Vehicle for flight test of advanced rotor concepts was consummated on November 1, 1971. The test vehicle will fulfill a need for a cost-effective means of flight testing new advanced helicopter rotors and new control concepts in the real and dynamic environment of flight to study problems under conditions that cannot be adequately simulated in ground facilities. A number of new rotor concepts are and have been under study analytically and experimentally in ground facilities at small and large scale which show promise for significantly improving rotorcraft performance, control, and vibration. The Rotor Systems Test Vehicle will be used to flight test the most promising of these advanced rotor configurations. The program will be conducted over a two-year period and the costs will be shared equably by the Army and NASA.

**TACT (Transonic Aircraft Technology) Program.**—An agreement between USAF and NASA for a joint USAF/NASA program for the procurement and flight test of supercritical wing on an F-111 fighter aircraft was signed on June 16, 1971. The program will provide "proof-of-concept" of the application of supercritical wing technology using a variable sweep F-111 aircraft. Program go-ahead for the wing and aircraft modification was approved in early July 1971. The first design review for tooling go-ahead occurred in mid-December 1971. The final design review is scheduled for the Spring of 1972.



**Joint DOT/NASA STOL Program.**—NASA and the DOT joined in a program which reflects common interests in the development and investigation of aircraft and electronic technologies, operational procedures, and system concepts which can improve the operational efficiency, public acceptance, safety, and reliability of a Short-Takeoff and Landing (STOL) short haul system. Flight experiments will include the use of STOL research aircraft equipped with an avionics system to allow investigation of alternative avionics functional configurations, flight paths, operational procedures, levels of automation, and landing aids. Initial flight experiments will use an area navigation system developed by the DOT's Transportation Systems Center to evaluate radio navigation systems performance in various potential STOL environments and to evaluate the adequacy of existing communications and radar surveillance in this same environment. The navigation system and data acquisition system will be ready to begin flight experiments in April 1972. In September 1971, a STOL airplane simulator at Langley Research Center was linked to the FAA's NAFEC-ATC simulation facility and flown in real time in a simulated ATC system to determine the effect of the STOL airplane on the ATC system and the effect of the ATC system on the STOL airplane in the New York terminal area operating from a downtown STOL port. The Ames Research Center was developing the airborne equipment which will be installed in a conventional C-8A "Buffalo" aircraft and the Augmentor Wing Jet STOL Research Aircraft to investigate STOL transport approach, landing, and takeoff performance as a function of navigation, guidance and control systems configuration, and flight management techniques; subsystem characteristics and performance; operational procedures and flight path geometry; and operational environment. The FAA will provide the microwave, scanning beam instrument landing system. The flight experiments were defined jointly to provide engineering data requirements to support the FAA's STOL short-haul system development plan. The equipment development is proceeding on schedule with flight experiments scheduled to commence in October 1972.

**Advanced Transport Technology.**—The Advanced Transport Technology program was initiated to develop technologies applicable to the next-generation long-haul subsonic air transports. It is intended to provide the technology base for industry application by 1978. The goal of the program is to insure that the next generation of U.S. long-haul air transports will have minimum environmental impact and will be competitively superior in the world market.

The program has three major elements: fundamental technology in the primary aeronautical disciplines of aerodynamics, propulsion, structures and

materials, flight control, and avionics; exploratory flight research on supercritical aerodynamics and related laboratory developments; and systems studies to relate the evolving technical advances to realistic future transportation requirements, markets, and economics.

During the past year, several significant events occurred in the program. The systems studies, which will provide guidance on where our efforts should be concentrated for the next several years in the key long-haul transport technologies, neared completion. Identification of advanced technology payoff areas and recommendations for further studies were made by the contractors. The contractual effort was redirected with strong emphasis on the application of advanced technologies to specific design concepts to more fully evaluate their impact.

Several flight tests were conducted to verify two applications of the supercritical wing: a thick wing to permit structural weight savings, and a wing designed for high-speed cruise. In a joint program with the Navy, a thick supercritical wing was incorporated on a T-2C trainer to investigate the performance of the wing at moderate subsonic speeds. Thus far 24 flights have been conducted. The results indicate that the drag of the T-2C with the thick supercritical wing at the design Mach number is identical to that of the T-2C with the conventional thin wing, and the lift coefficient for the buffet onset is greater for the supercritical wing for all Mach numbers up to the limit Mach number tested. This validates the new wing design concept as providing better structural efficiency and maneuvering performance than the old concept.

A high-speed supercritical wing was constructed for flight tests on a TF-8A airplane. Performance, pressure distributions, stability and control, buffet and flutter have been investigated during the 24 flights conducted thus far. The drag and handling qualities were as predicted from wind-tunnel tests. Buffet was intense but not severe, and no flutter was experienced. Flights have been conducted up to Mach 1.2 and up to an altitude of 50,000 feet.

The results from these flights have been very encouraging and indicated the importance of supercritical technology as one of the key technical advances for the next generation of air transports.

**Jet Transport Noise Reduction.**—Methods of reducing the noise of jet transport airplanes during take-off and landing were the subject of extensive research by NASA. This work showed the potential of a change in flight profile for noise reduction and developed the requirements for airborne guidance and control systems needed to effect the flight path control. The reduction that can be achieved with a change in landing approach profile or technique will depend mainly on the amount of thrust reduction

possible during the approach and the increase in height above the ground at any point. Steepening the approach angle will both decrease thrust and increase height above the ground. Noise reduction of about 18 decibels of perceived noise (PNdB) is possible when the approach angle is steepened from 2.65 degrees (the standard approach angle) to 6 degrees. However, a single-segment 6 degree approach results in a sink rate objectionable to most pilots, at least with currently available propulsion system response times, flight control systems, and landing guidance systems. Two-segment noise abatement approaches minimize the problem of high rates of descent near the ground while providing significant noise reductions. The reduction in noise—with a two-segment approach profile having an upper segment of 6 degrees that intercepts the lower segment of 2.65 degrees at 400 feet altitude—gave a noise reduction of about 10 PNdB at 1.25 nautical miles from the runway threshold, and a greater reduction beyond 1.5 mi. from the runway. NASA and a commercial airline completed a flight program which demonstrated that the technology and hardware are available now for two-segment noise abatement flight paths. Two problems require resolution before this technique is considered practical for implementation: (a) selling the line pilot on the suitability of three dimensional area navigation flight procedures as a means of flying two-segment noise abatement procedures under typical schedule service airline conditions and (b) demonstrating to major airlines that the avionics modifications to the aircraft are practical for fleet-wide implementation and are useful for other applications as well as noise abatement. NASA and FAA are planning a cooperative program with the airlines to accomplish these objectives. There are also effective departure procedures for noise abatement. Noise reductions of from 6 to 14 PNdB can be realized between a maximum continuous power climb and an optimum climb-out procedure.

**Noise Research.**—NASA continued to expand its research effort on aircraft noise. A new engine test stand for measuring noise performance neared completion at Lewis Research Center. The first engine to be tested there will be the Quiet Engine in its acoustically treated nacelle. Work to date indicated that substantial amounts of noise reduction are available by the use of acoustic treatment with rather small penalties in engine performance. Systematic fan noise tests have shown that the key parameter to control for low noise research resulted in the development of a scaling law for jet noise prediction. These developments together represent a significant advance in noise control for conventional takeoff and landing (CTOL) aircraft.

NASA specified the very low noise goal of 95 EPNdB at 500 feet for its experimental STOL research airplane. There is a significant noise research effort underway to support that airplane program at all four NASA research centers.

A facility for noise investigations of lift fans suitable for vertical takeoff and landing (VTOL) aircraft was under construction at Lewis Research Center. The noise problem of such propulsion systems is severe. Control of propulsion system noise is a pacing technology for VTOL aircraft.

Construction started on the Acoustic Research Laboratory at Langley Research Center. This laboratory will be devoted primarily to basic research on noise sources. Experiments will be initiated in the laboratory in about two years.

Close coordination of noise research programs with the Department of Transportation and the Federal Aviation Agency was strengthened by the creation of a joint DOT/NASA Office of Noise Abatement. The NASA Deputy Chief of this office has been appointed. Plans for implementation of the noise research recommendations of the Civil Aviation Research and Development study are being coordinated through this office.

**Community Response to Aircraft Noise.**—The social and psychological factors which cause the communities located adjacent to major airports to react adversely to aircraft noise were investigated under a grant from Langley Research Center.

The U.S. conducted social surveys around airports of seven large cities and two small cities; the U.K. conducted two surveys near London's Heathrow Airport. Detailed cross tabulations and special analyses of answers to questions concerning common human response variables made it possible to develop a single analytical model based on over 7500 responses from populations of more than one nation. Three of the most important variables influencing community annoyance were noise exposure levels or Composite Noise Rating (CNR), fear of aircraft crashes, and feelings of misfeasance on the part of aircraft operators. Misfeasance is the belief that the aircraft industry has the knowledge and ability to reduce the unwanted noise but chooses not to do so for reasons believed to be insufficient. The survey data indicated that feelings of misfeasance are positively correlated with intensity of noise exposure; these data can be used by DOT, FAA, and EPA in establishing guides and standards for maximum noise exposure levels.

**Quiet Engine Program.**—The experimental quiet engine program progressed on time and on schedule and within cost limits. Acoustic tests were initiated in July on the first quiet engine assembly incorporating a fan having low tip-speed, high aspect-ratio blades. The engine test program included: baseline

noise tests with three different fan nozzles and two core nozzles, investigation of two different types of sound absorbent materials for the core nozzles and determination of the effect of acoustic treatment of the fan inlet and fan exhaust ducts. Two different inlets were used in these tests; a thick lipped unit and a thin lipped unit with blow-in doors. Noise and performance data were taken in all tests and are now being reduced and prepared for publication. Preliminary results show that the original objectives of the program (15–20 PNdB reduction in noise levels as compared to present 707/DC-8 commercial transports) have been exceeded. A second experimental quiet engine, incorporating moderate tip-speed, high-aspect-ratio fan blades is now being assembled in preparation for tests to begin early in 1972.

**Aircraft Wake Turbulence.**—The swirling air masses trailing from the wing tips of large, heavy aircraft contain strong winds which can be hazardous to other aircraft encountering them in flight. NASA investigated the problem of wake turbulence behavior at its Ames, Langley, and Flight Research Centers and at the Marshall Space Flight Center. Instrumented aircraft and towers, laser Doppler wind systems, wind tunnel models, water tanks, and analytical studies were used to determine trailing vortex characteristics and methods for reducing wake velocities.

On the basis of information from NASA and other studies, the FAA has published wake turbulence avoidance procedures, but research was continued to obtain a better understanding of the phenomenon. Increased NASA efforts were underway to develop an aerodynamic or mechanical method to either inhibit the formation of high intensity vortices or to cause early dissipation of the wake.

**Clear Air Turbulence Measurement.**—NASA completed the design of an airborne radiometric temperature measuring device for the detection of areas of clear air turbulence (CAT) ahead of aircraft. This instrument was installed on a research jet aircraft at the NASA Flight Research Center and checkout and calibration flights were conducted. Experimental test flights will be started early in 1972 in cooperation with the FAA.

The purpose of this device is the early detection of CAT ahead of an aircraft so the pilot can either take evasive action or slow down to lessen the danger or discomfort to passengers. One of the characteristics of CAT is apparently a small but definite change in atmospheric temperature which would be sensed by the dual frequency radiometer and displayed to the pilot in the form of distance to and degree of the threat.

**Aircraft Pollution Reduction.**—The most significant

exhaust emission problem due to jet aircraft occurs during idle and other low power engine operating conditions where the greatest quantity of carbon monoxide and unburned hydrocarbon is produced. Research during the past year was directed to the reduction of these emissions by increasing the low combustion efficiencies typical of reduced power operation.

During takeoff, cruise, and approach operations, the engine is operated at much higher power levels and very high combustor efficiency levels which result in little or no emissions of carbon monoxide and unburned hydrocarbons. However, the higher combustor inlet and exit temperatures tend to increase nitric oxide emissions. NASA research in short length combustors during the past year has indicated that nitric oxide emissions can be reduced by reducing the combustion residence time, i.e., the time that the air is subjected to the high temperature zone within the combustors.

Another research activity initiated this year will lead to a program to determine the composition and ambient characteristics of the troposphere over a period of several years. An instrument package for measuring selected constituents of the atmosphere is now in preliminary design. It is planned to mount the instrument package aboard a number of commercial aircraft flying both domestic and international routes.

**Pilot Warning Indicators.**—The final flight tests of optical Pilot Warning Indicators (PWI) were completed in July 1971. The device detects the infrared radiation from a Xenon flash lamp mounted on the intruder aircraft, and displays warning signals to the protected aircraft.

Two types of PWI were tested in simulated collision flights at the FAA flight test facility in Atlantic City, New Jersey. Average detection ranges of over one mile were obtained. One of the systems, of improved design, demonstrated warning ranges up to 1.8 miles, which is considered adequate to initiate collision evasion actions under optimum conditions.

The flight demonstrated that an optical PWI is feasible, though considerable work remains to be done to make it operational and inexpensive enough for use by general aviation aircraft.

**Pilot-Oriented Management System.**—A unique aircraft management concept for terminal area operations, using an onboard display and computer, was developed by Langley Research Center. The desired flight path, time deviations of actual and desired aircraft position, and the position of neighboring aircraft are provided by a situation display, associated software, and information derived from the ground navigation and air traffic control (ATC) system. Initial simula-

tion results for this concept indicate that existing airport runway capacities could be significantly increased and that the hazard of mid-air collisions could be minimized through incorporation of the pilot-oriented management approach into aircraft and future operational ATC systems.

**Transonic Maneuverability.**—In early 1970, a flight test program was initiated to investigate the use of thrust vectoring for improved maneuverability using a Hawker-Siddeley Kestrel P-1127 aircraft. This aircraft obtains its maneuvering capability through rotation of the jet exhaust nozzles. In 1971, flight tests were concerned with performance and handling qualities. Results from the initial phase of the program indicated that vectored thrust is controllable in direction and magnitude, providing high longitudinal deceleration, a modest increment in normal acceleration, an increased turn rate, and the ability to fly and maneuver at very low speeds. This program is continuing to complete the documentation of dynamic maneuvers and simulated air combat maneuvers. A joint United Kingdom-NASA program for further research on thrust vectoring in an expanded flight envelope was initiated using British Harrier aircraft which has higher thrust engines and fewer engine and airframe limitations than the Kestrel. This aircraft will be modified in 1972.

**NASA-USAF YF-12 Flight Research Program.**—The Air Force and NASA YF-12 aircraft completed 66 flights in 1971 under the funding responsibility of NASA. The instrumentation installation of the NASA aircraft was completed early in 1971 and the aircraft was returned to flight status in March. Twenty-two flights were flown during which flight loads and temperature survey measurements were completed from subsonic to supersonic cruise speed conditions and a stability and control investigation was completed. This aircraft will undergo static calibration in the High Temperature Loads Calibration Laboratory early in 1972. The Air Force YF-12 aircraft was flown to more fully define the tactical performance and support requirements of an advanced interceptor. Twenty-four flights were made, nearly completing this phase of the program, when the aircraft was lost in a crash on June 24, 1971. On July 19, 1971 a third aircraft was acquired by NASA from the Air Force for propulsion research. This aircraft is currently being instrumented and is expected to be flown early in 1972.

**Hypersonic Research Engine.**—The hypersonic research engine project was initiated to explore the potential of a type of engine capable of operation at very high speed. Two distinct test models were constructed, one to demonstrate the structural capability of a flight-

weight, liquid-hydrogen regeneratively cooled engine design and the other to determine propulsion performance of a test model designed to operate with both subsonic and supersonic combustion within the test range of Mach 4 to Mach 8.

The flight-weight, hydrogen cooled engine structural investigation was completed in mid-1971, with successful tests at Mach 8 structural temperatures and thermal strains. These tests validated engineering design techniques, demonstrated requisite structural performance at acceptable levels of weight, and proved the feasibility of Mach 8 flight-type structures for supersonic combustion ramjets (Scramjets).

The propulsion performance model was being prepared for testing in the Lewis Research Center hypersonic engine test facility located at Plum Brook, Ohio. This model will be used to investigate component interactions in the integrated engine, and to improve and measure overall engine performance over a wide range of operating conditions.

**High Altitude Balloon Flights.**—The second phase of measurement of the atmospheric propagation of laser energy using high altitude balloons was completed by Goddard Space Flight Center.

Carbon dioxide (CO<sub>2</sub>) and argon lasers were used on the ground, and corresponding detectors in the balloon package. The two lasers radiating at wavelength of 10.6 and .5 microns were used to obtain measurement of atmospheric effects on radiation in the visible and infrared portions of the light spectrum. Factors such as attenuation, scintillation, and beam tearing were measured and related to local atmospheric conditions such as temperature, humidity, air velocity and altitude.

The knowledge of the effects of the atmosphere on light propagation is important in the design of laser communications systems, altimeters, geodetic observations, and earth resources applications.

**Space Shuttle.**—Over 25,000 hours have been spent in evaluating the aerothermodynamic characteristics of many different shuttle configurations in the Ames and Langley Research Centers wind tunnels. These studies were aimed at selection of the most promising configurations for more detailed tests. Successful new techniques for studying space shuttle heating have been devised which greatly reduce the time and cost of experimental investigations. New computational methods have also been devised for theoretical study of the flow field around the space shuttle. This work is important to fully understand the complex aerothermodynamic phenomena occurring during reentry into the Earth's atmosphere. Progress was also made in developing low-cost, easily replaceable ablative heat

protection panels for the shuttle. Additional tests were carried out on alternate surface insulation concepts which would allow extended reuse of the shuttle without replacement of the thermal protection system.

**Planetary Entry Program.**—At Wallops Station, Virginia, in June the Planetary Atmosphere Experiment Test was successfully completed. The primary objective of the test was to demonstrate in the Earth's atmosphere that the structure and composition of an unknown planetary atmosphere could be obtained from a probe vehicle entering the atmosphere at high speed. During the test, density, pressure, and temperature as functions of altitude were deduced from onboard instrumentation and from the motion and deceleration of the probe vehicle. The composition of the atmosphere was also determined from other special instrumentation. The data obtained from the test agree very closely with independent meteorological data taken during the day of the test.

The ability of engineers to design lightweight heat shields for planetary probes was significantly improved by making use of dielectric materials which accommodate very high radiative heating by means of reflection. By use of special materials which ablate and which diffusely reflect the very large amount of radiant heat present in Venus or Jupiter probe entries, a potential reduction of the heat shield weight by nearly 25 percent can be realized. The use of this type of heat shield would permit additional instrumentation in the probe.

**Lifting-Body Flight Research.**—The joint NASA/Air Force Lifting-Body Flight Research Program has been underway for several years and has provided a valuable base of technology for reusable horizontal landing spacecraft for the future. The successful demonstration of manned, supersonic and transonic flight and landing using the M2-F2, HL-10, and X-24A provided a major impetus for NASA's current space shuttle program. Flight tests with all three of these vehicles have now been completed. The M2-F3 is currently the only vehicle in flight status, having completed seven test flights during 1971. Spacecraft reaction control systems were tested at low altitude and high dynamic pressures. This system will be combined with an improved rate command augmentation system next year and further tests carried out. Both control systems have good potential for use on the space shuttle. Early next year another test vehicle, the X-24B, is scheduled to make initial test flights. The X-24B is characteristic of a higher performance class of vehicle compared to the lifting-body vehicles already tested and has good potential as a high performance military hypersonic aircraft for the 1980's. The

joint NASA/Air Force program will investigate flight performance and handling qualities from about Mach 2 to landing.

**Nuclear Systems.**—The overall aim of the joint NASA-AEC space nuclear systems program is to provide the technology and flight qualified space nuclear propulsion and power systems to meet the current and future needs of the Nation's space program. Significant advances in space propulsion and power will become increasingly more important as the goals for space exploration become more ambitious. While the detailed nature and specific pace of post Apollo missions have yet to be determined, the programs will require increasing amounts of energy for both propulsion and power; nuclear energy will play an increasing part in fulfilling these needs.

**Nuclear Propulsion.**—The major space nuclear propulsion program objective is to provide a flight-rated nuclear rocket engine, called NERVA, for application in a variety of space missions. NERVA development is proceeding at a reduced pace based on technology stemming from more than fifteen years of research and experimental analyses. In addition to activities related to NERVA, the space nuclear propulsion program also includes a variety of advanced research and technology activities designed to extend the capabilities of solid-core nuclear rockets, to conduct research on advanced nuclear rocket concepts and to provide a base of information for the development of a nuclear stage.

NERVA development progress during the year was marked by completion and review of the engine baseline design and the initiation of engine component detailed design and development activities. From a systems engineering standpoint, this included the updating of all engine design documentation, e.g., systems analyses, trade studies, data items, and the formal approval of the engine and component specifications for proceeding with the next phase of engine development.

The original plan for this period called for the completion of the engine detailed design and the initiation of the detailed design of all engine components. However, FY 1972 funding restrictions which became known at the beginning of the year necessitated a continuation of development activities on selected critical engine hardware only. Significant manpower reductions also were made; however, a core of the established NERVA capabilities was retained to permit the resumption of the full development program when appropriate.

Detailed NERVA design and development efforts conducted during 1971 were devoted primarily to the turbopump assembly, nozzle and nozzle extension and major valves and actuators. The detailed design review

of the turbopump assembly was completed and work was started on the fabrication of two units for development tests in 1972. Turbopump bearing tests were continued to provide design information for the development of radiation-resistant bearing assemblies capable of operating for long durations. The detailed design of the stainless-steel, regeneratively-cooled nozzle section was initiated, and several shaped graphite material samples were fabricated to permit the analyses of design and fabrication problems associated with forming, graphitizing and testing a graphite nozzle extension. The testing of other material selections for high-stress applications also was continued and final test plans were approved for the cryogenic evaluation of materials and components under irradiation at the Nuclear Aerospace Reactor Facility at Fort Worth, Texas, and the Plum Brook Reactor Facility in Ohio.

**Test Operations.**—In addition to the NERVA design and development activities conducted during the year work was continued at the Nuclear Rocket Development Station in Jackass Flats, Nevada, to prepare for the forthcoming tests of the first Nuclear Furnace, and to modify Test Cells "A" and "C" for NERVA engine component development tests. Test Cell "A" is to be used this year for turbopump bearing tests. Test Cell "C" will be used for the test of the Nuclear Furnace, and the NERVA turbopump assembly and parts. The Nuclear Furnace test program includes fuel-element experiments relating to the detailed design of the NERVA engine nuclear subsystem.

**Nuclear Stage Studies.**—Studies of nuclear rocket-powered stages were continued with primary emphasis on compatibility with space shuttle launch and logistic support. The principal applications of such reusable nuclear stages, specified for the studies, were manned and unmanned flights between low earth orbit, lunar orbit, and geosynchronous orbit. Propulsion of unmanned payloads into deep space was also considered. Study results for single-tank and modular-tank configurations were published in May, presenting all aspects of stage definition from preliminary design and operations analysis to development and technology program requirements. One study contract was continued to define alternate modular concepts, incorporate the effects of changes in space shuttle design, and to define engine/stage interface.

Consistent with plans to develop a reusable space shuttle for economical transportation into low-altitude earth orbit, nuclear stages have been configured for launch either inside the shuttle orbiter or externally mounted on some other shuttle configuration. Study results confirmed previous estimates of economy and high performance. This year's effort refined weight and cost estimates yielding improved cost-effectiveness.

A study was begun in December to assess the potential applications and utility of a dual-mode NERVA system, capable of operating as both a rocket and an electrical-power source. Mission requirements, system capabilities, and related design and operational factors will be combined to identify promising uses, make comparisons with alternate propulsion and power sources, and define the characteristics of a useful dual-mode NERVA. Previous studies have indicated that such a system may have attractive applications both as an alternative to a separate power supply for the payload and improvements in stage design and engine performance resulting from power availability and efficient afterheat removal. Results from the current study will be available in July 1972.

**Vehicle Technology.**—The activity in this segment of the program is directed toward the development of technology to meet the requirements for the nuclear stage.

During 1971, the activities of primary interest were long-term cryogenic storage, nuclear radiation effects, and hydrogen properties technology. The work centered on development of suitable instrumentation, e.g., to measure the properties of liquid/solid (slush) hydrogen mixtures. Work also proceeded on devices which could be useful in support of nuclear stage development flight operations such as neutron and gamma detectors adapted for unusual environments. Two such devices were recently successfully ground tested. One is a compact neutron detector which can operate satisfactorily in liquid hydrogen. The other is a neutron spectrometer which can detect and transmit information relative to the fast neutron energy spectrum of a nuclear reactor.

**Advanced Nuclear Concepts.**—Research was conducted on systems which offer high performance and/or significantly improved operating characteristics such as improved life, higher thrust-to-weight ratios, higher specific impulse, and reduced handling requirements. The cavity reactor (gas-core reactor) appears to offer the potential for the highest performance, but its development will require solving several uniquely distinct research problems. The present work consists of propellant heating experiments approaching engine operating temperatures, the development of radiant energy sources approaching the heat fluxes of gas core reactors, and fluid mechanics confinement simulation tests to predict acceptable fuel-propellant separation. Experimental investigations also were continued to determine the feasibility of the rotating fluidized bed reactor concept. The past year's work included pressure drop measurements, and high speed motion picture analysis of the particle behavior. These results

have been sufficiently promising to warrant continued flow behavior studies, including heat transfer experiments.

**Nuclear Power.**—The nuclear power program involves technology efforts and flight system development in response to specific scheduled missions. The flight system development is conducted by the AEC with NASA involved only in system integration and spacecraft interaction effects and in performance verification testing. The technology efforts are a joint venture with the AEC concentrating on the nuclear heat sources and static conversion and NASA concentrating on dynamic conversion and overall systems technology and verification testing. The major NASA funded activities are described below.

**Isotope Systems Technology.**—Long-term tests of electrically heated modified SNAP-19 radioisotope thermoelectric generators (RTG) indicated that stable generator performance can be expected in the Pioneer F/G and Viking Missions.

Analyses indicated that the nuclear radiation field from the modified SNAP-19 RTG would not interfere significantly with radiation-sensitive science instruments (charged particle telescope plasma probe) in the Pioneer F and G Missions.

Tests indicated that the modified SNAP-19 RTG would be able to perform satisfactorily under expected load transients, thermal cycling and surface winds on the Mars Lander of the Viking Mission.

Experimental and analytical RTG technology performed at JPL contributed to improved understanding of Multi-Hundred Watt (MHW) RTG design requirements and provided an improved base for RTG/spacecraft integration in nuclear radiation, thermal, mechanical and operational areas of very long duration, multiple outer planet (Grand Tour) science missions.

**Brayton Power Conversion.**—The 2-10 Kw Brayton combined rotating unit which has been under development for use with an isotope heat source successfully passed 8000 hours of operation, for the most part unattended. The contract was awarded for the development of a larger (15-80 Kw) Brayton turbine-alternator-compressor unit for eventual use with a long-lived nuclear space reactor heat source.

**Thermionics.**—Efforts continued on various thermionic materials and devices for use with high-powered nuclear reactor space power units. Irradiation tests of uranium carbide fuels at thermionic temperatures completed 12,000 hours at the Plumbrook Reactor. Long term electrical stability of advanced tungsten emitters was demonstrated by successful completion

of 5000 hours tests at 3270°F. An out-of-pile thermionic converter passed 37,000 hours of operation at an emitter temperature of 3100°F with a steady electrical output of 8 watts per square centimeter. Externally fueled thermionic converters were fabricated and tested as an alternate approach to the internally fueled thermionic fuel elements. A design study and a preliminary development plan were completed for a 120 Kwe nuclear electric propulsion system based upon a thermionic reactor power supply.

**Advanced Liquid Metal Reactor.**—Irradiation of various fuel element materials for possible use in a high temperature space reactor passed 8000 hours at 1900°F. A 1900°F liquid metal (lithium) corrosion loop completed 5000 hours of testing with no deleterious effects observed. A zero-power criticality experiment program for a "fast" space reactor assembly was completed and produced significant reactor design and control data.

**Electrochemical Power.**—To further improve the reliability, safety, and longevity of nickel cadmium cells and batteries, work was started on a non-gassing cell. This requires replacement of the nickel structure with cadmium or perhaps silver on the cadmium side of the cell. If successful, it will result in simpler charge control and elimination of all but a very low rate of gas evolution (oxygen) from the nickel oxide cathode during charging.

Another project that has just begun concerns pulsed charging of sealed space cells. Commercial equipment for unsealed cells is available, but is by no means optimized. A basic study is required to determine the best kind of pulsed charge to eliminate the "memory" effect in nickel-cadmium, to speed charge acceptance in silver, and to eliminate dendrite growth in zinc cells.

Work continued on novel structure for solid ionic conductors that operate below the boiling point of water and that are compatible with alkali metals, specifically sodium or potassium. The eventual goal is a cell with ten times the energy density of presently available cells.

**Solar Power.**—Recent theoretical studies indicated that a doubling of the efficiency of a solar cell should be possible. To reach this goal as well as to improve radiation resistance an investigation was begun of the factors responsible for degrading cell performance and of ways in which they might be minimized or avoided altogether.

Activity was underway to provide technology for solar arrays with 50 watts/lb. performance. Lighter solar cell substrates, solderless and glueless connections, and lighter, perforated booms are among the ap-

proaches being investigated for this purpose. It is believed that this new goal should be attainable even without improvements in cell efficiency, which would further increase the power density.

**Electric Propulsion.**—The first breadboard model of a fully automatic electric propulsion system for an interplanetary spacecraft was placed in test following a four-year development effort. This system is designed to demonstrate all the functions required of a solar powered electric propulsion system on an interplanetary flight mission, and represents a major step in establishing this technology. Electric propulsion systems are expected to provide an economical capability to reach extremely difficult exploration targets such as comets, asteroids, and planetary orbits.

In the area of auxiliary propulsion the prototype one millipound north-south station-keeping ion engine experiment for flight on the ATS-F spacecraft reached the test stage. A contract was let for a 25-micro-pound-sec. pulsed plasma thruster to prove its capability for the Synchronous Meteorological Satellite. This system promises high reliability because of its lack of moving parts. Initial feasibility demonstration of a pulsed monopropellant hydrazine resistojet also took place. Such thrusters offer the advantage of reliable operation at lower thrusts than those achievable with catalyzed engines, as well as the possibility of operating on propellants which are simpler to handle aboard spacecraft than those presently used. Initial tests were carried out on ceramic materials which, as resistojet heaters, may be capable of withstanding the severe environment associated with the use of space station waste products as propellants.

**Shuttle Auxiliary Propulsion.**—The shuttle auxiliary propulsion technology program moved ahead. System study results clearly indicated the superiority of the high pressure gaseous oxygen-gaseous hydrogen system over the low pressure design and all component work was directed towards meeting the high pressure system requirements. In the thruster area, technology efforts in thrust chamber cooling and performance, propellant valves and ignition progressed to the point where an integrated thruster assembly task can now be undertaken. Work in the propellant conditioning component area was initiated with the award of contracts for both the turbopump assemblies and gas generator/heat exchangers.

In the planetary spacecraft propulsion technology area, a major redirection of the program was made. The program to demonstrate the operational capability of a FLOX-Methane spacecraft propulsion system was deferred, and a decision was made to focus

the resources for this technology area towards FLOX-Monomethylhydrazine pressure fed spacecraft propulsion which is applicable to the small, low thrust planetary orbiter and landers, typified by the Mariner '71 and the Viking '75 Mars spacecraft. Nearer term mission applications of interest such as a Jupiter Orbiter would take advantage of the significant performance increase available from advanced chemical propulsion systems.

**Solid Propulsion Experimental Programs.**—The second and third static firings of the ASTROBEE F sounding rocket took place this year. This 2700-pound motor is intended as an Aerobee system replacement. It has a dual thrust level starting off with a 40,000-pound thrust boost for 2.5 seconds, followed by about 50 seconds of burning at a 10,000-pound thrust level. Its 25% cost advantage will allow its development to be amortized in a 2-3 year period. The first firing in this period was satisfactory until the last few seconds when a case leak occurred. The propellant and insulation system were redesigned and a completely satisfactory test took place in October. Hardware is now being processed for loading of two motors for flight tests in early 1972.

Successful static firings of high performance, low thrust motors having unusually long burning times for their size continued in this period. JPL fired two more 60 pound motors which successfully demonstrated performance of an all-carbon nozzle which is uninsulated and operates at a white heat. They also successfully fired one 800 pound motor to test propellant configuration, insulation and nozzle design. A contractor completed a program which culminated in the static firing of two low thrust motors weighing 300 pounds each. This design was different from that used by JPL to date and included novel concepts such as a cork insulator and a carbon nozzle covered by carbon felt to reduce the external temperature. The second of these was fired at simulated altitude and was satisfactory except for having 6 percent less energy than predicted. The reason for this performance loss is being investigated.

**Solid Propulsion Research.**—The addition of aluminum powder to solid propellants has been known to suppress combustion instability at relatively high frequency. Lewis Research Center (LRC) investigated potential reasons for its reduced effectiveness at the low chamber pressures which are of particular interest to spacecraft propulsion.

Also in the field of low pressure combustion, the JPL studied a novel means of improving the distribution of aluminum in solid fuel. The JPL concept incorporates the aluminum particle within the oxidizer particle, thereby enhancing burnings of small particles and avoiding surface agglomeration. Burning surface



pictures clearly indicated an improvement in combustion efficiency.

The concept of joining materials by exposing them to an explosive shock was refined considerably in experiments at the Langley Research Center. RDX explosive contained within a lead envelope in "tape" less than  $\frac{3}{8}$ " wide and  $\frac{1}{32}$ " thick was used to develop up to 90 percent of base material strength in joining aluminum sheets. Clad aluminums and other materials which are not normally weldable were joined very efficiently. Welds up to 12 feet long were made in a single shot. The potential of the system for joining or repairing structures and pressure vessels either in space or for earth applications was also investigated.

**Liquid Rocket Research and Technology.**—The liquid rocket research and technology program, which continues to explore basic processes and devices for advanced propulsion systems, established a computerized visualization of the reaction of rocket motors to pressure pulses. The simulation is printed out by a computer in the form of time lapse plots of pressure on the wall of a liquid rocket engine. It visualizes the waves in the combustor when a sudden disturbance is introduced. Through this method, the ability of an engine design to damp out a disturbance is visualized in a quantitative way, and concepts for further stabilization can be designed and evaluated for effectiveness.

A major focus of research effort was on the definition of the flow fields from rocket nozzles exhausting into vacuum. The purpose is to reveal the flow which can result in the deposit of materials on optical surfaces or spacecraft windows which may be adjacent to the rocket. Such deposits will degrade the performance of experiments and observations, and must be avoided or minimized. The flow fields are being determined through tests of small rocket nozzles in vacuum chambers. Ultimately this work will provide understanding of exhausts in vacuum thus giving the capability to locate rockets to minimize contamination, and to design rockets for minimum contamination material.

An element of the long life objective is the establishment of filters to remove from propellants the small contaminants which lead to clogging and failures. A special filter was designed and tested with the capability of removing particulate contamination which can cause a change in flow area or clogging. Such a possibility is especially severe in the small thrusters used for long duration missions to make small changes in attitude or velocity.

Long life elastomers are required for the bladders commonly used for the expulsion of liquid propellants into the combustion chamber. A new elastomer material based upon ethylene propylene polymer was

established and evaluated for long life capability. When exposed to the propellant hydrazine, widely used in deep space missions, the new elastomer, designated EPT-10, was found to be quite compatible.

A new concept of rocket engine design was being established to enhance the capability and flexibility of propulsion for future outer planet missions. In its conceptual form it is a bimodal engine with the capability of burning one liquid fuel as a monopropellant and burning the same fuel plus an oxidizer as a bipropellant. The first operating mode lends itself well to precision low energy trajectory and orbital corrections and to planetary or satellite landing maneuvers. In the second mode of operation a liquid oxidizer is introduced, promoting the secondary combustion and producing high thrust at high specific impulse. This bipropellant mode is more advantageous in high energy maneuvers such as orbit insertion and orbit plane change. A number of bipropellant mode tests were completed revealing that the basic hardware and component design is sufficiently understood to permit more ambitious and longer duration testing.

**Main Engine Technology for Space Shuttle.**—The supporting tasks to the main engine requirements for the space shuttle continued. Principal emphasis focused on investigations relating to the interaction of combustion with the vehicle structure producing an oscillating effect known as "POGO." Devices to damp out "POGO" by positive feed back were under investigation. Additionally, the operation of pumps and of combustors in the presence of oscillating pressure and flow fields was explored and designs to minimize design effects were being established.

**Power Processing Technology.**—Major advancements were made in power processing technology, particularly in terms of reduced complexity and weight. Weight and parts count (a measure of complexity) were reduced over 50 percent and 60 percent respectively, in an experimental 2.4 Kw power processor under investigation for future electric propulsion applications. This technology is highly promising for the general field of power processing for both aerospace and terrestrial applications.

Long term reliability continues to be a major consideration in spacecraft electrical systems. Notable related progress was made during the past year in saturable transformer concepts which reduce stresses and losses in semiconductor switching devices, in self-healing (resettable) electrical fuses, and in solar array drive and electrical power transfer mechanisms.

**Fluid Mechanics.**—Encouraging progress was made on resolving some of the confusion and scatter that exist in wind tunnel measurements of the location and extent of the transition of the viscous boundary layer from laminar to turbulent at Mach

numbers greater than unity. Transition must be known accurately to assess shear forces, heat transfer, shock location, and other effects that determine aeronautical and entry vehicle performance. Recent results of a research program to determine causes of discrepancies in the measured data showed that fluctuating sound fields radiating from the turbulent boundary layer on the tunnel walls cause premature transition. The degree of disturbance varies between tunnels and is a function of mean tunnel pressure. By comparing data at a given disturbance level, good correlation was obtained among a number of facilities. More work is needed, however, to assess the significance of many other factors that also influence the transition process.

**Electrophysics Research.**—Tests were completed at JPL to develop techniques for avoiding voltage breakdown in radio frequency transmission lines and antennas and thus increase spacecraft reliability. This electrophysics research resulted in the establishment of rules for separation of electrodes with varying voltages and ambient pressures.

The Mariner spacecraft now orbiting Mars is an example of the application of these findings. While undergoing laboratory environmental testing, the transmitter for the vehicle experienced a voltage breakdown problem. As a result of the research data available, engineers were able to redesign the circuit with confidence that a similar failure would not reoccur.

**Micro-Diode and Optical Mixing.**—A researcher working under a NASA grant developed an infrared tungsten-nickel rectifier diode and special micro-manipulation techniques which made it possible for the first time to measure light frequencies in the same way microwave frequencies are measured. Response time of the diode is of the order of a trillionth of a second which makes it fast enough to react to the variations of light waves. It therefore shows promise as a laser time-standard of greater accuracy than the best now available.

**Shielded-Gate Semiconductor Technology.**—Langley Research Center developed a shielded-gate complementary metal-oxide semiconductor structure which provides higher density, higher frequency logic suitable for use in large scale integrated (LSI) circuit computer systems. The shielded-gate structure offers three primary advantages: (1) a 30 percent reduction in cell area, (2) increased reliability, and (3) fewer processing requirements. Associated with these are a reduction in the overall cost of fabrication and operation, elimination of interference between adjacent information storage sites, and a minimization of leakage currents and problems associated with conventional multiple-layer interconnections.

**Inertial Laser Gyro.**—Inexpensive, high performance laser gyros for a three-axis strapdown system were

developed and tested by the Marshall Space Flight Center. Each laser gyro measures angular rates about its axis by sensing the difference in spatial arrival times of a split light beam traveling within the gyro in physically opposite directions and at equal distances. The digital gyro outputs are sent directly to a digital computer which processes the data to determine the precise rate and position of the vehicle. Test results showed that drift rates, an important factor in developing inertial quality gyros, of better than .04 degree per hour were achieved. Each gyro is in a five inch per side triangular configuration and three gyros can be packaged in a compact three-axis module. The modular design approach permits increased reliability, low-cost maintenance, testing and production, and reduced weight and size for present flight guidance and control systems and for future fully automatic aircraft landing systems.

**Control Moment Gyro.**—Langley Research Center (LaRC) developed a high-response, variable-momentum control moment gyro (CMG) prototype for spacecraft control systems. The CMG, which consists of a spinning flywheel supported by double gimbals, provides stabilization torques by changing the flywheel momentum vector relative to the spacecraft axes. The LaRC prototype has twice the momentum storage capacity of CMG's under development for Skylab and represents a substantial increase in control system lifetime and bandwidth. This control capability is essential for high-accuracy experimental missions, such as Earth resources or astronomical observations, and permits Earth-orbital or planetary spacecraft stabilization for up to 10 years.

**Electronographic Camera.**—A very high efficiency substitute for a photographic plate in which an optical image is converted and stored as an electrical pattern was devised and fabricated. The device retains either partially or fully the virtues of the photographic plate, such as large format, simplicity of operation, and ease of handling and has the additional advantage that the electrical image can be directly read out as an electrical signal suitable for analyses by a computer. At the same time, it eliminates such disadvantages as low photon efficiency, lack of sharp spectral discrimination, and inability to operate in the ultraviolet. It has immediate applications in astronomical instrumentation and image recording systems for high performance and diffraction limited space telescopes.

**Bubble Domain Magnetic Memories.**—A one-thousand bit memory using magnetic bubble domains as information bits, was fabricated from a complex garnet film-substrate system. The bubbles are generated by the presence of a magnetic field and moved from one position to another by the rotation of the field. The system shows promise of providing small, low cost computer memories for spacecraft and ad-

vanced landing control systems for aircraft. It provides substantial reductions in weight, cost, size, and power consumption over present systems, and represents the next generation in information storage and retrieval techniques.

**Silicon Solid State Triode.**—A solid state triode, fabricated for the first time from silicon, was operated in a mode analogous to that of a conventional thermionic vacuum tube triode. This device has the unique capability of performing reliably at high temperatures and under high radiation fields as a driver for switching magnetic and charge storage units in computer memories with a good frequency response, a low noise figure, and a high input impedance. It also has a wide range of electronic properties suitable for its use as an amplifier, impedance transformer, driver, and mixer.

**Green Light Emitting Diode.**—A new material, synthesized from gallium and phosphorus by advanced processing techniques, was used for the fabrication of the first solid state electronic device capable of emitting green light. Since the human eye is ten times more sensitive to green light than, for example, to red light, this device can operate with greater efficiency as an indicator light, as a trigger for light sensitive devices, in small alphanumeric displays, in high-speed, non-contact printers, and in matrix displays. It has the advantages of high reliability, long life, high visibility in bright ambients, rapid rise and decay times, high packing density, wide viewing angle, and low electronic power requirements.

**S-X Band Experiment for Venus/Mercury '73.**—As part of NASA's efforts to improve deep space tracking and communications capability, JPL completed the design of a dual frequency experiment to be flown on the Venus/Mercury flight scheduled for 1973. The experiment combines the currently used S-Band radio link and an X-Band capability for a simultaneous dual frequency operation.

The use of these two frequencies permits scientists to precisely calibrate the delaying effect of charged particles in space which contributes to large spacecraft position errors. Knowing this error contribution, a truer spacecraft orbit can be determined. Extreme accuracies are particularly important for Grand Tour missions in which a miss of 1000 kilometers in the Jupiter encounter, for example, translates into a million-kilometer error at the third encounter with Neptune or Pluto.

In addition to the radio navigation enhancement, the experimental use of the X-Band link will improve telemetry reliability by providing a redundant capability, and will permit the exploration of the operational use of X-Band for future missions.

**Low Noise Amplifier.**—NASA successfully completed tests on developmental models of an ultrasensitive receiver design called a parametric amplifier. This Goddard Space Flight Center development will make the communications systems of the space shuttle more feasible by reducing the size of the vehicle's antenna and thus relieve the problems associated with reentry.

It is estimated that the antenna size can be reduced one half by the use of this receiver. The design is completely solid state providing a compact and lightweight package weighing about seven ounces in a volume of six cubic inches. The receiver design is expected to be fully space qualified during the next year. It will be useful in both communications and radar systems where extremely sensitive and compact receivers are required.

### Tracking and Data Acquisition

The Tracking and Data Acquisition program continued to provide reliable, high quality ground support to all the NASA flight programs.

During the year, the tracking networks supported the two Apollo lunar landing missions and provided the means for millions of Americans to visually share the experiences of the astronauts. Also, the networks contributed to the success of several other flight projects, including Mariner 9 and OSO-7.

In addition to meeting operational requirements placed on the networks, good progress was made on the construction of large antenna facilities in Australia and Spain.

**Manned Space Flight Network.**—The operations of the Manned Space Flight Network were highlighted by the flights of Apollo 14 and 15. Precision tracking and high quality communications (both voice and television) were furnished by the network.

From the lift-off of Apollo 14 on January 31 until splashdown nine days later, the network was the only link between the astronauts and the Mission Control Center (MCC) at Houston, Texas. In-flight problems during the mission were all solved, largely through the ability of the crew to communicate with the flight controllers and ground-based support personnel at the MCC.

Perhaps the best illustration of the importance of this communications capability occurred shortly after the command module docked with the lunar module. Several attempts were necessary before the two spacecraft docked and it was feared that the docking mechanism was damaged.

However, television enabled project personnel at Houston to observe the astronauts as they disassembled the docking system and to issue step-by-step inspection procedure. A thorough examination of the system by the crew, as well as by the flight controllers via color television, revealed that the equipment was not damaged and that the Apollo 14 mission could proceed as planned.

Later in the flight, as the lunar module descended for its landing on the moon's surface, the precise tracking data provided by the network stations were used to revise the landing trajectory. A correction of some 2,800 feet was calculated from the network's tracking data and transmitted to the spacecraft computer, resulting in a pin-point landing between Doublet and Triplet Craters.

The network maintained a high level of operational readiness by supporting unmanned flight projects as well as extensive Apollo mission simulations. Then, the network supported the next manned flight, Apollo 15, in July. Apollo 15 placed the most complex support requirements on the network to date.

The new experiments on Apollo 15 required augmentations and modifications to network equipment systems. The most significant of these new experiments was the Lunar Roving Vehicle.

The network received color television from the Rover as the astronauts made their investigations on the Moon and relayed the data for transmission over commercial channels.

During previous Apollo missions, communications with the earth were transmitted via the lunar module. The range of exploration from the lunar lander module was therefore quite limited due to the short lunar horizon. To extend this range, NASA developed the Lunar Communications Relay Unit (LCRU), which serves as a portable relay station for voice, television, and telemetry data between the astronauts and the network stations on Earth. The LCRU was carried on the Rover and transmitted signals directly to the 26-meter (85-foot) and 64-meter (210-foot) parabolic antennas located around the world. Special demodulation systems were installed at the stations to receive the LCRU transmissions which operate at a different frequency than the lunar module.

Another significant scientific addition to the Apollo 15 mission was the Scientific Instrument Module (SIM) bay installed on the Command and Service Module. Large amounts of data were acquired by the network stations as the spacecraft orbited the Moon and were relayed to Houston for analysis. Although it may be years before all the data are completely analyzed, several important findings were made during the mission. For example, the real-time tracking data acquired by the network provided the first detailed profile of the four large *mascons*—areas of unusual gravitational force—on the moon's major seas. The largest area of mass concentrations, *mascons*, is under the Sea of Serenity and forms a dome almost four and one-half miles thick.

The network is still acquiring data on the lunar gravity field from an 80-pound subsatellite ejected into lunar orbit by the astronauts before their return home. The subsatellite, another scientific addition to the Apollo missions, will circle the Moon for a year, map-

ping its erratic gravitational forces and looking for a pattern to its weak magnetic field.

In addition to its long-term support of the subsatellite, the network will continue its support to the Apollo Lunar Surface Experiment Package (ALSEP). The ALSEP left by the Apollo 15 crew was the fourth automatic scientific station placed on the Moon by American astronauts. The ALSEPs from Apollo 12 and 14 are still working and sending valuable information to Earth.

As the year ended, the network was preparing for support of the Apollo 16 mission. As the Apollo Program approaches completion, the Manned Space Flight Network's most demanding tasks are operational in nature as opposed to the initial construction and equipment phases. During Apollo 16, the network must be prepared to support four ALSEPs, two satellites, the Rover, lunar lander module, and command and service module.

**Deep Space Network.**—The Deep Space Network continued to support Pioneers 6, 7, 8, and 9 and Mariner 6. Selected stations of the Network, including the 64-meter antenna station at Goldstone, California, provided joint support to the Apollo 14 and 15 missions along with the Manned Space Flight Network.

The major new planetary flight program supported in 1971 was the Mariner '71 mission to Mars. From lift-off to insertion into its elliptical orbit around Mars, Mariner 9 was monitored and controlled by the Network. On June 4, the first of two planned mid-course corrections was transmitted by the network to the spacecraft to correct the trajectory and refine the aiming point. The second mid-course correction had been scheduled for October 26, but analysis of months of tracking data revealed that the results of the first correction were so precise that further correction was not needed. This is noteworthy in the unprecedented accuracy required to orbit Mars—the aiming point for Mariner 9 after a flight of about 240 million miles was an area only 435 miles square.

On November 3, less than two million miles from Mars, the 2,200-pound Mariner lost navigational lock on its guiding star Canopus and its radio signal to Earth abruptly weakened. An exhaustive analysis of the tracking and telemetry data showed that the on-board systems were working and that the Canopus sensor was locked onto the star Sirius. By commands transmitted through the network, the spacecraft regained its proper orientation and its radio signal returned to Earth.

On November 13, the 64-meter antenna at Goldstone issued the commands for retroengine firing and Mariner 9 was injected into an orbit of Mars. Since that time the spacecraft has been completing two orbits of Mars each Earth day and recording some 30 television pictures of the Martian surface on each orbit.

After every orbit, when the spacecraft can be "seen" by the Goldstone antenna, it transmits back the tape recorded pictures. The science data received by the network to date has been excellent and should provide some clues as to whether Mars appears to be hospitable to life forms.

In addition to supporting the planetary flight missions, the Deep Space Network played a major role in the conduct of radio astronomy experiments during the year. One effort in this area was an extensive radar mapping of Mars. Initiated last spring, this mapping is required to obtain elevation profiles for possible landing sites for the Viking Program.

The first phase of the work was completed and maps were obtained of the Martian surface in the Southern latitudes of 15 to 25 degrees. Similar radar measurements of the area 4 degrees North to 15 degrees South are also needed for Viking and it is planned to accomplish this work during the 1973 and 1975 Mars oppositions.

The Goldstone facility was used in the spring for a joint US-USSR Very Long Base Line Interferometer (VLBI) experiment. The Goldstone antenna, together with a 22-meter antenna of the Crimean Astrophysical Observatory at Simeis, Crimea, made measurements of several dozen extra-galactic radio sources. The objective of the experiment was to obtain a measure of the diameter of the sources which were principally quasars. Soviet scientists proposed the experiment through the National Science Foundation which contacted NASA for use of the network facilities.

Construction work progressed throughout the period on the second and third 64-meter antennas for the network. The antennas are in Spain, 40 miles from Madrid, and in Australia at Tidbinbilla, a short distance from Canberra. Both are updated duplicates of the Goldstone antenna, and are scheduled to become operational in 1973. At that time, the three-antenna subnetwork will provide NASA the capability for continuous tracking of spacecraft hundreds of million of miles into space.

**Satellite Network.**—The Satellite Network continued to provide tracking and data acquisition coverage to an average monthly workload of over 40 individual scientific and applications Earth-orbital satellites. Several new flight projects were launched, including a number of international cooperative satellites.

One of these cooperative missions was the Canadian project, ISIS-2, launched March 31 from the Western Test Range. This international satellite, the third of a series designed for ionospheric studies, continued to be supported by the Satellite Network, the Canadian Communications Research Centre network stations, the French tracking network, and stations in the European Space Research Organization (ESRO). All twelve of the experiments aboard the satellite were

operational and the data received were processed at the Goddard Space Flight Center, Greenbelt, Maryland, and at the Canadian station in Ottawa.

The NASA tracking station at Quito, Ecuador, along with the mobile Italian telemetry station in Kenya, and the Kourou, French Guiana, tracking station provided tracking and telemetry support to the San Marco-C satellite launched April 24. The NASA station provides coverage for two to three passes per day of telemetry data and a back-up command capability.

Further U.S./international cooperation was achieved through spacecraft support agreements. As noted in the report for 1970, mutual satellite tracking arrangements between the French Centre National d'Etudes Spatiales (CNES) and NASA were instituted to provide support to each other's spacecraft under contingency situations.

An example of the value of this support was the CNES request for NASA support of the French D2-A satellite launch April 15, 1971. In early May, CNES advised NASA that the tape recorder onboard the spacecraft has ceased operation and requested support in accordance with the contingency plans. Under the plan, NASA provides real-time telemetry support from the network stations at Santiago, Chile; Orroval Valley, Australia; Rosman, North Carolina; and the Manned Space Flight Network station at Ascension Island. This additional coverage permits the recovery of importance science data that otherwise would be lost due to the tape recorder failure. The French stations providing support are located near Ouagadougou, Upper Volta; Pretoria, South Africa; Brazzaville, Congo; Bretigny, France; and Kourou, French Guiana.

NASA had requested similar assistance from the CNES a few months earlier for the Small Astronomy Satellite (SAS-A Explorer 42) launched December 12, 1970, when its onboard tape recorder failed in early February. The necessity for 24-hours-per-day, seven-days-a-week support for acquisition of telemetry data required support from the CNES stations at Kourou, French Guiana, and Brazzaville, Congo.

This year several more saturation tracking experiments were conducted for the International Satellite Geodetic Experiment (ISAGEX). This international effort used the EOLE French spacecraft and the NASA GEOS-2 satellite as prime data sources. Laser data was received at the Goddard Space Flight Center from the French CNES laser network, the Smithsonian Astrophysical Observatory lasers, and two mobile lasers located at Guam and at Goddard. In addition, numerous quick-look optical observations were obtained from the Astro-Soviet observatories.

The West German Max Planck Institute's Barium Ion Cloud (BIC) experiment was launched from Wallops Station, Virginia, on September 20. The Satellite Network, Wallops Station, and the Smithsonian Astrophysical Observatory provided primary support of the

BIC launch. The objective of this cooperative project was to study the electric and magnetic fields in the outer radiation belt by optical investigation of the behavior of a barium cloud released at several earth radii altitude. No major problems were encountered during the support of the mission and good optical and telemetry data were acquired.

The Satellite Network provided the means for saving the Nation's best equipped sunwatching satellite, OSO-7, which encountered problems shortly after launch on September 29. Control problems with the Delta launch vehicle's second stage caused the spacecraft to go into an elliptical orbit instead of the planned 345-mile high circular orbit. The malfunction also left the spacecraft tilted so it could not acquire the sun's rays to convert solar energy into electricity to operate the onboard scientific instruments.

A concentrated effort by the project and network personnel determined the problems and solutions, and resulted in a series of corrective commands radioed to the spacecraft. Network stations in Ecuador and South Africa, using emergency procedures, transmitted steering commands to realign the satellite. After thousands of commands and some eight hours later, the spacecraft was properly aligned and all systems were functioning well. The network is currently supporting OSO-7 in a normal mode of operation.

### International Affairs

NASA's international activities during 1971 were marked by expanded discussions with the Soviet Union on a variety of possible cooperative undertakings, a continuing dialogue with the Europeans on post-Apollo participation, an active program of satellite and sounding rocket launchings, and a broad range of other joint activities. In addition, increased efforts were made to provide opportunities for uniquely qualified foreign scientists in the planning and definition of future NASA missions such as the outer planets and High Energy Astronomical Observatory (HEAO).

Marked progress appeared to be made in the renewed discussions between NASA and the Academy of Sciences of the Soviet Union on the expansion of bilateral cooperation in space science and applications. A meeting in January (following the successful meeting of October 1970), produced an agreement on the exchange of lunar surface samples and specified a number of additional cooperative exchanges and arrangements to be the subject of detailed recommendations by Joint Working Groups:

—joint consideration and exchange of information regarding the objectives and results of space research by each side so that the other can take these into account to the extent desired,

—substantial improvement of existing satellite weather data exchanges,  
—coordination of meridional meteorological sounding rocket networks,  
—coordinated studies of ocean and vegetation surveys in agreed areas by space and conventional means, and  
—significantly expanded exchange of data on space biology and medicine.

The Joint Working Groups met in August and October 1971 on these matters and successfully developed recommendations for joint projects and exchanges. These recommendations have been confirmed.

Three Joint Working Groups, which had been set up to implement the October 1970 agreement on compatible rendezvous and docking, met in June in Houston and in November and December in Moscow to detail the technical requirements. Very substantial progress was made toward completing this task. In addition, NASA and the Soviet Academy are considering the technical and economic implications of possible missions to test in flight the compatible systems to be developed. A first such mission for consideration would entail the docking of an Apollo-type spacecraft with a manned orbital scientific station of the Salyut type.

In September a Joint US-USSR Editorial Board met pursuant to the NASA-Soviet Academy agreement of October 8, 1965 for the preparation and publication of a joint review of space biology and medicine. The Joint Board meeting was devoted to reviewing the chapter materials already exchanged, selecting authors to prepare the agreed sections of the review, and approving instructions to authors.

**Post-Apollo Participation.**—NASA continued its effort to solicit and encourage substantial foreign participation in the major programs of the post-Apollo era. In September, the United States addressed a key concern affecting European participation, the question of availability of United States launch services for foreign satellites. The Under Secretary of State assured the Chairman of the European Space Conference (ESC) that U.S. launch assistance will be available on a purchase basis for those satellite projects which are for peaceful purposes and are consistent with obligations under relevant international agreements and arrangements.

Following an October briefing for ESC on current NASA planning for the space transportation system and other elements of post-Apollo programs, European and NASA technical experts met late in the year to begin joint definition of candidate areas for European participation. Europe was involved substantially throughout the year in pre-development studies to define the technical requirements for the space transportation system. Six European firms, funded by their

governments, participated as subcontractors to NASA prime contractors in the Phase A and B space shuttle studies. In addition, the European Space Research Organization (ESRO) conducted studies of space station modules and space shuttle missions. The European Launcher Development Organization (ELDO) engaged in an independent study of alternative approaches to a reusable space tug and, together with NASA, sponsored studies of the technology needed for the space shuttle program. Approximately \$6 million in European funds were devoted to these efforts.

**International Satellite and Probe Launchings.**—During 1971, six spacecraft were successfully launched under a variety of international arrangements:

**ISIS-II.**—In March this Canadian-built satellite, the fourth in the cooperative Alouette/ISIS program begun in 1962, was launched by NASA from the Western Test Range to perform a variety of ionospheric measurements.

**San Marco III.**—This third spacecraft in a joint US/Italian cooperative space program was launched in April by an Italian crew on a NASA Scout vehicle from the San Marco platform off the coast of Kenya. This satellite, designed and built by Italy, carried one Italian and two U.S. experiments to study the density of the upper atmosphere in the equatorial region.

**EOLE.**—This cooperative experiment using a satellite/balloon system to prove new techniques for gathering meteorological data was begun when NASA launched the French EOLE satellite from Wallops Station in August.

**Barium Ion Cloud.**—This German-built probe was launched from Wallops in September to create a barium ion cloud at about 18,000 nautical miles altitude. Observations of magnetic and electrical field structures were made from multinational ground stations located in Brazil, Chile, Canada, the Canary Islands, Portugal, and in the United States in California, Arizona, New Mexico, and Florida.

**Explorer 45.**—This NASA Small Scientific Satellite was launched in November by Italy on a reimbursable basis from the San Marco platform. It was the second NASA satellite to be launched from this unique equatorial facility.

**Ariel 4.**—This fourth in the US/U.K. cooperative satellite series was launched in December from the Western Test Range for advanced studies on the radio properties of the upper atmosphere and their relation to the charged particle environment.

NASA and the Canadian Department of Communications concluded an agreement for an experimental Communications Technology Satellite with a planned launch date of 1974. This satellite will test a variety of new technology developments for satellite commu-

nications, including experimental transmissions at 12 GHz. Contracts were also signed in 1971 with Canada for reimbursable launchings in 1972 and 1973 of two Canadian operational telecommunications satellites (ANIK) and with the European Space Research Organization (ESRO) for three scientific satellites, HEOS-2A, TD-1 and ESRO-4, all in 1972.

**Foreign Scientific Participation in Approved NASA Missions.**—Four foreign experiments were selected or flown during 1971 on NASA missions. A German experiment (BIOSTACK) to study the biological effects of cosmic radiation (heavy nuclei) in the space flight environment was accepted from the University of Frankfurt for flight in 1972 on Apollo 16. The Swiss solar wind experiment, originally flown on Apollo 11, was flown on both the Apollo 14 and 15 missions. An advanced U.K. radiometer to obtain atmospheric temperature profiles was selected for flight on Nimbus F in 1974.

In addition to these flight hardware experiments, scientists from the Paris Observatory and the University of London were invited to become members of the Television Sciences Team for the Mariner Venus/Mercury 1973 mission.

**Mission Definition Teams and Preliminary Experiment Selection.**—A growing area of international space cooperation is the participation of foreign scientists in the early definition and other planning activities in connection with possible future NASA missions. During 1971, sixteen scientists from 6 countries were selected to serve on 9 of the 13 planning teams for the missions to the outer planets; a French scientist was chosen to head the Photo-Polarimetry Team. The U.K. Science Research Council and ESRO sponsored the participation of selected astronomers and spacecraft engineers with NASA in the design studies for a cooperative ultraviolet astronomy satellite project which, if approved, would become the fourth in the Small Astronomy Satellite (SAS) series. A proposal by the Center for Nuclear Studies in Saclay, France, and the Danish Space Research Institute of Lyngby, Denmark, was selected as a candidate for HEAO-B (High Energy Astronomy Observatory). The experiment would study isotopic and charge composition of primary cosmic radiation. A British scientist from University College, London was asked to bring his extensive background in X-ray detectors to assist in the mission definition phase of HEAO-C. In addition, two proposed experiments of University College, London were being studied for possible flight aboard an advanced Orbiting Solar Observatory (OSO-J).

**Earth Resources.**—NASA, joined by other U.S. agencies, sponsored an International Workshop on Earth Resources Survey Systems at the University of Mich-

## Industry Affairs

igan in May. Representatives from 40 countries and 16 international organizations attended. Following an international request for proposals to analyze data acquired by Earth Resources Technology Satellites (ERTS) and the Earth Resources Experiment Package aboard Skylab, 37 experiments from 22 countries were tentatively accepted in the first round of announcements. Others are expected in the future. The remote sensing agreement with Brazil was extended for two years, and a similar extension of the earth resources agreement between NASA and Mexico is expected. In May, Canada agreed to build a ground station capable of acquiring earth sensing data direct from the ERTS satellites. In response to a request from the United Nations' Food and Agricultural Organization (FAO), NASA provided a specially instrumented aircraft to assist in a hydrology survey of Jamaica.

**Lunar Sample Program.**—The analysis of lunar samples returned by the Apollo 14 and 15 missions was being undertaken by some 201 scientists, including 64 foreign Principal Investigators from 15 countries and one international organization (ESRO). Included for the first time are scientists from Brazil, ESRO, and the Republic of China. Ninety-five participants from 16 countries attended the Lunar Science Conference in Houston in January.

**Sounding Rocket Programs.**—During 1971 new sounding rocket agreements were signed with Norway and France. Launchings under previous agreements took place from Argentina, Brazil, Canada, India, Norway, and Spain.

**Tracking and Data Acquisition Cooperation.**—Through Canadian cooperation, NASA conducted sounding rocket launches for polar cap ionospheric studies from a Dewline site and held a geology field training trip for astronauts at Sudbury Crater in Ontario.

Cooperation continued between NASA and space agencies of other countries in support of each other's space projects by their respective tracking and data acquisition facilities. NASA received support for its Small Astronomy Satellite from French, Italian, and British facilities; the French network also supported San Marco 3 and geodetic studies with Syncom 3. Satellites of other countries supported by NASA were Japan's TANSEI and SHINSEI and France's Tourne-sol. Arrangements were made for removal of the transportable Apollo support facility on Grand Bahama Island.

Through the cooperation of Mauritania and Portugal, a NASA team made an exploratory visit to northern Mauritania and the Cape Verde Islands as a possible site for sounding rocket launches in conjunction with the June 1973 solar eclipse.

**Inventions and Contributions.**—The Inventions and Contributions Board completed action and made recommendations on 125 petitions for patent waiver received from NASA contractors—a 20 percent increase from 1970. In addition, the Board recommended the granting of monetary awards totaling approximately \$125,000 for inventions and other scientific and technical contributions made by NASA and NASA contractor employees. As a result of the issuance of new NASA Patent Licensing Regulations in the final quarter of the year, the Board became responsible, for the first time, for considering applications for exclusive and nonexclusive licenses to NASA inventions, and for recommending disposition of the applications to the NASA Administrator.

**The Price-Wage Freeze.**—The NASA Headquarters Procurement Office served as the focal point in NASA's implementation of the contracting aspects of Executive Order No. 11615, dated August 14, 1971, providing for stabilization of prices, rents, wages, and salaries. NASA Procurement Offices were directed to consider as a decisive factor whether contractors are in compliance with the price-wage freeze in all of their transactions. In particular, contractors are required to certify on invoices submitted for payment that amounts billed under the contract comply with the criteria established under the Executive Order. NASA worked closely with the Department of Defense and the General Services Administration in implementing the Executive Order, and the coordinated approach significantly minimized procurement problem areas from the standpoint of both the Government and its contractors.

**NASA Acquisition Study.**—A study of the NASA acquisition process conducted by senior NASA officials was completed in June. Three committees were formed to prepare implementing policies and procedures that will produce more effective utilization and controls over resources employed in acquiring new products and systems. The specific areas being worked on are: Project Planning—to improve the internal planning and control process; Requests for Proposals—to clarify this interface document between NASA and industry and generate economy in proposals; and Source Evaluation Boards—to insure clarity, equity, and understanding of the parties for the source selections process.

**Cost Sharing.**—Regulations were published to implement cost sharing policies for NASA's research grants and contracts pursuant to existing statutes and in conformity with general guidelines established by the Office of Management and Budget. The material is designed to standardize procedures among the various



NASA installations and thus facilitate the submission of proposals by prospective grantees and contractors.

**Mass Severance Pay.**—NASA questioned the reasonableness of allowing severance pay on support services contracts when an employee of the incumbent contractor gains immediate employment with a successor contractor. The NASA Procurement Regulation was amended (Sec. 15-107) to include "severance pay to employees on support services contracts" as an item suitable for an advance understanding. All Procurement Officers were notified of the change and told to investigate these matters before contract award and to consider them in source evaluation.

**Small Business and Minority Business Programs.**—Increased emphasis placed on assisting small business resulted in the highest percentage of NASA awards to that segment of industry since 1963. Small business firms received \$178 million in NASA prime contract awards or 8 percent of NASA total procurement awards to all business firms. Similarly, NASA increased its participation in the Minority Business Enterprise Program awarding \$1.3 million to minority firms through SBA Section 8(a) awards to the Small Business Administration. NASA also achieved good results in ensuring the participation of minority firms in subcontracting opportunities. In recent major support services procurements, 6 of 12 subcontract awards to small business were made to minority firms.

**Industrial Relations.**—Through September 30, the number of man-days lost due to labor disputes and strikes for all NASA contracts decreased 64 percent, from 3,797 to 1,360. The major portion (2/3rds) of man-days lost at NASA Centers was directly connected to strikes arising from negotiation of labor agreements. The balance of man-days lost was attributable to union and contractor disagreement over employee representation issues.

Headquarters Industrial Relations personnel worked with Center management to eliminate or minimize the impact of labor-management problems on Agency goals, and as a result there was no interference with Apollo 15 or other NASA programs.

**Computer-Aided Decision Making.**—NASA Headquarters used interactive computer terminals in conjunction with time-sharing services to shorten and improve management decision making and to make better use of NASA resources. The techniques are employed in connection with the development and refinement of NASA long range schedules and cost plans, development of medium range budgets, analysis of manpower and salary distributions, development of budget projections through regression analyses of financial data bases, development of cost estimates for program alternatives, and similar applications.

**Reliability and Quality Assurance.**—The NASA-wide system of disseminating information of general concern on parts and materials problems was improved and expanded to include safety reports and aerospace structural materials. These NASA reports (called ALERTS & SAF-ALERTS) reach contractors and Department of Defense agencies through the Government-Industry Data Exchange Program, in which NASA is a leading participant.

Progress in microelectronics reliability continued through application of the scanning electron microscope in production monitoring. The application of neutron radiography was developed to inspect numerous pyrotechnic devices used in spacecraft and launch vehicles, particularly to examine explosive materials and internal structures within metal housings.

**New Technical Publications.**—Technical publications released during the year included: *This Island Earth, Guide to Lunar Orbiter Photographs, Lunar Photographs From Apollos 8, 10, and 11, The Pioneer Mission to Jupiter, Apollo 14: Preliminary Science Report, and the Third Conference on Sonic Boom Research.*

**NASA REMOTE CONSOLE (NASA/RECON).**—To promote overall Government cost effectiveness in information processing, a number of Federal agencies joined NASA in applying the NASA/RECON to their needs. The Atomic Energy Commission, Department of Justice, and the Central Intelligence Agency installed the system, the Federal Mediation and Conciliation Service, Defense Communications Agency, and Department of Health, Education and Welfare (National Library of Medicine—Toxicology Information Program) have adopted the system and plan to install it.

**Technology Utilization.**—The Technology Utilization Office is responsible for facilitating the useful application of NASA technology in commerce and industry.

Added emphasis was placed on bringing NASA technology to bear in the solution of problems of national concern. Eight public sector application teams actively seek to match available NASA technology to important problems in health care delivery, urban construction, mine safety, criminalistics, law enforcement and transportation.

**New Technology Publications.**—Over 550 Tech Briefs were issued and nearly 40,000 requests for further descriptive information were received. Almost 30 compilations, collections of Tech Brief items published under one cover and announcing innovations and improvements within a single technical category, and other special publications for the non-aerospace sector were published. Compilations contain reader service cards, and each issue produced an average of 800 requests for further information.

**Regional Dissemination Centers.**—The six Centers, constituting a national network to provide technology transfer services to industrial firms, governmental units, universities, and other groups, continued to serve a growing number of clients. More than 1,600 different fee-paying organizations made use of RDC services for their own benefit.

**Public Sector Application Teams.**—Biomedical and technology application teams employ a problem-solving approach to match existing NASA technology with problems in health care delivery and public sector areas of concern, such as environmental quality, urban construction, and transportation. The number of problems identified by these teams continued to grow. Over 175 institutions and other groups are now participating with the teams and more than 200 problem solutions have been proposed.

**COSMIC.**—The Computer Software and Management Information Center (COSMIC) added 100 software packages to its inventory, making a total of 900 programs available for dissemination to industry, government and other interested users. The first cumulative index of available programs was published in *Computer Program Abstracts*, the quarterly journal available through the Government Printing Office.

### **Research Grants and Contracts**

NASA funded 1,570 project-oriented research grants and contracts at 233 universities with expenditures of approximately \$123 million. Their purpose is to increase fundamental knowledge in space science and aeronautics in support of major NASA programs.

This year, emphasis was placed on cooperative ventures. Unique equipment was made available to universities engaged in NASA research. The Agency made project research grants to 14 predominantly black colleges and universities for research projects of mutual interest.

### **Relationships With Other Government Agencies**

Responsibility for coordinating NASA relationships with other Federal agencies engaged in aerospace activities is assigned to the Office of Department of Defense and Interagency Affairs.

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 FY '72 facilities program; development of data relay satellites; NASA aeronautics program for FY '72; areas where advance coordination and pooling of effort between NASA and DOD may be essential; Phase B shuttle decisions and coordination; Apollo 14 lunar science and exploration.

Also, U.S. Navy space activities; coordination of unmanned spacecraft programs; shuttle site selection; spin

related aircraft accidents (an ad hoc group was established to define a national program to accelerate R&D in stall and spin related technology); large new aeronautical facilities; Army aeronautics activity; and the status of satellite warning, defense satellite communications system, and future communications programs.

The military services continued to collaborate with NASA in assigning military personnel to NASA for 2- to 3-year tours. In addition, several agreements were reached between the Air Force and NASA for exchange of engineering and scientific personnel.

The Office of DOD and Interagency Affairs coordinated arrangements between DOD and NASA whereby the Advanced Research Projects Agency of DOD selected the NASA Ames Research Center as the site for the ILLIAC IV computer which is part of an ARPA program to develop, test, and evaluate the concept of parallel array processing. Ames will carry out final system integration and testing and operate the ILLIAC IV for the DOD and NASA.

Also coordinated were activities associated with earth resources and environmental research and operations (including those at the Mississippi Test Facility) by the Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and the Geological Survey.

Additional agreements were concluded between NASA and other Federal agencies: with the Federal Aviation Administration for civilian aircrew and support of the information system, civilian aerospace physiology training, runway traction, and aeronautical technology related to civil aviation; with the Navy covering endeavors at the Mississippi Test Facility; with the Air Force covering loan of two U-2 aircraft, logistic support for a NASA C-141 aircraft research on techniques for visual inspection of microcircuits, and programs for transonic aircraft technology, runway traction, C-130 wing box structure, and integrated propulsion control systems; with the Army for tilt rotor research and rotor system test vehicles; with the Department of Agriculture covering the corn blight watch experiment; with the National Science Foundation for additions and modifications to the National Astronomy and Ionosphere Center at Arecibo; with the Department of Commerce for an ion microprobe facility; and with the General Services Administration covering conduct of the dual-fuel program.

The Office of DOD and Interagency Affairs continued to coordinate NASA research, design, development, test and evaluation support of major DOD aeronautical systems including the B-1, F-14, and F-15 aircraft.

NASA and DOD continued joint studies on methods of achieving manpower and resources economies in common endeavors; one result was that the two agencies continued consolidation of activities at the

Kennedy Space Center and the Air Force Eastern Test Range.

The Office of DOD and Interagency Affairs continued to coordinate special reviews of the NASA Space Transportation System Development by the Aeronautics and Space Engineering Board.

The Office also provided a NASA representative to participate in the National Academy of Sciences study of NASA's life science programs. Results of the study were reported in the Academy publication "Life Sciences in Space."

NASA continued to assist the U.S. Bureau of Standards in studies on the impact on the Nation of the increased use of the international metric system of units. NASA also adopted a policy making the metric system the primary method of expressing measurements in Agency technical reports.

The Office of DOD and Interagency Affairs continued to coordinate NASA activities with the Federal Council for Science and Technology, including the spring previews of NASA technical issues for the President's Science Adviser.

## IV



## Department of Defense

### Introduction

The list of achievements in the Department of Defense space and aeronautics programs continued to grow in 1971. Efforts in the space program were focused on communications, navigation, solar radiation and monitoring and numerous areas of space technology. The first two satellites of Phase II of the Defense Satellite Communications System (DSCS) were successfully launched on a Titan IIIC space booster from Cape Kennedy on November 2. The objective of Phase II of the DSCS is to provide on an evolutionary basis improved communications capabilities for the DOD. Following testing and system evaluation these new high power satellites will be moved to equatorial positions over the Atlantic and Pacific Oceans. Development of the Navy's Fleet Satellite Communication System, an outgrowth of the Tactical Satellite Communications Program, was initiated. This new system is intended to provide improved communications for Navy ships on a worldwide basis and to satisfy a number of Air Force communications requirements. The second NATO Phase II communications satellite was successfully launched by the United States in February. SOLRAD 10, a satellite for monitoring electromagnetic and particle emissions from the sun, was launched on July 8. This launch marked the beginning of the transition of the SOLRAD program from a single low-altitude research satellite to a system of high altitude satellites, designated SOLRAD-HI. This system, when fully implemented, will provide continuous real time monitoring and predictions of space environment disturbances in support of military com-

munications and other systems affected by solar disturbances.

Progress was made in 1971 toward meeting the country's need for modern military aircraft. Flight tests of the second test aircraft of the advanced carrier-based tactical fighter (F-14) began in May. Preliminary flight rating tests of the new engine for an improved tactical antisubmarine aircraft (S-3A) were successfully completed in April. The first flight of key avionics equipment of the S-3A in a flying test bed aircraft was accomplished in August. Development of carrier-based aircraft with the capability of an improved airborne warning system (E-2C) and with sophisticated electronics warfare capabilities (EA-6B) continued with the first flight of a prototype E-2C aircraft in January and the delivery and system evaluation testing of production EA-6B aircraft. The development of these aircraft is leading to an improved readiness of the fleet to operate in any warfare environment. The Air Force's advanced tactical fighter (F-15) program continues on schedule and the first flight test aircraft is being fabricated. Delivery of F-111D and F-111F aircraft began in August and September, while the F-111 force passed the 100,000 flying hour mark in June. Development of the B-1 bomber is proceeding on schedule and completion of the aircraft preliminary design review and full-scale mock-up review were important steps leading toward construction of the first test aircraft. The Air Force initiated development of the A-X, a close air support aircraft, to be optimized for effective support of friendly ground forces. The A-X will be a single-place twin-engine aircraft with a short take-off and landing capability. Two competitive

radar systems for the AWACS aircraft (E-3A) were delivered in December and will be flight tested next year. The E-3A will provide command and control for interceptor forces and for sustained air operations such as close air support. A program was initiated to develop a heavy lift helicopter (HLH) to complement current lift capabilities. The HLH will be a tandem rotor helicopter and will have the capability to transport a 22½ ton payload. Development of the utility tactical transport aircraft system (UTTAS) began in June. The UTTAS helicopter will carry a combat infantry squad and the design will stress improved maintainability, reliability, survivability, safety and performance.

### Space Activities

**DOD Communications Satellite Program.**—During the past year efforts began toward consolidating the DOD communications satellite endeavors into a single program to be named TRISAT. In the near term two satellite systems are planned: the Defense Satellite Communications System (DSCS-Phase II) and the Fleet Satellite Communications System (FleetSat). These systems jointly will form a DOD space complex and provide complementary services. The FleetSat will provide multi-access service to many small terminal users such as airplanes and ships and later to mobile land vehicles operating in a relatively undisciplined communications environment. The DSCS-Phase II will provide wideband communications service in the controlled network of the Defense Communications System.

**Defense Satellite Communications System (DSCS).**—The mission of the DSCS is to provide secure communications in support of critical command, control, intelligence and warning needs and to satisfy requirements of the President and other special users.

The DSCS is evolutionary by nature, thus ability of the system to satisfy its objectives will increase as it progresses through each successive phase. Phase I, the Initial Defense Satellite Communications System, has continued to perform satisfactorily during the past year. It now consists of 21 operational satellites and 29 earth terminals. These small near-synchronous satellites are low in power output and limited in bandwidth. They are designed to turn off automatically during the period 1972-1974.

The Phase I system continues to satisfy unique and vital communications requirements in accordance with the DSCS mission. For example, it continued to transmit high resolution photographs during the past year and in mid-1971 the transmission of secure voice service was inaugurated.

Procurement of equipment for Phase II of the DSCS continued. The objectives of this phase are to provide significantly increased capabilities through the

addition of new satellites, to improve the existing earth terminals for use with the new satellites, and to develop concurrently new earth and shipboard terminals for future acquisition. Work on this phase began in early 1969 with the award of a contract for procurement of six high-power geostationary satellites equipped with both broad earth coverage as well as steerable narrow beam antennas. The higher power and wider bandwidth of these satellites and their synchronous orbits will offer significant improvements in performance and capability. The first two satellites were launched on a Titan IIIC space booster at the Air Force Eastern Test Range on November 2, 1971. Following system checkout, operational evaluation and geographical positioning of each satellite, existing earth terminals will start using these satellites for operational service in early 1972.

Progress was made toward converting present earth terminals to permit their use with the new satellites and at the same time to improve their reliability and bandwidth. Some of these terminals were moved to new locations to meet changed requirements. These terminals will continue to be used with the Phase I satellites until the new satellites are committed to operational service.

The Army and the Navy continued the development of new Phase II ground and shipboard terminals, including more efficient modulation equipment. The new terminals will offer high reliability and large communications capacity.

The total numbers of new satellites and terminals needed for the Phase II system are being studied. Other government agencies and certain allied governments also will be provided service through the Phase II satellites, via their own earth terminals.

**Fleet Satellite Communications System.**—The objective of the experimental program, TACSATCOM, was to investigate the use of spaceborne communications repeaters to satisfy selected communications needs of our mobile forces. The initial phase of this effort, using the Lincoln Experimental Satellite No. 6 (LES-6), the TACSAT I satellite, and 65 terminals installed in aircraft, jeeps, trucks, ships, and submarines is complete. The data obtained during the test program confirmed the design concepts of both the satellites and terminals. The communication links established through these satellites have proven the value of satellite communications to mobile users throughout the world. The LES-6 and TACSAT-I satellites are currently positioned, in geostationary orbits, over the mid-Atlantic and mid-Pacific, respectively. The continued satisfactory orbital performance of the satellites has permitted the continued use of TACSATCOM assets in an interim operational status and for certain selected testing of techniques and hardware.

The development of the Fleet Satellite Communications System was initiated. This system, an outgrowth of the TACSATCOM program, is intended to provide improved communications for Navy ships all over the world and, in addition, satisfy important Air Force communications requirements.

**International Cooperation.**—The United States, through negotiated agreements, has developed, procured and launched several advanced communications satellites for the United Kingdom and NATO, the latest being the United Kingdom SKYNET satellites launched in November 1969 and August 1970. Since that time the United Kingdom has implemented full operation of their SKYNET space and ground communications system. A new Memorandum of Understanding regarding the follow-on SKYNET II system of two satellites has been implemented. These satellites are being produced by the United Kingdom with the assistance of the United States. The satellites will be launched by the United States, with the first launch expected in mid-1973. In accordance with the Memorandum of Understanding, an investigation was undertaken to determine the desirability of implementing a joint US-UK military communications satellite system for the post 1976 era. It is expected that a decision will be reached early next year.

The second NATO Phase II communications satellite, the in-orbit spare, was successfully launched by the United States in February 1971. The equipment for the 12 earth terminals is on site and undergoing acceptance testing. All terminals are expected to be operational by June 1972.

A new Memorandum of Understanding is under review regarding development of a NATO Phase III satellite system by the United States.

**Titan III Space Booster.**—A new member is being added to the Titan III family of launch vehicles. Taking its place beside the DOD space launch vehicle "workhorses", the Titan III B, C and D, is the Titan III E. This version is similar to the Titan III D but modified to launch a Centaur upper stage for the NASA Viking program. NASA also has two Titan IIIC's on order to launch the Applied Technology Satellites ATS-F and G. So far there have been 53 Titan III launches, and 58 additional vehicles are in production or on order for firm launch requirements.

**Geodetic Satellites.**—The mission of the Department of Defense Geodetic Satellite Program is to define more precisely by satellite the size and shape of the earth, develop a refined mathematical model of the earth's gravity field and provide highly accurate geodetic positions of world-wide sites on the earth surface. The final phase, data reduction and analysis, of the original Sequential Collation of Range (SECOR) geodetic satellite program was completed thus strengthen-

ing the established equational network of precise reference stations for the World Geodetic System. The observation phase of the PAGEOS program wherein geodetic positions are determined by photographing satellites against a background of stars was completed. The data reduction phase has been initiated and is nearing completion.

During 1971 Navy's Satellite Geophysics Program maintained 14 semipermanent tracking stations and occupied 12 sites with mobile tracking stations in support of the overall DOD Geodetic Satellite Program. Data was acquired from the Navy's navigational satellites and NASA's geodetic satellites: the harmonic coefficients defining the mathematical model of the earth's gravity field have been determined to the nineteenth degree and order. Position of any site on the globe can be determined to an accuracy of 10 meters (rms).

As a corollary effort, data acquired by the Navy Doppler Tracking Network (TRANET) is being used to evaluate precise national and international time standards as determined by astronomical observations. Polar coordinates derived by satellite geodesy are being furnished to the U.S. Naval Observatory which is the DOD facility responsible for precise time and time interval. In addition the Director of France's Bureau International de l'Heure, the international time standards agency, has requested on a continuing basis polar motion coordinates derived from doppler satellites. These polar motion coordinates have made it possible to determine the instantaneous spin axis of the earth which moves in a five-meter circle with respect to the earth's crust throughout the 400-day Chandler period. Analysis of the doppler satellite and astronomical results by the Bureau International de l'Heure has revealed small biases in the doppler results. Investigation is continuing to determine the nature of the biases.

National Astronomical Observatories of Japan, Belgium, Italy, and Chile have requested stationing of Navy doppler satellite tracking stations at their observatories for data analysis and comparison with astronomical results.

The Navy has continued to participate in NASA's National Geodetic Satellite Program (NGSP). To date TRANET has positioned to a high degree of accuracy approximately 90% of the 45 sites comprising the NGSP. This effort represents the major DOD contribution to NASA's National Geodetic Satellite Program.

The Navy started procurement of highly accurate, state-of-the-art, man portable doppler satellite tracking stations identified as geoceivers (geodetic receivers). Thirty-six of these geociever tracking stations are being procured to meet the requirements of the Army, Navy, and Air Force. Portability and automatic operation of the geociever provides a cost effective,

readily deployable, and highly accurate mobile tracking station.

**Navigation Satellite Activity.**—The DOD Navigation Satellite Program is a multiservice effort designed to investigate the feasibility and desirability of developing a precise, worldwide, three-dimensional position and velocity capability in a common reference grid for use by passive users. The effort is coordinated by the DOD Navigation Satellite Executive Steering Group. A number of studies, experiments and analyses have been undertaken to validate system concepts and establish a basis for the determination of equipment performance and cost. For example, a joint Army-Navy-Air Force test program was recently established to use an experimental navigation satellite developed by the Navy and modified to include an Air Force navigation signal modulator. The joint tests will demonstrate a partial system capability with a single satellite and will influence decisions on the future of this program.

### Space Ground Support

**DOD National Range and Tracking Facilities.**—Department of Defense space activities are principally supported by the Air Force Eastern Test Range, the Space and Missile Test Center (which includes the Air Force Western Test Range), the Air Force Satellite Control Facility, the Navy Pacific Missile Range, and the Army White Sands Missile Range. Each is available to any Government user who may require its support.

**Eastern Test Range.**—The Eastern Test Range (ETR) continued its basic support role of providing the necessary services to DOD space and missile programs. Support to NASA space programs such as Apollo also continued, but on a reimbursable basis as in the previous year.

Resizing of the ETR to the configuration required to support the basic DOD work load also continued throughout the year. Significant actions resulting in this regard included the deactivation of ETR instrumentation at Eleuthera Island, the subsequent transfer of certain facilities to the Navy on July 1, 1971, and the complete deactivation of the ETR station at Trinidad on October 1, 1971.

**Western Test Range.**—The Western Test Range, operated by the Air Force Space and Missile Test Center (SAMTEC) at Vandenberg AFB, California, continued during 1971 to provide range support to all launches from Vandenberg.

During 1971 many changes occurred in SAMTEC's range support capability. The range instrumentation ship fleet was further reduced by the deactivation of the telemetry reception ship, the USNS SWORD KNOT, during the first quarter. Telemetry reception

functions at Vandenberg have been consolidated at the new Oak Mountain site. Computerized telemetry processing functions have also been consolidated within the telemetry data center. During September, the range acquired an IBM 360/65 computer for range safety purposes. This third generation machine will replace an older IBM 7044. The range has installed a precision C-Band tracking radar at Kaena Point, Oahu, Hawaii. This radar should be fully operational in early 1972. Build-up of the new Pacific terminal instrumentation site is nearing completion and it should be fully operational in the spring of 1972.

**Satellite Control Facility.**—During 1971 satellite support activities increased because of the greater complexity of satellite systems. Planning is underway to increase the data handling capability of the system. This improvement will allow faster handling of larger amounts of data. The first of three new 46-foot antennas to replace the present 14-foot antennas was completed at the New Hampshire Station. Facilities work was completed at the Hawaiian Tracking Station for the second antenna. Studies and analyses continue to provide increased reliability and responsiveness of the overall system.

### Aeronautics Activities

**C-5A Heavy Logistics Transport Aircraft.**—The C-5A is a heavy logistics transport which provides a capability to airlift military forces world-wide under general war, limited war and peacetime conditions. It is capable of transporting and air-dropping troops and equipment. The C-5A is able to transport military equipment larger and heavier than any other aircraft in the free world.

To date, 51 aircraft have been produced; 43 of these are assigned to the Military Airlift Command and have been performing strategic airlift missions on a world-wide basis. Six aircraft are in test and refurbishment programs, and two have been destroyed. Operational programs have achieved over 30,000 flying hours.

The static and fatigue test programs have revealed certain weaknesses in the aircraft's wing structure. Analysis of these incidents indicates that the aircraft have the static strength necessary to satisfy essential operational requirements. The aircraft can also be expected to operate free of fatigue damage for at least 6,000 hours, or over 5 years under normal usage, with relatively minor modification and repair programs. Additional modifications are under consideration to increase both the static and fatigue life expectancy of the wing.

The results of the program to date indicate that the C-5A will meet the military operational requirements.

**F/FB-111 Aircraft.**—The F/FB-111 program involves the production of four models of tactical aircraft, the

F-111A, F-111D, F-111E and F-111F, one strategic bomber, the FB-111A, and one model, the F-111C, for the Royal Australian Air Force.

All of the F-111As, F-111Es and FB-111As have been delivered. Delivery of F-111D and F-111F aircraft began in August and September 1971 and will be continued into 1973. A follow-on procurement of 12 additional F-111Fs was approved and delivery of these aircraft is projected during 1973. Delivery of F-111C aircraft to the Australians is anticipated after completion of a modification program during 1972.

Deployment of the last F-111E to USAFE occurred in July 1971. The Strategic Air Command continued crew training and operational mission qualification with the FB-111A and moved its combat crew training support activities from Carswell AFB, Texas, to Plattsburgh AFB, N.Y. The Tactical Air Command took delivery of its first F-111F at Mountain Home AFB, Idaho in September 1971.

The extensive inspection program and cold proof test of the airframe, which was established after an F-111 accident in December 1969, has been completed and all operational aircraft have been returned to the using commands.

A significant milestone was passed in June 1971 when the F-111 force passed the 100,000-flying-hour mark. This represented approximately 39,500 flights.

The contractor and the Air Force are continuing with the final phases of the F-111 development and test program which involves certification of the F-111 to its full design maneuvering envelope and service life. The demonstration of performance specification requirements will be concluded in 1972 with completion of the static, fatigue and flight loads test programs.

**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 utilize the TF30-P412 engine and the AWG-9 missile control system which will control Phoenix, Sparrow, and Sidewinder missiles and 20 mm. guns. The F-14A will have an improved area air defense capability and will be superior to the F-4 in other fighter roles. It will also have a significant air-to-ground capability. First flight of the F-14A occurred on December 21, 1970.

The number one F-14A crashed on its second flight as a result of a hydraulic failure. The cause of the failure was pinpointed and corrective fixes have been incorporated in subsequent aircraft. The flight test program resumed in May 1971 with the flight of the number two F-14A. Testing is proceeding on schedule with performance meeting or exceeding major design specifications. The first total system aircraft has been delivered to Pt. Mugu, California, for installation of the AWG-9 weapons control system and avionics.

**F-15 Advanced Tactical Fighter.**—The F-15 is programmed as an advanced tactical fighter for the air

superiority mission. It is a twin engine, single crew, fixed sweep-wing aircraft and is characterized by design features providing maximum acceleration and maneuverability. The F-15 is being developed to counter the threat predicted for the late 1970s and early 1980s.

The program continues to proceed on schedule. Design review of both the airframe and engine have been completed and the initial flight test aircraft is being fabricated. Progressive test programs for the engine, avionics and other major subsystems will culminate in first flight of the aircraft scheduled for July 1972.

**A-7 Attack Aircraft.**—Delivery of the Air Force A-7D to the Tactical Air Command is continuing and will be completed in 1973. The first operational wing at Myrtle Beach AFB has achieved combat ready status. Pilot training has been moved from Luke AFB to Davis Monthan AFB where the second operational wing is being formed. The program has achieved marked success, meeting cost and schedule requirements as well as weapon system performance guarantees.

**B-1 Bomber.**—The B-1 development program is proceeding on schedule and is within the projected cost estimate. Through improved management procedures the original development contract has been restructured to reduce the number of flight test aircraft from five to three. Recently proven practices of the aircraft industry for the structural testing of commercial airlines made possible the elimination of one of the two static and fatigue test airframes. This contract modification significantly reduced the cost of the research and development phase of the program. In October 1971, a plan for development of appropriate avionics was approved and requests for proposal issued for a contractor to integrate and test the avionics suite. Most of the avionics components will consist of off-the-shelf equipments with new developments planned only in the navigation and threat counter-measures areas.

Program activities have concentrated on design validation and verification for the full release of engineering drawings and specifications. Two major milestones were completed in 1971, the preliminary design review and the full-scale mock-up review. Achievement of these milestones permits the contractor to proceed with the actual construction of the test aircraft; the first flight is scheduled for 1974.

A one-year flight test program emphasizing airframe and engine performance will precede the B-1 production decision point and allow the Air Force to confidently make a timely and logical decision on production.

**Carrier-Based Antisubmarine Warfare Aircraft (S-3).**—In 1971, the Navy continued engineering development of the S-3A. A second major program review was held in September 1971. A significant engine

milestone was passed ahead of schedule in April 1971 when the TF-34 engine successfully completed the Preliminary Flight Rating Test. By the end of the year a total of over 8,000 hours of running time, both in the air (test-bed aircraft) and on the ground, had been completed. This advanced turbofan engine will give the speed, range and high-altitude capability to the S-3A, while still enabling it to operate economically at lower altitudes necessary to complete the various anti-submarine warfare tasks. The S-3A with its crew of four will be equipped with the latest ASW sensors which are integrated for optimum effectiveness by a digital computer. A flying test bed (P-3 aircraft) is being utilized to test the various components and total avionics system to recognize and correct any developmental problems prior to S-3A testing. First flight with selected avionics was accomplished by the flying test bed in August 1971 and follow-on flights are continuing.

**E-2C Development.**—The E-2C is an all-weather, carrier based combat information center aircraft which extends task force defense perimeters by providing early warning of approaching enemy units and vectoring interceptors into attack position. Additionally, it provides command and control in air-to-surface strikes, search and rescue operations and general air traffic control.

Continued development and procurement of the E-2C, the latest of the E-2 family of airborne early warning (AEW) systems, will result in increased operational reliability and availability, improved radar performance and will alleviate quantitative AEW aircraft shortages.

Two prototype E-2C aircraft have been flying and undergoing tests since January 1971. Testing is proceeding on schedule with performance meeting or exceeding design specifications. Initiation of production was approved on 15 September 1971.

**EA-6B Development.**—The EA-6B aircraft system development will be a tactical airborne electronic jammer aircraft which will provide support for carrier and advanced base strike aircraft. The EA-6B system will use the basic A-6 airframe, modified for a four-man crew, with new powerful jamming devices.

Several production aircraft have been delivered and are engaged in systems evaluation and tactics development prior to an impending overseas deployment aboard an aircraft carrier. Flights to date have been most successful in validating the program concept, and in some areas have showed the system to exceed specifications. A recent decision has been made to provide the basic EA-6B with an expanded capability against additional threats. Testing is scheduled to begin soon.

**A-X (A-9/A-10) Aircraft.**—The Air Force has initiated development of the A-X, a new close air support aircraft optimized for effective support of friendly

ground forces. The A-X will be a single-place twin-turbofan aircraft providing STOL characteristics, excellent maneuverability, long loiter, large payloads, and ease of maintenance. Firm-fixed-price contracts for the competitive prototype phase were awarded in December 1970. First flights are scheduled for June 1972 with the Air Force competitive fly-off evaluation scheduled for October-December 1972. Award of full scale development contract to the winning contractor is scheduled for February 1973.

**E-3A Airborne Warning and Control Systems (AWACS).**—The E-3A radar development program, continued throughout 1971, resulted in the delivery of two competitive radar systems during December 1971. Both competing radar designs are characterized by the ability to detect low flying targets in the presence of severe ground clutter. The radar systems will provide extended low-altitude surveillance over both land and water. A competitive radar flight test program will be initiated in 1972 utilizing a modified commercial Boeing 707 aircraft as the airborne platform.

The E-3A system will provide an airborne surveillance capability and associated command, control and communications functions in a military version of the Boeing 707 aircraft. Tactical forces will use the E-3A for command and control during the movement of a Composite Air Strike Force, while achieving and maintaining air superiority in a battle area and for rescue and airlift missions. Defense forces will use the E-3A to provide detection and tracking of enemy aircraft and for battle management of interceptors. The E-3A will provide a long-endurance on-station capability that will be enhanced with in-flight refueling.

**Helicopter Research.**—The Army seeks to improve the response efficiency, economy, and utility of rotary wing aircraft by focusing on the aerodynamics and dynamics of lifting rotors, aircraft structures, and the control and stabilization of rotary wing aircraft. Advanced rotor concepts being investigated are coaxial mounted rotors and the tilt prop/rotors. The use of advanced armor concepts to reduce vulnerability is being pursued to determine the feasibility of forming helicopter structures from armor. In the area of flight controls, new anti-torque devices for helicopters are being analyzed with the objective of reducing tail rotor blade strikes and providing more responsive pilot control. Additionally, fluidics have progressed to the advanced development phase for the design, fabrication and flight testing of a complete hydrofluidic control system for a helicopter.

The Advanced Research Projects Agency completed a program under the technical direction of the Army which demonstrated that helicopters can be significantly quieted. The noise emitted by the test vehicle was reduced to less than one-tenth of its original level.



This achievement is expected to have a major impact on the future design of military helicopters. Since low altitude flight over populated areas would be virtually unnoticeable from the ground, a quieted helicopter may also have important implications in the civil and commercial sectors.

**Heavy Lift Helicopter.**—To complement current lift capability, a joint Army-Navy program for a Heavy Lift Helicopter development has been initiated. Competition was completed in June 1971 and a 36-month contract was awarded to design, fabricate, and test the critical components of a tandem rotor HLH. The Heavy Lift Helicopter will have a design gross weight of 118,000 pounds when transporting a 22½-ton payload. Prior to initiation of full engineering development, the advanced technology rotor/drive system, cargo handling and flight control systems will be demonstrated.

**Utility Tactical Transport Aircraft System (UTTAS).**—The utility tactical transport aircraft system (UTTAS) is to be the Army's first true infantry squad carrier. It is designed specifically to lift and infantry squad (11 combat equipped troops) with its normal attachments in tactical troop assault and related missions now performed by the UH-1 series helicopter. The UTTAS provides a follow-on helicopter with increased payload and substantially improved maintainability, reliability, survivability, safety, and performance. Full-scale development was approved in June 1971. The Army is following the new Department of Defense weapons system acquisition policy of competitive prototyping and fly-off prior to the award of a production contract. The UTTAS engine engineering development contract was awarded in December 1971. Contract award for the prototyping phase of the airframe development is scheduled for June-July 1972.

**AH-56A (CHEYENNE).**—The Cheyenne is being developed to fulfill the Army's requirement for an advanced attack helicopter with a day/night and adverse weather antimechanized/antitank capability which can also perform the missions of direct aerial fire support and armed aerial escort. Cheyenne prototype aircraft have completed over 1,200 flight hours. Flight evaluations by Army test pilots, initiated in early 1971, are progressing satisfactorily. The weapons and navigation subsystems have equaled or bettered contract accuracy specifications. The integrated TOW missile/night vision subsystem is now undergoing flight and firing tests and has scored a number of direct hits at extended ranges. Flight testing with the improved rotor control system is progressing satisfactorily with no evidence of the previously encountered rotor instability. In 1972 the Cheyenne is scheduled to complete its developmental tests.

## Supporting Research and Technology

**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.

During 1971 the liquid rocket engine technology development program emphasized fabrication and test of critical components of a lightweight aerospike engine and conduct of system design analyses of advanced aerospike and bell nozzle engines optimized for future high energy upper stage and reusable orbit-to-orbit stage applications. Specific task objectives of this project are continuously coordinated with NASA as well as DOD program needs through the joint Advanced Chemical Rocket Engine (ACRE) working group.

**Upper Atmosphere Investigation.**—A sounding rocket experimental program was conducted at Eglin Air Force Base, Florida, in January and February 1971 to study the characteristics of high-altitude ionized barium clouds. As a result of this program, ambient ionospheric electron density profiles were obtained for seven rocket firings for those parts of the trajectories where the radio signal did not pass through the clouds. The results will contribute to the general understanding of the ionization phenomenology of the ionosphere with significant applications in the fields of communications and radar tracking.

**Solar Radiation (SOLRAD) Monitoring Satellite Program.**—The SOLRAD-10 satellite, launched 8 July 1971 into a 235 by 340 nautical-mile orbit, together with SOLRAD-9, are measuring solar emissions.

Information gained by the satellites is contributing to better understanding of the physical processes involved in solar flares and other solar activity. This knowledge is being utilized in the development of improved techniques for predicting and assessing space environment disturbances that are required for support of systems which operate in, or are affected by, that environment. Operationally, the SOLRAD-9/10 satellite output continues to be routinely used by the Navy, Air Force and National Oceanic and Atmospheric Administration to support the operation of communication and surveillance systems and the APOLLO lunar landing missions.

The launch of SOLRAD-10 marked the beginning of the transition of the SOLRAD program from a single, low altitude, research satellite to a system of high altitude satellites, designated SOLRAD-HI. The SOLRAD-HI system now under development, consists of a replaceable satellite constellation deployed in a circular orbit 70,000 nautical miles high. This system, when fully implemented, will provide continuous, real-time monitoring, alerts and predictions of space

environment disturbances to operational users to qualify the performance of or determine alternative action for communication, navigation, surveillance and space systems affected by solar disturbance.

**Space Vehicle Subsystems Technology Program.**—The space vehicle subsystems technology program is an advanced development program to develop and demonstrate satellite subsystems technology essential for a spectrum of DOD space missions in the 1975–1985 time period. To meet advanced mission requirements, development efforts are under way to reduce the volume and weight of satellite subsystems and to increase subsystem performance, survivability and life-time.

Over the past year project activity included development of advanced space guidance, power supply and satellite secondary propulsion systems components and initiation of a project to develop and demonstrate the capabilities of a laser space communications subsystem. In October, a flight demonstration of the 1.5 kilowatt flexible, roll-up type solar array was successfully accomplished on a Space Test Program satellite launched from Vandenberg Air Force Base. The demonstration of this high performance array provides the technology base to enable a 50 percent reduction in the weight and volume over existing solar cell array subsystems. Electric colloid thruster technology development was continued to provide a high performance secondary propulsion system to perform satellite attitude control and station keeping functions. The colloid thruster will operate in the millipound thrust range and will have a specific impulse which is at least four times higher than current state-of-the-art thrusters. Development of a laser communications subsystem was initiated in 1971 with emphasis on critical component development. This device, scheduled for launch in 1976, will feature very high data transmission rates and a narrow beam carrier. The technology to be demonstrated includes the transmission, modulation, and alignment techniques associated with this advanced concept communications subsystem.

**Space Test Program.**—The DOD Space Test Program successfully conducted three primary missions in earth orbit this year. The program provides the means to conduct flight tests of advanced development payloads in space and to evaluate their contribution to new or improved DOD space systems. A refurbished Thor booster with a Burner II upper stage launched an infrared celestial mapping sensor system on 8 June 1971. On 6 August 1971, a refurbished Atlas F booster placed two Orbiting Vehicle (OV-1) satellites into orbit carrying nine DOD experimental payloads. A Thor-Agena was launched on 17 October 1971 to test a closed cycle cryogenically cooled infrared sensor system to conduct celestial mapping. In addition to the celestial mapping sensor, a 1500 watt roll-up solar array

was demonstrated and is undergoing life tests on orbit, the BATSON command system was successfully demonstrated, and an experiment was completed which investigated energetic particle interaction with the ionosphere. The Space Test Program is the only substantial DOD spaceflight test bed capability available to fly-before-you-buy advanced and exploratory development designs and concepts for the military services and other government agencies.

**Advanced Turbine Engine Gas Generator (ATEGG).**—The ATEGG program is an Air Force advanced development program in which new technology and advanced design concepts are tested in a turbine engine environment. It is based on the fact that new technical approaches which appear attractive in laboratory or isolated component tests may not be representative of that component's operation when installed in a high-performance engine. A secondary objective is to maintain a strong competitive industrial base from which to procure advanced engines for future weapon systems.

Advances in propulsion have depended on the verification of new technology and engine design philosophy in representative engine conditions. This demonstration provides that verification and an accurate assessment of the capability to build future aeronautical systems.

The five participating engine contractors in the past year have demonstrated continuing improvements in the engine performance parameters of thrust-to-weight, thrust-to-volume and fuel consumption by increased thermal efficiency, higher operating temperatures and higher pressure ratios per compressor stage.

**Advanced Propulsion Subsystem Integration (APSI).**—This Air Force advanced development program evolved in 1967 from the need to more effectively define and substantiate the integrated propulsion system performance of future weapon systems prior to a vast commitment of engineering funds. Initial program efforts were directed toward providing improved development procedures, techniques and criteria for assessing inlet engine compatibility as a baseline for the F-15 and B-1 propulsion system evaluation and development. The continuing efforts in this area provide the critical technology baseline for future system development and are an important data source for insuring the early resolution of any integration problems encountered during system development programs. The current program is closely coordinated with the ATEGG program to assure substantiation of the turbine engine performance and propulsion system integration technology required for future advanced aircraft.

The scope of this program encompasses the total propulsion system from the inlet through the nozzle. This includes the development of the advanced engine

components necessary to adapt the ATEGG core gas generator into a complete engine to meet specific systems requirements.

Current programs in the turbine engine component development area include the application of advanced high temperature and composite materials in future engine designs. The APSI program is also developing components sized to be compatible with the ATEGG hardware. The integration of APSI components with the ATEGG gas generators will establish a flexible turbine engine technology base for meeting the propulsion system requirements of future aircraft.

**Turbine Engine Development.**—The Army completed the advanced development of two 1500-shp demonstrator gas turbine engines in July 1971. The technology demonstration of this program provided the basis for a decision to initiate engineering development of the 1500-shp UTTAS engine. Significant reductions in engine weight and fuel consumption were demonstrated in this program. Advanced development of a small turbine advanced gas generator (STAGG) was initiated in June 1971 with competitive solicitations. Contracts were awarded to four engine manufacturers in November 1971. This advanced development will provide for the integration of turbine engine components investigated in the exploratory development program and will provide the nucleus for demonstrator or development engines oriented towards future Army aircraft and APU power plants. STAGG is directed toward engines with 3500 to 1000 shp outputs.

**Survivable Flight Control System Development Program (SFCS).**—The objective of this program is to develop technology to increase the tactical survivability of future aircraft by reduction in vulnerability of present complex hydro-mechanical flight control systems. Flight tests will demonstrate the principles of component separation, redundancy, and hardening as applied to aircraft primary flight control systems by use of an all-electronic control system and integrated hydraulic servo-actuator package. The all-electronic system will decrease vulnerability of the control linkages from the pilot's control stick to the surface actuators, while the integrated servo-actuator package will decrease vulnerability of the power source for the control actuators. The integration of both normal and backup operation into a single unit permits keeping the weight to a minimum while increasing survivability and reliability.

The first of a series of flight tests was made in April 1970 and demonstrated the integrated actuator package portion of the system which provides for emergency control for a "get-home-and-land" capability in the event normal hydraulic power to the stabilator is lost or rendered inoperative from battle damage. The actuator exceeded performance expectations

beyond the required emergency flight envelope. This demonstration represents a significant step in the development of the complete fly-by-electrical-wire control system.

Phase I performance testing was continued in 1971. The emergency get-home-and-land capability of the Simplex integrated actuator package in the longitudinal flight control system of the F-4 test aircraft exceeded design predictions.

Phase II flight testing of a three-axis, quadruply-redundant fly-by-wire system is scheduled to begin in early 1972.

**Aircraft Component Development Crash-Resistant Fuel System.**—To reduce post crash fire casualties significantly, a new crash-resistant fuel system for Army helicopters has been developed. First tanks were installed beginning in 1970 and the program will be completed by 1975. Accident data for helicopters equipped with the system clearly depict its effectiveness. To date there have been no thermal injuries or fatalities recorded in a survivable crash in which the crash-resistant fuel system was installed.

**Fly-by-Wire Control.**—The advanced development program continues on the Tactical Aircraft Guidance System (TAGS) which is designed to replace all mechanical controls, stability augmenting systems, and navigation systems with highly reliable, redundant electronic controls to improve all-weather mission reliability and reduce pilot training time. A joint U.S. Army/Canadian government test program using CH-47B helicopters is now in progress.

**Circulation Control Rotor.**—The Navy has performed two-dimensional wind-tunnel tests of the Circulation Control Rotor (CCR) concept which demonstrated good correlation with theory. Substantial increases in blade section lift coefficient at zero angle of attack are possible with consequently improved lift capability over standard rotor configurations. An improvement in helicopter operational speeds appears to be feasible using this concept. A six-foot CCR model has been built for wind tunnel and hover testing for proof of the concept. This test will be followed by more refined and optimized test models and investigations of structural, dynamic and manufacturing characteristics of the CCR for ultimate application to full-scale flight vehicles.

**Medical Projects.**—The Naval Aerospace Medical Research Laboratory (NAMRL) at Pensacola, Florida, continued to conduct aeronautics and space-related medical tasks. A study on the physiological effects of long term exposure of mice to low magnetic fields was completed with normal findings. Vestibular studies included the calibration of susceptibility to motion sickness, adaptation, and training at normal gravity to overcome motion sickness in the weightless condi-

tion, and the development of hardware to test vestibular function in flight. The effects of radiation are being measured for the Apollo 14 flight, for flight at SST altitudes, and for flight at commercial altitudes. Methods for evaluating the vector cardiogram under weightless conditions for SKY LAB, the effects of enhancing tolerance to gravitational forces through use of lower body negative pressure, and the preflight study of primates in long duration weightlessness are continuing. The NAMRL detachment at New Orleans has started an investigation to determine the dynamic response of humans to impact acceleration.

**Aerodynamics.**—The Services are conducting aerodynamic investigations in several areas which appear to have potentially high payoffs in improved aircraft performance. These include an improved family of airfoils, conformal carriage of external stores and the canard configuration. Full-scale flight tests of the supercritical wing have been encouraging. Analytical and experimental work on this new class of airfoils is continuing. Analysis and wind-tunnel tests of conformal carriage of weapons have indicated potential decreases in drag and improvement in aircraft range. An F-4 aircraft is being configured for full-scale flight tests of the concept. Wind-tunnel tests of a generalized canard/wing/fuselage research model have been conducted at subsonic and supersonic speeds. Results indicate improvements in lift and buffet. This work is continuing in an attempt to develop a rational theory of canard/wing interference.

#### **Relationship With Other Government Agencies**

The Department of Defense continued close coordination and cooperation with other Government agencies. Four military officers (two Air Force, one Navy, and one Army) are assigned to the National Aeronautics and Space Council in the Executive Office of the President and 132 military personnel assigned to NASA (69 Air Force, 22 Navy, 38 Army, and 3 Marine Corps). Other areas of cooperation and coordination are described below.

**Aeronautics and Astronautics Coordinating Board (AACB).**—The AACB met four times during the past calendar year. In performing its functions as the principal coordinating mechanism between the DOD and NASA in space and aeronautics, the Board gave special consideration to a number of items. The Board continued to examine the NASA Space Shuttle activities and the implications to DOD for the future operational use of the Shuttle. The Board recognized that, while knowledgeable DOD and NASA elements are convinced of the need for large new aeronautical facilities (Large Engine Test Facility, Full Scale Subsonic Tunnel, and High Reynolds Number Tunnel); there are important segments of the aeronautics industry, educational institutions and the government that

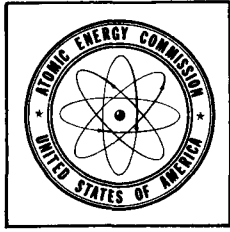
are not convinced of this need. Other items that received attention during the year include the current family of launch vehicles for space, the general area of communications and data relay satellites, and navigation and air traffic control satellites. Through its Aeronautics Panel, the Board has stimulated coordinating efforts within the Army, Navy, and the Air Force and NASA on the problem of spin and stall research.

**Aerospace Feeding Systems.**—Extensive storage test and periodic evaluations for texture and flavor are in progress on a variety of dehydrated foods used aboard the different space flights. Nutritional analysis of these and other space foods before and after storage is also being conducted. Four flexibly packaged, thermally stabilized meat products were produced in-house and supplied for Apollo 14. Two new flexibly packaged meat products, hamburgers and beef steak, were added to Apollo 15. Technical assistance has been provided to NASA on draft SKYLAB specifications for microbiological inspection procedures and is continuing in proposed food specifications.

**Apollo Mission Support.**—The U.S. Army Engineer Waterways Experiment Station developed and provided information to NASA and its contractors concerning the mobility of the Lunar Roving Vehicle. This information provided the principal basis for the design of the vehicle and plans for its deployment on the lunar surface on the recent Apollo 15 mission.

**Remote Sensing Oceanography (RSOC) Project.**—The Navy established under the Oceanographer of the Navy a Remote Sensing Oceanography (RSOC) Project to provide focus for related efforts under way at various Navy laboratories, and to promote applications of airborne and spaceborne sensing techniques developed under the NASA Earth Resources Survey Program to Navy oceanographic environmental-data-acquisition problems. The Navy participates in the NASA Earth Resources Survey Program by representation on the Earth Resources Survey Program Review Committee and through program support provided by the RSOC Project. Navy consultants assisted NASA in reviewing proposals submitted for Earth Resources Technology (ERTS) and Earth Resources Experiment Package (SKYLAB) experiments directed toward oceanographic applications, and provided membership for the Earth Observatory Satellite Mission Review Group.

Other cooperative experiments in the RSOC Project include a joint Navy/NASA/National Marine Fisheries Service experiment conducted over the Gulf of California in early 1971 to refine techniques of extracting sea-surface temperature data from satellite infrared imaging and a Navy/NASA/NOAA airborne microwave experiment to derive sea surface roughness data under all-weather conditions.



# Atomic Energy Commission

## Introduction

Effort continued during 1971 on the development of nuclear power systems for future space applications both for propulsion and for on-board electrical power. Highlight events include the following:

**Nuclear Space Power**—Two more SNAP-27 radioisotope generators were placed in operation on the moon by Apollo-14 and -15 astronauts. The SNAP-27 deployed during the Apollo-12 mission in November 1969 has performed exceptionally well beyond its 1 year design life objective.

All the isotope power units in space continued to operate beyond their design life goals with the first nuclear space power unit (SNAP-3A) passing its tenth anniversary in orbit.

The flight generator for use on the Navy's advanced Transit navigation satellite was accepted by the AEC.

Modified SNAP-19 generators were delivered to NASA for use on the Pioneer F Jupiter Fly-by mission scheduled for an early 1972 launch.

Requests were received and accepted by the Commission to provide the modular multi-hundred watt isotope generator for use on the DOD's experimental communication satellites (LES-8 and -9) and for NASA's Grand Tour missions to the outer planets starting in 1976.

A study was completed, jointly with the Air Force, concerning the use of a multi-kilowatt reactor-thermoelectric system on an unmanned military satellite mission. Such a system is potentially much lower in costs than competitive power systems.

**Nuclear Rockets**.—Although funding restrictions have slowed progress in the development of the nuclear rocket propulsion (NERVA) system, technical progress continues and a capability has been retained for future resumption of the full development program.

## Space Electric Power

The objective of the joint AEC-NASA space electric program is to provide operational systems and advanced technology development which will satisfy the need for nuclear electric power in space applications. During 1971, the major emphasis was on operational systems for the near-term national space program. Some effort was also continued on several

other technology areas which are candidate systems for future space missions.

## Space Radioisotope Power Systems

**Operating Systems in Space**.—Two additional SNAP-27 units were deployed on the moon during 1971 by the Apollo-14 and -15 astronauts. These two units joined the earlier SNAP-27 unit placed on the moon by the Apollo-12 astronauts and are providing the electrical power for a network of three scientific stations at different locations on the surface of the moon. Each station has a design life of 1 year, but the first SNAP-27—deployed on the moon in November 1969—is still exceeding its design power (63 watts) after over 2 years of operation, enabling the experiment station to continue operation. The network of three stations makes it possible to pin-point the origin of seismic events, and to obtain more accurate data on magnetic and charged-particle fields. Additional SNAP-27 generators have been delivered to NASA for use on the planned Apollo-16 and -17 missions in 1972.

Three other isotope generator systems launched during the 1960's, i.e., SNAP-3A, SNAP-9A, and SNAP-19 still continue to operate though at significantly reduced power levels. The grapefruit-sized SNAP-3A, the first isotope generator to be orbited in space, passed its tenth anniversary of continuous operation aboard a navigational satellite during 1971.

**Transit Generator**.—Fabrication and testing of the 5-year-life Transit generator for the Navy's advanced navigational satellite was continued. The first complete, electrically heated unit was delivered to the Navy for spacecraft integration efforts early in 1971. A complete plutonium-238 fueled ground-test unit was tested at mid-year, and the flight generator was fabricated and accepted by the AEC late in 1971.

**Pioneer Generator**.—Modified SNAP-19 generators are being developed for use as the sole electrical power source of NASA's Pioneer Jupiter Flyby missions scheduled for launching in early 1972 and 1973. Fabrication of four isotopically fueled prototype generators for NASA spacecraft integration efforts was completed and the generators were delivered to NASA early in 1971.

While undergoing testing with the spacecraft, the generators exhibited more power degradation than was expected. The generators were returned to the AEC where the refractory metal components in the heat source were found to be embrittled and, in some cases, cracked. Corrections were made and new generators with new heat sources were fabricated and delivered to NASA late in 1971.

**Viking Generator.**—Modified SNAP-19 generators are also planned for use with the NASA Viking Mars Lander missions scheduled for launch in 1975. Two electrically heated generators were fabricated and were delivered to NASA in May 1971 for early spacecraft integration tests. Further Viking efforts were deferred during the last half of 1971 until the Pioneer problems could be solved.

**Multi-Hundred Watt Generator.**—A modular multi-hundred watt (MHW) generator is under development as a basic building block for space power systems in the 100 to 1,000 watts of electricity range. This generator technology program has been underway since 1969. In 1971, the AEC accepted a requirement from the Department of Defense (DOD) to deliver MHW generators for use on the Lincoln Laboratories Experimental Communications Satellites, LES-8 and -9. With the approval of the Grand Tour missions to the outer planets, NASA also requested the AEC to support those missions by developing the MHW generator to meet the stringent lifetime (10 years) and weight constraints of the Grand Tour missions. The first Grand Tour mission is scheduled for launch in 1976.

Extensive testing of the MHW generator and heat source materials and components was conducted during 1971. The first electrically heated MHW test-bed generator, employing silicon-germanium (SiGe) thermoelectric materials and high-temperature, vacuum foil-type thermal insulation, was fabricated and tested during 1971.

**Space Isotopic Fuel Development.**—Efforts in 1971 were concentrated on the plutonium-molybdenum cermet fuel form for the Pioneer, Transit, and Viking programs and a pressed plutonium-oxide fuel form for possible use with future generators. Investigations continued, at a reduced level, on Curium-244, an alternate space fuel which potentially offers significantly reduced fuel costs.

### Space Reactor Power Systems

**Zirconium-Hydride Reactor.**—The Zirconium-Hydride reactor can be used with several conversion systems. The AEC is pursuing the development of the compact thermoelectric conversion system. The reactor-thermoelectric system provides a long-lived power system of high reliability and simplicity from a few kilowatts up to around 35 kilowatts of electricity.

This makes a reactor system which is cost effective and very attractive for high-powered unmanned satellite applications such as military and communications satellites. A similar, but heavier, shielded version of this reactor-thermoelectric system is also of interest for the manned space missions of the 1980's.

During 1971, the AEC, jointly with the Air Force, studied the use of a multi-kilowatt reactor-thermoelectric system for an unmanned military satellite. This study showed the potential usefulness of a reactor power system for operational satellites of this type, but final selection of the power system must await results of further flight tests of various spacecraft components in the near future.

The AEC will also provide NASA a larger zirconium-hydride reactor for use in a combined systems test at the NASA Plum Brook facility in the mid-1970's. This reactor will be operated under space-simulated conditions in conjunction with a dynamic Brayton (closed gas cycle) conversion system currently being developed by NASA.

**Thermionic Reactor.**—Progress continued on the development of the thermionic fuel element and fabrication of an experimental reactor to be operated in the late 1970's. This reactor will convert heat to electricity within the reactor core and be capable of long endurance operation. Emphasis is currently directed toward demonstration of a full-length thermionic fuel element, the first of which was tested in a reactor during 1971. The in-core thermionic reactor power system is a high-performance source of power which can provide an electrical propulsion capability for missions to the outer planets or to perform comet rendezvous missions, e.g., with Halley's Comet (which would require a launch in 1983). When developed, the thermionic concept may also be used for high-power requirements for manned space laboratories and advanced unmanned satellites.

### Nuclear Rocket Program

The major objective of the joint AEC-NASA space nuclear propulsion program is the development of the NERVA (Nuclear Engine for Rocket Vehicle Application) flight-rated engine for a variety of space flight missions. This flight engine development is based on technology stemming from many years of research and experimental investigations. The program also includes a variety of advanced research and technology activities conducted to support the NERVA development effort and to explore novel concepts for applying both fission and fusion to propulsion.

**NERVA Development.**—NERVA development progress during 1971 was marked by the completion and review of the NERVA engine and nuclear subsystem baseline design and the initiation of engine and reactor component detailed design and development activities.

The original plan for this period called for the completion of the detailed engine design and the initiation of the detailed design of all engine components. However, fiscal year (FY) 1972 (ending June 30, 1972) funding restrictions became known at the beginning of the calendar year which necessitated the deferral of this design approach and a reduction of NERVA development activities to the design and development of selected critical engine and reactor hardware. By adapting this approach, technical progress continued and a capability was retained which would permit future resumption of the full development program.

Nuclear subsystem design and development activities consisted primarily of work on the reactor fuel elements, core support structure and periphery components; and, materials research and analysis.

Fuel element development activities continued to be directed toward achieving the 10-hour, multiple-cycle performance goal established for the NERVA engine. It had been planned to test two of the prime NERVA fuel element candidates in the Los Alamos Scientific Laboratory (LASL) Pewee-2 reactor during 1971. However, the funding restrictions forced the cancellation of the Pewee-2 reactor test program. Laboratory work on those elements was continued, and it is now planned to test representative samples in the LASL Nuclear Furnace early in 1972.

In addition to the fuel element development activities, work is continuing on materials and fabrication processes.

**Advanced Research and Development.**—AEC-funded activities in space propulsion advanced research

and technology activities were directed toward increasing the performance level of solid-core nuclear rocket engines and the investigation of advanced nuclear propulsion concepts. LASL is the principal contributor to advanced research and technology. During 1971, the emphasis of the LASL effort was on the development of graphite-carbide composite materials along with work on advanced carbide fuel materials for possible use in advanced solid-core reactors. In addition to solid-core nuclear rocket reactor technology activities during 1971, work also continued at LASL on advanced propulsion concepts. Most of this effort was devoted to pulsed-propulsion studies and laser research.

### **SATELLITE-BASED DETECTION OF NUCLEAR EXPLOSIONS IN SPACE AND THE ATMOSPHERE**

Vela satellites (carrying neutron, gamma ray, x-ray, optical and electromagnetic pulse detection systems) continued to perform a monitoring function for possible clandestine nuclear testing in the atmosphere and in space during 1971. They also are continuing to provide valuable information to scientists on the nature of solar x-rays, the solar wind, and other natural phenomena.

The joint AEC-DOD satellite based detection program began in 1963 with subsequent launches in 1964, 1965, 1967, 1969 and the last launch in 1970. Each launch successfully placed AEC-instrumented twin satellites into near-circular orbits about the earth at an altitude of approximately 65,000 nautical miles.

VI



## Department of State

### **Introduction**

Expansion of international space cooperation in support of foreign policy objectives and the National Aeronautics and Space Act was again a matter of high priority to the Department of State during 1971. Attention continued to be focused during the year both on expanded cooperation with individual countries and on space endeavors with multilateral and international organizations.

Progress in international space affairs during 1971 included continued discussions with foreign officials on

participation in major new US space programs in the '70s and '80s, increased possibilities for cooperative activities with the Soviet Union, significant developments in international cooperation in communication satellite systems, several new bilateral space cooperation agreements, and expansion of interest and activities in earth resources survey satellite programs.

**Activities Within the United Nations.**—The Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space reached agreement in June 1971 on a draft international convention on

liability for damage caused by objects launched into outer space. The convention was subsequently adopted by the parent committee and received the endorsement of the General Assembly at its 26th session. It is expected that the convention will be opened for signature by UN members early in 1972.

These actions culminated eight years of difficult negotiations. In the US view the convention establishes an international legal basis for the prompt and reasonable settlement of claims for damage caused by returning space objects or fragments and represents a significant advance in the development of space law.

Also during 1971 the Scientific and Technical Subcommittee of the Outer Space Committee agreed on the establishment of a Working Group on the Remote Sensing of the Earth by Satellites. The Working Group held an organizational meeting in September. Its substantive work will be keyed to the availability of appropriate data from the NASA experimental Earth Resources Technology Satellite ERTS-A, scheduled for launch early in 1972.

In response to the growing international interest in the possible applications of earth resource surveys, the United States was host in May to the first UN Panel on Remote Sensing. The panel visited the University of Michigan, Purdue University, the NASA Manned Spacecraft Center at Houston and the Goddard Space Flight Center near Washington. The Panel was a project of the UN Expert on Space Applications in his program of promoting the study of possible applications of space technology, in particular as they may be relevant for developing countries. An expanded 1972 program for the Expert was supported by the United States and approved by the Outer Space Committee and the General Assembly in late 1971.

**Cooperation With Europe.**—Discussions undertaken in 1970 with European space officials regarding possible participation in the US post-Apollo program continued during 1971. Questions on possible arrangements for European participation in the development and use of a new space transportation system and several variations of Research Application Modules were explored with representatives of the European Space Conference at a meeting in Washington in February hosted by the Under Secretary of State for Political Affairs. Additional meetings of technical experts were held in October in Paris and December in Washington to further define possible areas for European participation in the whole range of NASA programs throughout the rest of the 1970s. The Department also continued to facilitate the participation of European firms in study efforts on post-Apollo programs by US industries.

The Western European Union Committee on Scientific, Technological and Aerospace Questions initiated a study in 1971 of European participation in the US post-Apollo program. In support of the

study, and at the request of the Committee, the Department made arrangements for Committee members to discuss the subject with US officials and visit space installations during a one-week visit in October.

At the request of NASA, in October the Department instructed our Embassy in Rome to open discussions with Italian authorities on a renewal of the bilateral agreement for launchings of NASA satellites by Italian crews from the San Marco platform off the coast of Kenya. In view of the highly successful launch operations to date from the San Marco facility and with the next NASA satellite to be launched from the site now scheduled for late 1972, an extension of the bilateral beyond its December 31, 1971, expiration date was requested. As the year ended, agreement in principle for a renewal had been reached with the Italian government and an exchange of diplomatic notes was expected momentarily.

At the initiative of British space officials, discussions with NASA during 1971 produced an understanding on arrangements for launchings of British satellites by NASA on a reimbursable basis. An exchange of diplomatic notes to confirm the provisions of a Memorandum of Understanding between NASA and the British Department of Trade and Industry is expected early in 1972.

Cooperative sounding rocket activities with European countries continued in 1971. The Department provided assistance as NASA concluded two new arrangements with the Norwegian Council for Scientific and Industrial Research and the French National Center for Space Studies for additional scientific sounding rocket projects.

**Cooperation With Canada.**—Discussions with Canadian officials begun in 1970 and continued in 1971 culminated in May in the conclusion of a bilateral agreement with Canada for a cooperative Communications Technology Satellite (CTS) project. The CTS project is designed to advance the level of technology in telecommunications via satellites by developing new equipment and conducting experiments with a Canadian-built satellite launched by NASA.

Another significant development in the long history of fruitful cooperation in space activities with Canada took place in April when a bilateral agreement covering a joint program in the field of experimental remote sensing from satellites and aircraft was concluded. Under the agreement Canada will build ground stations in Canada to receive data from NASA's Earth Resources Technology Satellites (ERTS) as part of a joint program to study the application of remote sensing to the detection of environmental conditions at and near the surface of the earth.

In December agreement was reached on an exchange of diplomatic notes with the Canadian Government to confirm provisions for the establishment and operation of a tracking and communications facility near St.



John's, Newfoundland, in support of NASA's Skylab project operations now scheduled for 1973. The facility will consist mainly of transportable equipment which will be removed at the conclusion of Skylab operations.

Other NASA activities in Canada in 1971 arranged by the Department included geological training for Apollo astronauts at Sudbury Crater in July and a series of sounding rocket launches during the year from the Fox-Main Dewline station in northern Canada.

**Cooperation With Japan.**—Space cooperation between the United States and Japan during 1971 was dominated by an increased flow of space technology to Japan, as authorized under terms of the 1969 US/Japanese Space Cooperation Agreement. This technology, being transferred under US/Japanese industry arrangements subject to approval of the Department's Office of Munitions Control, is to be used in Japanese efforts to develop a space launch vehicle and a number of scientific and practical applications satellites.

As a matter of maintaining close coordination with Japan on its launch vehicle and satellite development programs, the Department hosted a meeting in July of US space officials and the President of the Japanese National Space Development Agency.

The Department also participated with NASA in meetings with a special committee of the Japanese Federation of Economic Organizations (Keidanren), which visited the United States in July to gather information on possible participation in the post-Apollo program by Japan. The report and recommendations of the special committee will contribute to decisions by the Japanese government with respect to post-Apollo and other long range plans for space cooperation with the United States and other nations.

**Cooperation With the Soviet Union.**—Our long standing efforts to engage the Soviet Union in a significant measure of cooperation in space activities proved unusually fruitful in 1971. Of particular note was the exchange between NASA and the Soviet Academy of Sciences of samples of lunar soil obtained in US and Soviet lunar exploration missions.

In January, officials of NASA and the Soviet Academy of Sciences met in Moscow and agreed to establish joint working groups to examine the possibilities for collaboration in specific space tasks in such areas as space meteorology, biology and medicine, the study of the natural environment, and the exploration of the moon and planets. Subsequent meetings of these working groups in August and October further developed subjects and tasks in these areas for more concentrated consideration.

In late 1970 the US and the Soviet Union agreed to discuss the possibilities of defining the means and equipment which would at some time in the future enable US and Soviet manned spacecraft to rendez-

vous and dock during space operations. These discussions continued in 1971 as groups of US and Soviet experts met in June and November to more clearly define compatible rendezvous and docking systems, techniques and equipment. The group of experts also made significant progress in describing a possible demonstration in orbit of these compatible systems using US Apollo and Skylab and Soviet Soyuz and Salyut equipment. Such a demonstration could be conducted in the next few years.

**Communications Satellites.**—The negotiations of the Definitive Agreements for the International Telecommunications Satellite Organization (Intelsat) which were begun in February, 1969, were successfully concluded in May. The Definitive Agreements will replace the Interim Arrangements negotiated in 1964 by eleven countries, including the United States, and which eighty-one countries have now signed. The Definitive Agreements consist of an Intergovernmental Agreement to be signed by governments of participating countries, and an Operating Agreement to be signed by the governments themselves or by the telecommunications entities designated by the member governments. The United States has signed the Intergovernmental Agreement and the Communications Satellite Corporation was designated to sign the Operating Agreement for the United States. These Agreements will come into force when they have been signed and ratified by two-thirds of the signatories to the Interim Arrangements holding two-thirds of the investment in the system. It is expected this will occur after mid-1972.

During 1971 four countries acceded to the Interim Arrangements bringing the total membership to eighty-one countries. The new members are Mauritania, Malagasy Republic, Gabon and Ghana.

In March the first satellite of the Intelsat IV series was put into commercial service over the Atlantic Ocean. It has a capacity of 3,000 to 9,000 telephone circuits depending upon antenna configuration, or 12 television channels, or certain combinations of telephone, television, data and other forms of communications traffic. The Intelsat IV series will augment the global circuit capacity now provided by Intelsat III satellites in the Atlantic, Pacific and Indian Ocean basins.

Access to the Intelsat satellites increased as the result of the construction of nine new antennas during 1971. It is estimated that at the end of 1971 there will be 62 antennas at 51 ground stations in 38 countries.

Worldwide usage of the Intelsat system was stimulated during 1971 by a 25% reduction on the first of January of the charge for full-time and occasional use (except television) of an Intelsat circuit. A further reduction of at least 13% is planned to go into effect January 1, 1972. The total number of full-time circuits using Intelsat satellites at the end of October

represented an increase of 38% over those in use at the end of October 1970.

The World Administrative Radio Conference for Space Telecommunications (WARC-ST) was held at Geneva in June and July under the auspices of the International Telecommunication Union (ITU), to revise the International Radio Regulations as they apply to space telecommunications. The new provisions, which take into account recent and anticipated technological advances, will come into force on January 1, 1973, superseding those adopted in 1963.

The US objectives in the Conference were, in general, either achieved or acceptable compromises were worked out. While broadcasting satellites proved to be the most contentious issue of the Conference, in the end, besides adopting radio frequency allocations for broadcasting satellites, the Conference passed a resolution calling for a World and/or Regional Broadcasting Satellite Planning Conference. Technical coordination procedures were also adopted permitting the establishment of such satellites until that Conference is held, which will probably not be until 1975 at the earliest.

New provisions were also established in respect to other space telecommunication requirements, such as additional frequency allocations for communication satellites, space research, and radio astronomy; new allocations for earth exploration satellites; and new procedures for the coordination and use of radio frequencies and the geostationary orbit.

**Apollo Program Support.**—The Department and its posts overseas continued their support during 1971 of the Apollo program by arranging for basing of recovery, tracking and other support forces at foreign installations for Apollo 14 and 15 missions. Apollo contingency recovery procedures in the event of an emergency landing were also again activated for the two missions.

Facilities of the Department and its overseas posts continued to support NASA's lunar samples investigation program by transporting and handling lunar samples consigned to foreign scientists for experiments and lunar material being returned to NASA after completion of analysis abroad.

**Aeronautical Service Satellites.**—Exploratory meetings were held during 1971 between the United States, and member countries of the European Space Research Organization (ESRO), and Australia, Canada, Ireland, Japan, the Philippines and Portugal to consider an experimental program to test the feasibility of using aeronautical satellites for air traffic control and related civil aviation purposes in the Atlantic and Pacific Ocean basins. Because air traffic control technologies and procedures must be integrated and coordinated on a global basis to ensure the safety of life and property, a major objective of the United States in these meetings has been to establish the basis for a program with

broad international participation in the pre-operational test and evaluation. Such participation would facilitate the emergence and widespread acceptance of standards for use of aeronautical satellites beyond the experimental period.

**Earth Resources Survey Programs.**—As part of our pledge to the United Nations, the Department of State co-sponsored with other US government agencies a ten-day workshop on remote sensing at the University of Michigan Ann Arbor campus in May. The workshop was designed to meet in particular the needs of the small countries. Invitations to the workshop were extended through the offices of the United Nations, with representatives from forty foreign countries and sixteen international organizations attending the sessions.

The US was also represented at a seminar on remote sensing held in November in Ankara, Turkey, under the auspices of the Central Treaty Organization (CENTO).

In addition to the bilateral agreement with Canada on remote sensing from aircraft and satellites, reported above, the agreement with Brazil on earth resources survey projects was extended for an additional two years in February. Extension of a similar bilateral with Mexico was being considered at year's end with a formal extension expected early in 1972.

**Technology Transfer.**—The Department of State's Office of Munitions Control continued its efforts aimed at reducing the number of space-related items covered by export controls in the International Traffic in Arms Regulations. The increased number of license requests processed by the Office of Munitions Control in 1971 for export of space-related hardware and technology to foreign space programs included technical assistance and equipment for the Japanese Launch Vehicle and Satellite Development Program, the NASA-German Helios satellite, the United Kingdom Defense Communication Satellite (Skynet II), and most recently the NATO Satellite Communications (Phase III) System. In addition, during 1971 an increasing number of applications for technical cooperation between foreign industry and US industry were processed in conjunction with studies on post-Apollo programs, including the proposed Space Transportation System program.

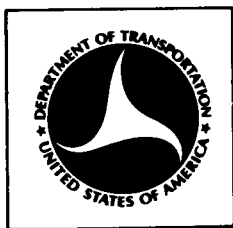
**Cooperation With the Department of Defense.**—The Department of State continued to work closely with the Department of Defense throughout 1971 on military related space activities having international implications. Improvements in the NATO Satellite Communications System continued with earth terminals in Belgium, Italy, and Germany having conducted satellite communications tests during the year. The terminal at Norfolk, Virginia is now scheduled to be operational

in February 1972. The NATO Satellite Communications (Phase II) System is expected to be operational by mid-1972.

Cooperation with the United Kingdom on the development of the Skynet space communication system continued throughout the year. Despite the malfunction

of some components shortly after launch in 1970, the back-up Skynet I satellite remains operational. Work on the design and construction of the second generation Skynet satellite proceeded normally during the past year with the initial Skynet II launch planned for mid-1973.

VII



## Department of Transportation

### Introduction

During the past year the Department of Transportation made considerable progress in its research programs relating to operations and utilization of techniques and hardware generated by the aeronautics and space activities. There are notable successes and one significant disappointment. A major advantage derived from the establishment of the Department is evident from the manner in which research and engineering activities sponsored, coordinated and conducted by the various elements of the Department are combined in an effective effort toward solution of transportation problems. The great disappointment was the cancellation of the U.S. SST program which is considered a major setback in aeronautical development progress.

Within the Department, the Assistant Secretary for Systems Development and Technology has the function of leading the research and development efforts of all DOT elements in addition to conducting a research program under his own direction. A Research and Development Management Council, established last year to facilitate the coordination efforts between the organizational elements of DOT, continued its role to assure that the intermodal aspects of any research project are fully considered, that no unnecessary duplication exists, and that effective utilization is made of the Transportation Systems Center and other departmental research and development facilities.

Through such mechanisms, and by bringing the Secretary's broader perspective to bear on the Department's research and development budgets, significant improvements are underway in the management of all of DOT's research and development effort, including aeronautical R&D.

The Civil Aviation Research and Development Policy Study (CARD) mentioned in last year's re-

port, sponsored jointly by the Office of the Secretary of Transportation, the National Aeronautics and Space Administration and the Federal Aviation Administration was completed in March 1971 and has been characterized as the most comprehensive, in-house interagency aviation activity that has been undertaken in recent years. The study was collaborated in and supported by the DOD, as well as by the CAB. Industry, academia, and local government organizations participated by both direct involved contribution and by top management advice.

In the 25 years since the end of World War II, the growth of the air transport system has been spectacular, and has had a major impact on the way of life in the United States. This rapid growth has generated major problems which restrain continued increases in commercial aviation. Allowing constraints to continue would not only result in a deterioration in service to the public, but would limit the potential growth of the economy and even the freedom of choice.

The problems that have beset the air transportation industry are not exclusive to that mode. One of the earliest of the systematic studies to develop solutions for the new decade was the Northeast Corridor Transportation Project (NECTP), which in essence, focused upon implementation and current technology. It considered the near-term opportunities for new technical applications during the period between now and 1976 and utilization for the rest of the decade. The CARD Policy Study focused on development and particularly on new technical developments which could be achieved and implemented by the mid-70's or beyond. Therefore, the conclusions of the NECTP Report emphasized implementation in the near-term transportation technology and identified new options to be evaluated.

Both studies concluded that substantial effort was required in the air and ground systems to improve the

environmental quality of the transportation, to relieve congestion, and to improve short-haul efficiency. There were new aerospace technology applications identified. As a clear example of the commonness of purpose, in the area of access and egress to an airport, the desirability of implementing high-speed ground service between a major center's central business district and an airport serving long-haul operations was emphasized by the CARD Policy Study. Such a system is certainly compatible with the recommendations of the NECTP, whether it is an ancillary service provided by a high density corridor operation or the local service provided by a metropolitan district.

Basic recommendations of the CARD Policy Study include:

**Noise Abatement.**—Because the problem is severe, noise abatement has been identified as the highest priority for aeronautical research and development. The research programs are addressed at the reduction of noise at the source, the optimization of aircraft flight path in terms of noise abatement, and identification of compatible land use in the vicinity of airports.

**Air Pollution.**—Although aviation has not been the major contributor to air pollution, as the number of aircraft increases and the quantity of pollutants contributed from other sources is curbed, aviation must minimize the amount of pollutants emitted. Improved aviation fuels and engines will consider pollutant emissions a fundamental design parameter.

**Congestion.**—Congestion at various points in the air transportation system is a complex problem and has several elements. Congestion in the terminal air traffic control and air navigation system has caused quotas to be placed on air traffic activity at major terminals. Planned near-term development efforts, and long-term R&D efforts will produce a high capacity air traffic control system. Terminal congestion is usually expressed in terms of aircraft in the holding pattern, or aircraft awaiting takeoff. Airport congestion arises in the process of movement of goods and services within the airport, as well as in access to the airport and in the efficient processing of passengers, cargo, and baggage.

**Low-Density Short-Haul.**—The CARD Policy Study concluded that while noise and congestion constitute a most urgent problem, solutions to the problem of low-density short-haul, or regional service are important to the future growth of civil aviation and can play a major role in satisfying the national goal of balanced economic growth.

**Other R&D Requirements.**—The long-haul market has been the backbone of the air transport system. A continued effort in advancing the technology of effi-

cient operations is required in order to maintain a growing productivity for commercial aircraft.

**Regulatory Actions.**—The CARD report suggested that the government examine its regulatory role in several areas to be sure that current regulatory policies are not inhibiting innovation by industry.

**System-wide Actions.**—It was recognized that most development activities have been oriented almost entirely toward the physical sciences technologies. It is in the national interest to devise a set of indicators which can provide assessment of social impacts resulting from changes in service.

A joint DOT/NASA CARD policy implementation group was formed to develop a plan for implementing the recommendations of the Study. A draft of the plan was completed.

Increased emphasis has been added to the FAA's airport development and system engineering and development activities. This effort has been supported by a rapidly increasing capability at the Transportation System Center (TSC) in Cambridge, Massachusetts. This organization is taking the lead responsibility for the long-range development program leading to a very high capacity traffic control system and several aerospace-related new activities. The Office of the Secretary is also assuring an integrated effort of the Federal Railroad Administration, Federal Highway Administration and the Urban Mass Transport Administration in support of aviation interests. These activities utilized much aerospace developed technology in the form of control mechanisms, data processing, sensors and vehicle systems.

Although the SST prototype development effort was terminated as a result of Congressional action in March 1971, certain key technology efforts were continued. These advanced technology projects were identified by a multi-agency review panel and represented carefully selected R&D projects. The Department recommended that they should be completed and documented to make the technology available in useful form to current and future air transportation designers. Passage of enabling legislation by Congress late in the year has assured the continuation of this vital effort.

**Regulation and Noise Abatement.**—Accomplishments were made toward the completion and implementation of a noise certification regulation for all civil aircraft. Benefits accrued to residents near airports as the new civil transports were certified, meeting the new stringent Part 36 noise regulations. In addition, new regulations are being developed for existing aircraft, for supersonic aircraft, and for other special category aircraft. Demonstration programs have been initiated for the development of hardware to help sup-

press existing jet engine noise. Contracts have been awarded and flight tests will be conducted next year. A joint DOT/NASA noise abatement function has been established to provide overall leadership and to act as a focal point for a national program to solve the noise problems associated with current and planned transportation systems.

Environmental planning guides for airports have been prepared and several areas of legislation have been developed.

**Aviation Safety—En Route Operations.**—The following program areas typify efforts during the year by the Federal Aviation Administration to reduce or eliminate in-flight hazards:

(a) *Wake turbulence.*—The program to reduce this hazard continued during the year and its progress included: (1) Completion of several milestones on laboratory testing using laser and acoustic devices; (2) beginning of field testing of two related but not identical acoustic devices, and initiation of a scale study of airport environment modification.

(b) *Aircraft piracy and sabotage.*—A new weapon-detecting magnetometer and computer were installed and tested at Washington's Dulles International Airport to screen passengers and luggage before boarding of the aircraft. Work was also continued on a concealed-weapon detector using X-rays, which thus far has been unacceptable on two counts—high radiation emission and poor image quality.

(c) *Midair-collision avoidance.*—Efforts continued in the two basic areas of this problem, the collision-avoidance systems (CAS) and the pilot-warning indicator (PWI). This included reviewing preliminary specifications for a family of PWI's, conducting detailed flight testing, and establishing separation criteria. In the CAS area, efforts have been concentrated on evaluating collision-avoidance systems developed by private industry.

(d) *Head-up display.*—Work continued on the problem of pilots flying VFR (visual flight rules) who sometimes lose visual reference and the ability to orient themselves. During the year, two types of simple head-up displays were tested. Additional tests are required before system certification can be made.

**Takeoff and Landing Operations.**—Efforts to reduce hazards attending these phases of flying were directed notably to the following:

(a) *Wet-runway stopping distance.*—A series of wet- and dry-runway tests were conducted to obtain better information on which to base runway-length requirements for airplanes on wet runways. Variable-slip runway friction tester and

an instrumented nonflying test aircraft were used. Further studies will be conducted before standards may be issued.

(b) *Fog dispersal.*—Fog, like other adverse weather conditions, can result in flight delays and reduce airline revenues. A study was completed which determined the effects of airport terrain features on the design and cost of thermal fog dispersal systems. The conclusion reached was that no cost-benefit analysis pertaining to installation of a thermal fog dispersal system can be relied on unless specific terrain effects are taken into consideration. Two major programs were initiated to evaluate such installations in a systematic way.

**Post Crash Safety.**—Significant results were obtained in the following areas:

(a) *Gelled fuels.*—Effort in testing gelled fuels to reduce post crash fire hazards continued. Results have shown that a number of gelled fuels have excellent fire-reducing qualities, but the high viscosity of these fuels makes them incompatible with the fuel systems of modern jets. This incompatibility between gelled fuel and jet fuel systems has been evaluated and it has been determined that several gels represent the best compromise between fire-reducing ability and fuel-system compatibility. Further extensive tests are planned.

(b) *Crashworthiness of general aviation aircraft.*—Statistics show the survival rate for passengers in automobile crashes to be much greater than the rate for passengers in crashes of general aviation aircraft involving G-forces in the same range. The conclusions of a study by the Civil Aeromedical Institute showed that the crash safety design in light aircraft had fallen far behind that for equivalent automobile accidents. Many aircraft were found to have rigid instrument panels studded with heavy instruments, protruding knobs, and sharp edges, and lack adequate restraint equipment and slow-return padding on instrument panels. Fatal or serious head injuries were inflicted during airplane crash decelerations as low as 3 or 4 G's, whereas a single square inch of human forehead can withstand 80 G's without fracture if the force is evenly distributed over the area impacted.

### Air Traffic Control

**Upgraded Third Generation Air Traffic Control System.**—A technical Development Plan for the Discrete Address Beacon System (DABS) has been developed and a contract effort is being prepared. The DABS systems constitutes an element in the upgraded Third Generation ATC. Increased automation in data proc-

essing and display being the primary functional improvements.

**Microwave instrument landing system.**—A national plan for the development of new microwave-scanning-beam instrument landing system (ILS) for civil-military common use was published and implemented. This is the system recommended earlier by DOT's Air Traffic Control Advisory Committee, and by a special committee of the Radio Technical Commission for Aeronautics.

**Fourth Generation Air Traffic Control System.**—Draft reports of two in-depth technical studies, including conclusions and recommendations, were completed and submitted for DOT review. These reports are major milestones in a program of concept formulation and system definition to systematically arrive at a substantially higher capacity air traffic control system.

### Navigation and Communication

**Aeronautical Satellite Policy.**—On January 7, 1971, the Office of Telecommunications Policy of the Executive Office of the President issued a Statement of Governmental Policy on Satellite Communications for International Civil Aviation Operations which designated DOT/FAA as the lead management agency. It recommended the implementation of a preoperational capability for test and evaluation in both the Pacific and Atlantic ocean areas. It also stated that the Government should utilize commercial telecommunication facilities and services to the maximum extent feasible in both preoperational and operational systems. There is general agreement that an operational system will be required in both the Atlantic and the Pacific by 1980; therefore, the policy statement directed that a preoperational capability be established in a timely fashion. The proposed satellite system, which would employ an ultra-high-frequency (UHF) band of near 1,600 megahertz (one MHz is a million cycles per second), would provide the increased communications capability necessary in view of the increase in air traffic projected by 1980. Extensive activity has been expended in exploration and definition of a feasible basis for international cooperation to provide the needed oceanic preoperational capability.

**Area Navigation.**—Four transcontinental high altitude area navigation routes were established in April between New York City and Los Angeles and Oakland, California. These four transcontinental routes, forerunners of a nationwide area navigation network,

constitute the first major expansion of the airway system since the introduction of omnidirectional navigational radio transmitters in the early 1950's and permits new flight paths to be established without deployment of ground-based navigation aids along each path. Approximately 89 high-altitude area navigation route segments are now available for use.

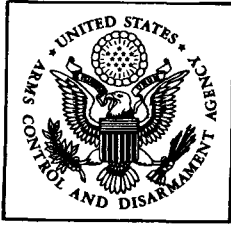
### Applications of Space Technology

The U.S. Coast Guard continued the development and application of space technology suitable to the operational needs of the maritime community. Primary emphasis has focused on the use of communication satellites for relay of safety and operational messages, including position determination for vessels at sea. A long series of experiments in these areas continues, using satellites from the National Aeronautics and Space Administration (NASA) Applications Technology Satellites (ATS) series.

The Coast Guard, the President's Office of Telecommunications Policy (OTP) and the Maritime Administration, contracted for a special analytical study to examine technical criteria and frequency requirements for a maritime satellite system to serve the needs of world shipping. Data from this study were used heavily in the United States' preparation for the World Administrative Radio Conference for Space Telecommunications (WARC-ST). The study provides vital planning documentation for future efforts.

Efforts were continued to attempt to find a reliable method of automatically locating and identifying the position of vehicles in distress at sea. It has been concluded that satellite relay of this information offers the potential of worldwide satisfaction of the requirement. A frequency allocation for this purpose has been proposed by the United States at the WARC-ST with approval of all the participating nations. A developmental effort was initiated in coordination with NASA and the Navy Department, leading to an operational system.

In order to facilitate international experience in maritime satellite techniques, the Coast Guard loaned sets of shipboard satellite communications terminals to The Netherlands and England. These were installed on merchant vessels of those countries, which then conducted extensive experiments using the ATS satellites. Much of their work necessarily duplicated results achieved in earlier U.S. tests, but new information was obtained on modulation methods and reliability of selective signalling.



## Arms Control and Disarmament Agency

### Introduction

The Arms Control and Disarmament Agency continues to have a strong interest in space programs, both international and national. The Agency maintains an active research effort on arms control aspects of international space programs, participates in preparing U.S. positions on international space policy issues and joins with other agencies in formulating and implementing bilateral and multilateral space agreements. In such activities the Agency seeks to direct space programs toward peaceful rather than military goals. Regarding U.S. national space activities, ACDA continues to study the capabilities of existing and potential satellite-borne sensors for verifying arms control agreements. An example of the use of such sensors is provided by the DOD's VELA satellites that currently monitor compliance with the Limited Test Ban Treaty. In addition, ACDA is interested in the use of satellite communication systems to reduce the risk of war by providing secure, reliable communications channels between nations for use in potential crises. The improved "hot line" agreement, negotiated at SALT and signed in Washington on September 30, 1971, provides for such channels between the U.S. and the USSR.

**International Space Programs.**—Space programs in many countries can provide prestigious outlets for national ambitions that might otherwise be channeled into the development of sophisticated weapon systems. These programs focus national energies on peaceful rather than military uses of space. When carried out on a multilateral basis, such programs also set precedents for effective cooperation between nations in other constructive endeavors. In this way they materially improve the climate for dealing with arms control issues and other problems on an international basis.

The type of rocket system that a nation employs to launch satellites is often adaptable to a ballistic missile configuration. ACDA has studied this problem for some time and believes that, under certain conditions, this risk can be minimized through cooperative efforts

with particular attention to hardware design and application control. Along with other US government agencies, ACDA takes an active interest in implementing international space cooperation in a creative way, seeking to minimize the proliferation of missile technology while considering the legitimate needs of other nations as they develop space launch vehicles and satellites.

**The Outer Space Treaty.**—The Outer Space Treaty serves three major purposes. First, it seeks to ensure that space exploration and development will be carried out in accordance with international law and for peaceful purposes only. By banning the emplacement of "weapons of mass destruction" in space, on celestial bodies or in earth orbit, it closes off the largest of man's new environments to the strategic arms race. Second, the treaty establishes a desirable precedent for generality in arms control agreements by banning all such weapons, not just nuclear weapons. Along with the Antarctica Treaty and the Seabed Arms Control Treaty it has provided impetus for closing off other frontiers on earth to the arms race. Third, the treaty has contributed to steadily increasing confidence among nations that the arms race can be controlled. The spirit of optimism and dedication that underlies SALT and other current arms control negotiations can be traced in part to the success of earlier negotiations that produced agreements such as the outer space treaty.

In 1971, the Federal Republic of Germany and Greece both ratified the outer space treaty, bringing to 64 the number of states that are parties to the treaty.

**The Improved "Hot Line" Agreement.**—The improved "hot line" agreement, on which negotiation was concluded at SALT in 1971, is intended to help preserve stability in possible future crises. Under the agreement, satellite communications systems will allow the U.S. and Soviet governments to communicate directly without depending on radio relays or land lines in other countries.



### Introduction

The Department of the Interior is responsible for the management of the nation's natural and cultural resources. In order to meet this responsibility the Department utilizes aircraft operationally and in research projects. It is also actively involved in space operations and research through its Earth Resources Observation Systems program and through the support of several Bureaus to lunar exploration and Martian mapping. International cooperation in aerospace activities exists both in departmental operations, primarily in support of treaty commitments, and in departmental research programs.

### Aeronautics

**Operations.**—The Bureaus of the Department made the following operational use of aircraft during 1971:

The Bonneville Power Administration operated their own helicopter and fixed-wing aircraft, for aerial reconnaissance, site location, and maintenance of transmission lines, and for transportation of personnel to remote sites. Contract aircraft were used in a cooperative program with the Bureau of Reclamation to maintain remote controlled and cloud seeding equipment in a network in the Hungry Horse Basin, Montana.

The Bureau of Indian Affairs used government-owned and contract aircraft for obtaining aerial photography and for visual observation in wildlife management research and operations as well as for forest insect detection and control. Mineral surveys and evaluation of road and highway design and construction were also accomplished with use of aerial photography.

The Bureau of Land Management continued to operate its own helicopters and fixed-wing aircraft as well as those of private contractors for forest fire control, cadastral surveys, seeding of storm clouds to induce rainfall over newly formed forest fires primarily in Alaska, for forest and soils inventory work, and to locate hot spots in the heavy smoke of forest fires using an infrared scanner. High-altitude aerial photography was obtained for both forest inventory work and for the preparation of managerial photomaps. Photography already obtained represents approximately the first 1 percent of what is to be complete coverage of the public domain in the conterminous U.S.

The Bureau of Mines utilized both fixed-wing aircraft and helicopters for transport of supplies and personnel involved in the evaluation of mineral resources in wilderness and primitive areas, and for reconnaissance of rugged terrain. Aerial photography was used to monitor mine fire control operations and progress of surface mine reclamation projects.

The Bureau of Reclamation, as in the past, used aircraft and helicopters to transport control survey parties to remote areas; for inspection, construction, and repair of transmission lines and communication facilities; and for other project planning and operation activities. Contract aircraft continued to be used to obtain aerial photography for controlled mosaics to facilitate location of waterways, structures, and other features and to assist in project management and operation. Gross land characteristics, such as topography, drainage, soil, and vegetation, continue to be interpreted from aerial photography as basic information for water and land resource development planning.

The Bureau of Sport Fisheries and Wildlife maintains a fleet of about 40 small aircraft for use in its aerial wildlife surveys. The data gathered are for research and for the development of annual hunting regulations for those species over which the Federal Government has primary jurisdiction. These surveys are conducted in the appropriate seasons from the Arctic south through Mexico and from coast to coast. Another use of the Bureau's aircraft is to aid in the enforcement of Federal game laws.

The Geological Survey used aircraft to acquire standard mapping photography for more than 205,000 square miles and high-altitude photography of approximately 16,000 square miles of the conterminous U.S. for the national topographic mapping program. The U.S. Air Force USQ-28 system in operation over Alaska obtained additionally approximately 20,000 square miles of aerial photography, which is being evaluated for its usefulness to the mapping program. The Geological Survey operated aircraft on loan from other U.S. agencies and its own aircraft, both equipped with a variety of remote sensors, to monitor oil spills and seepages, to conduct photo and other sensor reconnaissance of proposed reservoir and damsites, to determine previous hydrologic conditions at archeological sites, to conduct water sampling, wetland delineation, and water circulation studies of bays, for algae and



phreatophyte studies, and for snowpack studies. Aircraft were also used in 1971 for environmental impact studies of the proposed Alaskan pipeline. Both fixed-wing aircraft and helicopters were used in support of geological and geophysical research in reconnaissance geologic mapping, appraisal of mineral resources, and evaluation of wilderness areas. Many of the studies were conducted using one or a combination of the following—aeromagnetic, electric, gamma ray, infrared, aerial photography, and geochemical (mercury) instrumentation. Aircraft continued to be used in the management of Federal Outer Continental Shelf mineral resources, mostly in the Gulf of Mexico, for transportation of personnel to operation sites, for inspection purposes, and for locating and monitoring sources of oil spills.

**Research.**—Research is conducted to improve techniques and develop new methods for fulfilling the Department's mission of natural and cultural resources management. The following are Bureau research projects in which aircraft have been used.

The Bureau of Reclamation project in atmospheric water resources research is using aircraft as platforms for cloud seeding and for collection and relay of meteorological and hydrological data. To augment research capabilities, the Bureau has obtained a set of four cameras for use in aircraft, balloons, and on the surface for acquiring multispectral imagery on 70mm film.

The Geological Survey developed a surface sampling technique from a light aircraft for reconnaissance geologic studies. A study of Yellowstone National Park was completed to identify cool-water aquifers that may be suitable for potable water in park expansion, through use of thermal imagery, radiometric studies, and interpretation of snow melt patterns, readily identified on aerial photography.

The Office of Water Resources Research funded research in several subject areas: to develop a broad spectrum microwave system for remote measurement of soil moisture; to determine applicability of remote-sensing techniques for monitoring the quality of lake water; to test the ability to map land use categories by airborne multispectral sensing using the technique of spectrum matching; to investigate the values of thermal mapping and aerial multispectral photography to identify flow patterns and transverse differences in water quality of lakes and streams; to conduct radar investigations of summertime land and lake rainfall variations over Lake Michigan; and to appraise aeromagnetics, microwave reflectivity, multispectral photography, and other remote-sensing techniques for measuring ground-water resources.

The National Park Service has undertaken to correlate high-altitude photography of Cape Lookout National Seashore with lower altitude photography

and ground observations in order to study shoreline processes and to relate the present nature of these barriers to the conditions described in historical records. This is part of a larger study of the east coast barrier islands, the purpose of which is to establish management objectives for all National Park holdings within this environment. Analysis of the spectral reflectance of shade tree leaves in the urban environment is continuing with one emphasis of this study being the detection of diseased shade trees using remote-sensing techniques.

## Space

**Research.**—EROS (Earth Resources Observation Systems) is the Department of the Interior program to acquire, process, utilize, and disseminate remote-sensor data collected from aircraft and spacecraft of natural and manmade features of the Earth. It works directly with NASA to coordinate and develop Interior Department programs in research of the applications of aircraft and spacecraft as platforms for observations, and of remote sensors as information gathering devices to support resources mapping, evaluation, and management.

The EROS Program has initiated Regional Ecological Test Sites in Arizona (ARETS) and in the Central Atlantic (CARETS) area to consolidate research efforts designed to test and evaluate air and spaceborne remote-sensor methods and their application to environmental and resource problems such as the relationships between changing land use and its environmental impact. The projects are open to Federal, State, and local organizations, universities, and resource industries willing to participate in the free exchange of information, and contribute their findings to comprehensive project reports. A similar effort is being made in the Pacific where several Bureaus of the Department have identified their information requirements, collection of multiband photography is underway by Naval aircraft, and training and data collection centers have been established.

In the process of developing useful applications of space remote-sensing systems, the Department, through the EROS Program, submitted 68 Earth Resources Technology Satellite (ERTS) experiment proposals, 16 of which have been accepted and 29 of which are still to be negotiated. There were 24 Skylab experiment proposals submitted by the Department, of which 8 have been accepted. The proposals reflect the wide range of interests within the Department and should be very helpful in evaluating the usefulness of satellite data to Department functions.

The EROS Data Center began operations at an interim facility in Sioux Falls, South Dakota, in October 1971. The Center is to provide access to ERTS imagery for the general public, industry, educational institutions, and foreign and domestic government

agencies at all levels. In addition to the ERTS imagery, the Center also holds NASA aircraft imagery and photography, and current Geological Survey aerial photography.

Under the aegis of the EROS Program and in cooperation with NASA the Department is conducting research on the development and evaluation of new techniques to specific departmental applications, and for the development of new instruments and equipment. Aircraft are used as data gathering platforms for this research that is contributing to the understanding of the potential of space-acquired data and has led to the ERTS experiment. Such departmental research for 1971 has been as follows:

The Bonneville Power Administration is a participant with the Bureau of Reclamation, and the Geological Survey in a contract research program to develop techniques for determining estimates of precipitation from meteorological satellite images and to apply this information to the operation of hydroelectric systems.

The Bureau of Indian Affairs is conducting a study of the use of remote sensing in making a soil and range inventory of Indian lands in South Dakota using aerial multispectral imagery. These inventories are to be used to help make land management decisions. The Bureau has completed a comparative study of the use of Apollo 9, multispectral high-altitude, and low-altitude photography and aeromagnetism in mineral resource evaluation of the Papago Indian Reservation. The study correlates the space and high-altitude photography to mineral exploration and to location of mineralized zones which might contain economic ore deposits. The economic potential of a circular structure on the San Carlos Indian Reservation, first identified from an Apollo 9 photograph, continued to be studied by the Geological Survey at the request of the Bureau.

The Bureau of Indian Affairs and the Bureau of Land Management contracted for the design of a Natural Resources Information System to store, process, and display a variety of natural resources and land use data in both graphic and tabular form. Emphasis is placed upon the use of air and space-acquired remote-sensing data as the main input to the system. A demonstration of the system will be performed utilizing data from southeastern Arizona.

The Bureau of Land Management used infrared imagery together with conventional aerial photography in a research project to determine the feasibility of using such imagery for cadastral surveys in heavily wooded areas.

The Bureau of Mines is conducting research into the use of various types of photography, thermal infrared imagery, and side-looking radar imagery together with surface and subsurface data to guide well placement in oilfields to attain maximum oil and gas

recovery, to aid in the selection of natural gas storage sites, and to assist in the detection of potential for roof falls in coal mine fields. Aerial infrared imagery is being used in an investigation of both burning areas and moisture concentrations within coal refuse banks in the Anthracite Region to develop heat flow equations and to generate models of each burning area, and to update statistics on burning refuse banks there and in part of the bituminous coal mining area in Pennsylvania. The Bureau of Mines is also investigating the possibility of detecting underground fires in coal beds and abandoned mines with high-altitude aerial and satellite multispectral photography, by identifying a unique spectral signature of effected flora. The Bureau studied space and high-altitude photography of the Twin Buttes, Arizona, copper mining district and continues to study high-altitude photography of Black Mesa in Arizona to assess the potential of satellite photography as an aid in solid waste inventory, in monitoring progress of strip mining and evaluating its impact on the semi-arid environment, and in evaluation of reclamation measures. Research was begun in 1971 on applications of remote-sensing techniques for monitoring and inventorying surface mining of coal in Appalachia and other eastern States, and two studies are in progress, one in Farmington, New Mexico, and the other in Pennsylvania, to investigate the utility of remote-sensing data and imagery for monitoring the environmental effects of air pollution discharged from large coal-fired electric powerplants.

The Bureau of Outdoor Recreation is evaluating various sensors and imagery interpretation techniques for their capability to generate essential recreation planning data at the required level of detail. A second project underway is evaluating aerial remote-sensing techniques for measuring use of outdoor recreation resources.

The Bureau of Reclamation is investigating the feasibility of using data from aircraft and satellite overflights to aid in the management of undesirable vegetation on Bureau water projects. A research project has been completed to develop techniques for using multispectral data from aircraft and satellites in detection of wetlands, ascertaining the severity of the wetness, and evaluating the effectiveness of subsurface drainage in irrigation regions affected by rising groundwater levels. The technique has only limited application on existing irrigated land, but shows more potential for detecting wet areas on undeveloped land or for detecting seepage from canals. The Bureau has undertaken the development of a monocylic radar system to measure the depth and water content of snowpack, currently from stationary and moving ground-based platforms, but with expected adaptability to aircraft.

The Bureau of Sports Fisheries and Wildlife is preparing for its participation in ERTS experiments in Alaska, Hawaii and the conterminous U.S. These in-

clude studies of: waterfowl production habitat in the northern United States and Canada; ice leads in bays and general hydrology of wetlands in Alaska; thermal sensing of the Porcupine caribou herd; spectral characteristics of arid lands vegetation in Arizona; and pollution of bays and infestations of the predacious starfish (*Acanthaster*) in Hawaii.

The Geological Survey produced an experimental photomap of the Phoenix quadrangle with the published conventional line map on one side and space photo-image on the reverse side; a photomap covering the Atlanta, Ga., quadrangle from Apollo 9 photography, reproduced photographically in various color tones; and photo-image maps of the Mesa, Arizona, area from very high altitude aerial photographs taken by U-2 aircraft. Tests and studies were conducted on the resolution of space and aerial photographic systems, and on characteristics of precision mapping photographs using various film and filter combinations. A universal thematic mapping system is being developed and currently involves experimentation on the automatic extraction of the distribution of snow, open water, vegetation, and the massed works of man. Basic data for this system will come from all types of remote sensors carried on both space and aircraft platforms. A space photograph simulation program has been produced that mathematically simulates different camera systems in different orbits and evaluates the photographs as maps on four different projections. In addition, a data bank of photoidentifiable ground images is being compiled to relate ERTS and other space imagery to a specified map projection. The EROS Program is cooperating with NASA and RCA in a geometric calibration of the Return Beam Vidicon system for ERTS. Calibration is essential for register and cartographic referencing of photo-image data and is required by the NASA Data Processing Facility. The Geological Survey is investigating distortion patterns and methods of applying corrections to RBV systems.

Preparation of ground and satellite data relay systems for use in the ERTS experiments is underway, including successful testing of a seismic event counter and borehole tiltmeter; the existing Water Resources stream gaging network is available for integration into the system. Relay of temperature data from thermal probes installed in steam vents near the summit of Mt. Rainier has been performed via the Nimbus satellite.

In continuing research to develop ecological prediction models for a given hydrologic condition a mosaic of three, high-altitude, near-infrared photographs of the Shark River Slough in Everglades National Park was prepared. This work revealed the presence of a previously unknown hydraulic flow barrier and an area of ground-water upwelling in the Slough. Continuing research in data processing of multispectral, optical-mechanical scanner data demonstrated the feasibility of delineating benthic and on-shore vegetation species

in Biscayne Bay and of detecting some contamination effects on vegetation along the Alafia and Peace Rivers. Film density analysis of aerial photography of the karst terrain near Tampa revealed lineations believed to reflect fracture zones related to underground water flow. A study is underway to determine the source, movement, and fate of sediment and other pollutants discharging into Long Island Sound using high-altitude aircraft data obtained over the northern part of the Sound by NASA. An investigation is being made of the application of computer-processed thermal infrared scanner data to the determination of the thermal regime of a reach of the Missouri River. A study on the Sabine estuarine system indicated film and filter preferences for enhancement of certain industrial wastes and indicated the importance of the background water effects in pollution detection. And a study of the Raritan River attempted to identify a known exothermic reaction of industrial effluents by use of thermal imagery. Although the exothermic reaction was not evident, the thermal patterns of industrial wastes could be identified. Aerial photography was used to provide surficial thermal information on Barnegat Bay prior to the operation of a nuclear powerplant, and shortly after the plant became operational. A research project in South Dakota is being conducted to determine by analysis of vegetation cover and condition the availability of soil moisture. The relationship of surficial thermal patterns to identification of shallow aquifers is also being investigated. These projects are utilizing aircraft-acquired data in the development of techniques leading to better water resources management. High- and low-altitude photography over sites in the Great Plains, Lake Ontario, southern Florida, Long Island Sound, and the regional ecological test sites were obtained for simulation studies of ERTS. These data provide a means of calibration of the forthcoming data from space.

The Geological Survey in cooperation with the University of Michigan and the Air Force Cambridge Research Laboratories completed a thermographic mosaic for most of Yellowstone National Park which depicts the thermal characteristics of a large area and the relationship of active geothermal phenomena to topographic, hydrologic, and other geologic features.

An airborne scanning technique was used successfully to permit selective imaging of quartz sand and quartz sandstone versus dolomitic limestone. A study of thermal contrast on infrared imagery of limestone, dolomite, and granite showed image density to have good agreement with values predicted from mathematical models of such rock properties as thermal inertia, albedo, and emissivity. An analysis of satellite photographs of the southwestern U.S. revealed striking parallelism between major fracture trends and adjoining boundaries of the copper belt.

The Geographic Applications Program of the Geological Survey focused its major efforts on the use of aircraft and satellite-acquired data in the development of land use information systems and environmental changes which are national or regional in scope, thus providing the overview of national conditions and the means of integrating the results of state and local studies that differ in date, scale, category of information and objectives. Pilot studies are being carried out to develop cost effective techniques for mapping and computerizing data pertaining to land use changes. In 1971, efforts were concentrated on Washington, D.C., Boston, Phoenix, San Francisco, and the surrounding regions.

The National Park Service investigation of archeological sites in the southwest using infrared photography is continuing.

The Office of Saline Water-NASA sponsored research on porous glass for recovery of potable water from urine was discontinued when it became evident to OSW that there were more promising approaches than reverse osmosis. However, development of systems for wash water recovery was continued. At present there is a joint NASA-OSW research program on the development of new reverse osmosis membranes capable of renovating wash water in a space vehicle. The key requirement of the membranes is the capability of rejecting components of wash water (detergent, lactic acid, sodium chloride, etc.) at a sterilization temperature of 165°F for an extended period of time. Membranes which have shown promise for this application are a cross-linked cellulose acetate methacrylate and a polyphenylene oxide sulfonate.

**Operations.**—Investigations were made in Bureau of Mines Research Centers on the utilization of lunar resources. Simulated lunar materials were tested in simulated lunar environments to develop systems and methods of utilization of extra-terrestrial resources on future space missions. The Bureau also made infrared and Raman spectroscopy analyses of moon rock samples from Apollo Missions 11, 12, and 14. This research seeks to determine mineral and chemical properties of lunar samples.

The Geological Survey provided support to NASA in the form of astronaut training, mission planning, and post-mission analysis for the Apollo 14 and 15 missions. Geologic mapping of the frontside of the moon culminated in publication of a summary map at a scale of 1:5,000,000. Additional geologic mapping of the moon concentrated on the limbs and farside and made use of photography taken by the orbiting Apollo spacecraft. The first geologic maps of Mars were constructed from Mariner 6 and 7 photography and analysis of photographs returned by Mariner 9 was started.

## International Cooperation

The EROS Program was a co-sponsor of the International Workshop on Earth Resources Survey Systems held in May 1971 to provide other nations with knowledge of the latest techniques for acquiring earth resources information by use of aerial and satellite remote-sensor systems. Tutorial papers on applications as well as papers on remote-sensing program concepts, organization, and operational aspects were presented by Departmental personnel. The workshop was attended by about 250 scientists from 40 nations and 16 international organizations. The EROS Program cooperated with the Central Treaty Organization in the presentation of a seminar, Application of Remote Sensors in the Determination of Natural Resources, in Ankara, Turkey, in November 1971, providing coordination and leadership in seminar planning. Turkey, Iran, Pakistan, and the U.S. participated. U.S. delegates presented papers describing aerial and space flight remote-sensing systems being developed to support resources exploration, evaluation and management functions. EROS and the Geological Survey are participating with Canada in the International Field Year for the Great Lakes (IFYGL) which is developing studies of lake meteorology, energy balance, terrestrial water balance, and water movement, using the Lake Ontario Basin as the test site. Intensive data collection is set for 1972 to coincide with ERTS-A and to utilize the potential of this data source. Current research by the Geological Survey involves analysis of infrared imagery and multispectral aerial photography in the study of the dynamics of heat plumes, delineation of ground-water discharge for inference of adjoining areas underlain by high-yielding underdeveloped aquifers; sedimentation dynamics; and application of ERTS analog data to limnological problems.

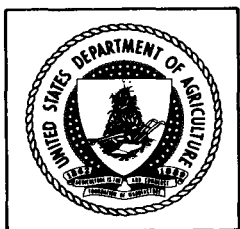
The Geological Survey is cooperating with the Government of Jamaica, the United Nations Development Programme, the Food and Agriculture Organization, and NASA to develop and demonstrate remote sensing for resources planning and development. Aerial imagery and photography were obtained during the summer of 1971 and Geological Survey hydrologists are assisting in the hydrogeologic interpretation of these data. As part of a UNESCO-sponsored study of the hydrogeology of the Canary Islands, aerial thermographic surveys were made by contract aircraft and interpreted by a consultant from the Geological Survey during 1971. Research into the usefulness of color infrared aerial photography in the identification of archeological sites was undertaken with permission of the Mexican National Institute of Anthropology and History and using NASA photography of Tehuacan Valley, Mexico. It was determined that visibility of sites depends primarily on their environmental situation and that the delineation of such environments and

microenvironments is especially easy with this type of film. The Geological Survey has provided advisory assistance to the Government of Brazil on the interpretation of Brazilian-acquired radar imagery and aeromagnetic surveys for their Amazon Basin development program and is cooperating with the Colombian Institute of Geological Mining Investigations in interpreting radar imagery as a major source for geologic mapping in a deep tropical environment.

In a cooperative geologic-geophysical-geographic mapping and minerals exploration program with the Republic of Liberia, fixed-wing aircraft and helicopters are providing the only feasible means of rapid regional geologic reconnaissance, ground checking of photo, magnetic, and radiometric data interpretation, and river-trail traverse field party support. Survey scientists and their Peruvian counterparts engaged in natural disaster reconstruction work are utilizing fixed-wing aircraft and helicopters in observing debris and geological effects of earthquakes. The Geological Survey carried out tests from fixed-wing aircraft over known copper deposits in Panama in the process of studying the use of infrared reflectance of vegetation in mineral

exploration. In cooperation with the U.S. Department of State and the Government of Saudi Arabia, airborne photographic and radiometric surveys were made in support of a geologic mapping program to aid in definition of the mineral resource base of Saudi Arabia. In addition, fixed-wing aircraft and helicopters were frequently used for logistic support of ground parties. With the Agency for International Development (AID) and the Government of Indonesia, a continuing study of the resource base of Indonesia is making use of a broad spectrum of aircraft-collected data, particularly photograph and magnetic surveys. Of particular interest has been a study of potential geothermal power sources in central Java. The Geological Survey is involved in joint planning with Brazil, Argentina, Mexico, and Peru in preparation for the use of ERTS data in geological interpretation and resource studies. Personnel also served on an AID-NASA investigational team in Mali to determine specific applications of ERTS data in the interpretation of geology, exploration for mineral and water resources, and better utilization of grasslands and areas of heavier vegetation cover.

X



## Department of Agriculture

### Introduction

Helping to establish sound public policies for the use of agricultural, forestry and wildland resources, as well as aiding farmers in the efficient conduct of their work, are primary responsibilities of the U.S. Department of Agriculture (USDA). To meet these responsibilities, the Department is constantly concerned with improving the efficiency of its activities concerning agricultural crops, soil surveys, watershed management, forests, range and wildlife management, land use management and classification, environmental protection, and outdoor recreation.

In 1971, as part of these efforts, USDA's Agricultural Research Service and Forest Service continued to collaborate with NASA in remote sensing research investigations. The Department also continued its preparation for the anticipated 1972 ERTS-A satellite program. Ten technical proposals for investigations to utilize data from the ERTS-A and Skylab satellites, were submitted to NASA for consideration as potential

experiments in its space flight investigations program. Among the proposals were experiments to utilize space-acquired data for potentially more comprehensive and timely collection of agriculture, forestry, and range data, and the dissemination of these data for rapid interpretation into meaningful information required by various components of the agricultural community. The Department also participated in an intensive simultaneous coordinated effort with NASA, and other Federal agencies, to evaluate and prioritize some 700 domestic and foreign ERTS-A and Skylab flight experiment proposals.

### Remote Sensing Activity

**Research and Development.**—The Department's objectives in developing remote sensing technology are to study, develop, and utilize the unique multispectral characteristics of aerospace-acquired data. These data will improve the use of agricultural, forestry, and range resources and will develop greater efficiency in the in-

ventory, protection, and management of these resources as a major part of man's critical environment.

The research is devoted to both software and hardware development, including updating the state-of-the-art, and developing systems and methods. This approach is made from ground, aerial, and space vehicles and makes use of multispectral photographic, multi-point scanner, and thermal infrared technology, as well as through various biophysical and biochemical techniques. Computer processing and analysis techniques are used to solve the data handling problems.

Such R&D approaches prove new capabilities for: (1) detecting and assessing disease, insect and weed infestation, salinity and moisture stress, drought, and fire; (2) assessing crop and timber stand vigor to predict yield; (3) determining soil characteristics; (4) identifying, mapping, and measuring agricultural, forestry, and rangeland use; and (5) assessing environmental and ecological conditions, and man-environmental interactions.

Advances made during 1971 include the following:

#### ***Agricultural Research Service:***

1. Development of a better understanding of the interaction of diffuse light with leaves, and the effect of variations in leaf structure on reflectance and transmittance.

2. Publication of the following: effective optical constants of field grown leaves over the range of 0.5 to 2.5 microns; a generalized plate model of leaves; and a 5-parameter system for specifying plant canopy reflectance. These are essential in predicting reflectance as sensed by aircraft or spacecraft.

3. Initiation of studies in crop species discrimination, utilizing film optical density differences.

4. Determination of the usefulness of aerial photography for ascertaining citrus fruit yield estimates.

5. Establishment of the feasibility of using aerial thermal scanner data for monitoring frost distribution and as a basis for scheduling crop irrigation.

6. Improvements in the estimates of parameters affecting watershed runoff.

7. Determination of space imagery usefulness to soil scientists in preparing county soil surveys.

#### ***Forest Service:***

1. Development of microdensitometer techniques for interpreting and quantifying aerial photography.

2. Establishment of the feasibility of utilizing space photography for classifying forest and non-forest land and for detecting forest disturbances.

3. Continuation of work in establishing the feasibility of employing imagery that is both low and high altitude and small and large scale to detect forest and wildland vegetation stress due to insects, pathogens, and other agents.

4. Development of a multi-stage probability sampling theory for single parameters, and its successful implementation in a pilot timber inventory covering 10 million acres. Utilized in making the inventory were space photography, three scales of aircraft photography, and ground measurements.

5. Completion of systems analysis and accessory computer programs for testing the effects of photo rotations and image matching procedures. These will be used in the automatic mapping of wildland resources with digitized stereopairs of aerial photography.

6. Use of Apollo 9 photos to develop optical density signatures for high altitude photography and for 13 land-use classes.

7. Classification and mapping of specific rangeland ecosystems through aircraft and spacecraft photography, for use in photo interpretation testing.

8. Demonstration of the need for—and the advantage of—multiseasonal and multispectral imagery in the remote sensing of native vegetational resources.

#### ***Southern Corn Leaf Blight Watch Experiment:***

A preliminary investigation, begun in late 1970, explored the potential for using remote sensing technology to detect southern corn leaf blight. During 1971, as joint USDA/NASA/States experimental operations and management plan was undertaken to evaluate further the use of these techniques and concepts to:

1. Detect the development and spread of corn blight during the growing season across the Corn Belt region;

2. Assess different levels of infection present in the Corn Belt;

3. Amplify information acquired by ground visits in order to better assess current blight status and the probable impact on crop production by blight; and

4. Estimate through extrapolation the applicability of these techniques to similar situations that may occur in the future.

The Southern Corn Leaf Blight Watch Experiment was conducted over a seven state region, including approximately 64 percent of the total U.S. corn acreage, or about 41,388,000 acres. The sample area included 210 segments, each approximately one mile wide and eight miles long. Thirty of the segments were concentrated in an intensive study area in western Indiana to allow a more detailed study of the various modes of data collection. Low and high altitude aircraft flew over these segments, obtaining data that was analyzed and interpreted on a biweekly basis. The size of the area monitored was determined by resources available for the experiment, i.e., suitable instrumented aircraft, numbers of data analysts and

photo-interpreters, computer processing, amount of ground data which could be collected, etc. The area under study was the largest possible with available resources.

This experiment involved the resources and personnel of 26 Federal and State agencies and organizations. Participating were the Agricultural Research Service, Agricultural Stabilization and Conservation Service (ASCS), Cooperative State Research Service, Economic Research Service, and the Statistical Reporting Service; NASA; the Department of Commerce; seven Agricultural Experiment Stations; Cooperative Extension Services of the States of Illinois, Iowa, Minnesota, Missouri, Nebraska and Ohio; Purdue University (Laboratory for Applications of Remote Sensing); and the University of Michigan (Willow Run Laboratories). NASA made available an RB-57F aircraft to collect high-altitude photography and a C-47 aircraft with a multispectral scanner to obtain data over an intensive study area. NASA also provided research effort funding, photography and photographic support, photo-interpreters, and other technical assistance. The Department of Commerce's Agricultural Climatological Office monitored the weather through its various stations and exploited the data through its EPIMAY project.

Corn Blight Watch activities were divided into three phases. Baseline information was obtained during Phase I. High-altitude black and white photographs of the selected segments, obtained in late April and early May, were used by county ASCS personnel while interviewing farm operators within each segment. Fields were identified on the photographs, and basic information about crops and land use was obtained.

The purpose of Phase II was to obtain soil background information. In early May, high-altitude color infrared photographs were taken over all segments and multispectral scanner data were obtained over the intensive study area segments. These data were analyzed to identify soil patterns.

The flight portions of Phase III began June 14 and continued through October 3, 1971. During this phase, the incidence and severity of southern corn leaf blight were mapped in the sample segments and inferences drawn for the total area. High-altitude color-infrared photographs were taken biweekly, and multispectral data were collected over the intensive study area segments on the same schedule.

A sample of corn fields, stratified by cytoplasm, was selected before the start of Phase III. These fields were visited at two-week intervals by Extension and ASCS personnel, who obtained data on the general condition of the crop, and particularly on the severity of southern corn leaf blight. The ground sampling scheme was designed to provide data throughout the large area (seven-state region) and in the intensive study

area (western third of Indiana). A sampling model allowed inferences to be made concerning the degrees of blight present over all of these areas. The field observation data was also used as training data in analyzing the remote sensing data.

Results of the experiment have been encouraging. While very early detection of southern corn leaf blight has not been accomplished, fields suffering medium to severe levels of infection were found to be identifiable. The ability to delineate different species and to identify crops and land uses has also been extremely encouraging. A framework has been established for continuing efforts to solve problems in crop identification, acreage measurements, and land use inventories.

One important benefit from the experiment was the development of guide lines for similar research in the future. Key problem areas have already been identified and efforts are being made to find solutions. The experiment is providing investigators with an opportunity to evaluate more fully how well remote sensing techniques can be used to identify different crop species at various stages of maturity over a very large geographic region.

The Watch has also provided a real world environment in which to make evaluations. Much was gained through learning the mechanics required to operate a large information system that makes use of remote sensing on a scheduled basis. The experiment has also given participants from all of the cooperating institutions a better basic understanding of remote sensing and a greater appreciation for its applicability to blight detection and other agricultural problems. These people are now considered to be better qualified to support future research and development programs involving remote sensing.

The effectiveness of the Federal, State, and University interagency cooperative effort was outstanding. This cooperation could well serve as a model for future large-scale investigations involving remote sensing.

### **International Cooperation**

In view of the recognized potential for international cooperation and benefit from Earth remote sensing surveys, USDA is participating with other Federal agencies in programs to inform the international community about program developments, to provide orientation and training, and to give technical assistance in cooperative projects involving remote sensing.

USDA and other Government agencies sponsored a two-week International Workshop on Earth Resources Survey Systems at the University of Michigan in May 1971. USDA also participated in the Seventh International Symposium on Remote Sensing of Environment held in May 1971 at the University of Michigan.

In order to apprise FAO of recent remote sensing developments that could be useful to UN member nations which do not have facilities in remote sensing technology, USDA participated in the FAO Technical Consultation on the Applications of Remote Sensing to the Management of Food and Agricultural Resources held in Rome, Italy, September 1971.

USDA also participated in the Remote Sensing Symposium sponsored by the Inter American Geodetic Survey held in the Canal Zone, November 30–December 2, 1971. Nineteen Latin American countries were informed of the potential for using remote sensing techniques in inventorying, protecting, and managing their national resources.

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## Department of Commerce

### Introduction

Department of Commerce activities that contribute directly to the national aeronautics and space program are concentrated within four major organizational elements. These are the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Maritime Administration, and the Office of Telecommunications. Other elements contribute to the national program through indirect efforts. Among these latter units are the U.S. Patent Office, which issues patents on inventions with aeronautical and space application, and the National Technical Information Service, which collects and distributes scientific and technical information produced through the national program.

### National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) fulfills the Department of Commerce responsibilities for improving man's comprehension and uses of the physical environment and its oceanic life. These responsibilities stress exploring, mapping, and charting the global oceans, their basins, their geophysical forces and fields, and their mineral and living resources; monitoring and predicting the characteristics of the physical environment in real time to warn against impending environmental hazards; and monitoring and predicting gradual changes such as those of climate, seismicity, marine-life distribution, earth tides, continental position, the planet's internal circulations, and the effects of human civilization and industry on the environment and oceanic life. Six major subelements of NOAA provide direct contributions to the aeronautics and space program. These are the National Environmental Satellite Service, the National Weather Service, the Environmental Data Serv-

ice, the Environmental Research Laboratories, the National Ocean Survey, and the National Marine Fisheries Service.

**National Environmental Satellite Service.**—The National Environmental Satellite Service (NESS) has the responsibility for establishing, operating, and improving the nation's system of operational environmental satellites. To satisfy the operating requirement NESS commands and controls satellites in orbit, acquires and processes data from satellites, arranges for dissemination of both processed and unprocessed data, and works with the NOAA Environmental Data Service to maintain an archival system for making data available for research and application to specific environmental problems. The NESS maintains and improves current ground and data handling systems, plans for future spacecraft systems, and coordinates with the NASA in the development of new and improved sensors and spacecraft systems. Major research and development efforts are devoted to the analysis and application of satellite data, and the development of new sensor systems for use on or with spacecraft.

**Operation of NOAA Satellites.**—As the year began, NESS was controlling four polar-orbiting spacecraft. Two of these were the primary source of data used operationally; the other two spacecraft were controlled in orbit as backup data sources in the event of failure in the primary operational system. The primary spacecraft were the ITOS 1 (TIROS M, a NASA funded prototype), and NOAA 1 (ITOS A), the first operational NOAA spacecraft of the ITOS series. The ITOS spacecraft provide two services, global observations for centralized application, and direct readout for immediate local use. Day and night observations of the earth and its cloud cover are stored on the satellite, read out at one of two command and data



acquisition stations (CDA), and transmitted to central processing centers for operational use on a global scale. In addition, day and night observations are broadcast continuously for reception by relatively simple and inexpensive direct readout stations for realtime application in local or regional environmental service programs. Measurements of the solar proton flux are recorded over the polar regions, acquired at the CDA stations, and relayed to NOAA's Space Environment Laboratory at Boulder, Colorado for use in national and international space environment advisory services.

All data transmissions from the ITOS spacecraft ended in mid-year as a result of spacecraft malfunctions associated with the stabilization and control assembly. The replacement spacecraft, ITOS B, was launched October 21 but failed to orbit due to problems associated with the second stage of the launch vehicle. This failure necessitated "calling up" the two stored in orbit backup spacecraft. These two, the older TOS series ESSA 8 and 9, continued to provide useful information through the remainder of the year. These spacecraft differ from the later ITOS series in that each is limited to a specific service and that only daytime observations are obtained. ESSA 8 is the Automatic Picture Transmission (APT) satellite and provides direct local readout. ESSA 9 provides the stored data (global) service.

**Applications Technology Satellites (ATS).**—NESS, with the cooperation of NASA, continues to acquire and use the data from the NASA research and development geostationary satellites ATS 1 and 3. ATS daytime pictures, which cover most of the Western Hemisphere, can be acquired at 15 to 30 minute intervals. A time-lapse movie sequence technique has been applied to show development and motion of large and small scale cloud systems during daylight hours. Movement of cloud elements is used to estimate low and upper level wind speed and direction; these wind estimates are used in the numerical weather prediction program. The animated cloud sequence also is used in diagnosis of hurricane and severe local storm situations.

Technical difficulties prevented picture taking by the ATS 3 from July 30 through September 1. The difficulty was corrected so that pictures were available for use in September, the busiest tropical storm period in 1971.

**Nimbus IV.**—The NASA research and development satellite, Nimbus IV, continues to provide environmental information which is used daily in operational programs. The Satellite InfraRed Spectrometer (SIRS B) provides data which is converted to a description of the vertical temperature distribution in the atmosphere. These data are used daily in objective weather analysis techniques.

**Operational Applications.**—During this year the operational environmental satellite system completed five years of uninterrupted service. As part of an on-going program to assess the value of the satellite system in terms of practical benefits, the wide range of satellite data applications was reviewed. A number of applications with practical benefits were reported by users of the satellite system. Among the benefits cited were the use of these data in forecasting weather conditions which endanger livestock in western ranching regions; specialized forecasts for harvest conditions; use in public news media; marine advisories; sea and lake ice forecasts; public weather forecasts; and in forecasting east coast winter weather. The satellite data are applied routinely as basic guidance information by the National Meteorological Center (NMC). One of the more important and well known applications is the use of satellite data in tracking and forecasting movement and intensity of severe storms and hurricanes.

An operational technique has been introduced for deriving quantitative heights of constant pressure surfaces using satellite observed cloud patterns. This technique known as Satellite Input to Numerical Analysis and Prediction (SINAP), is applied routinely to the northeast North Pacific Ocean weather analysis. SINAP separates the 12-hour 500 millibar (about 5.6 kilometers) height field forecast into short- and long-wavelength components. Satellite data are used to modify the short-wavelength components. Statistical techniques have been developed to derive the magnitude of the deviations where spiral cloud centers occur. Addition of the long-wavelength and the modified short-wavelength components produces the 500 millibar height field.

In cooperation with the USAF Air Weather Service, a global climatology of relative cloud cover was prepared. Data from the period 1967–1970 were used as the base for computing the relative cloud cover statistics.

**Research and Development Programs of the National Environmental Satellite Service.**—Research efforts during the year continued to emphasize the development of more objective, quantitative methods of incorporating environmental satellite data in the daily routine of numerical analysis and prediction of meteorological fields. Satellite data are being studied to enhance our knowledge of the behavior of circulations and energetics, particularly in areas where conventional data are incomplete or do not exist.

Studies of satellite visual and infrared observations over several years, have shown that most tropical cloudiness and intense cloud development is confined to South America, Africa, and Indonesia southeastward to French Polynesia. Relatively cloud free areas extend for great distances along the equator between these three areas.

Satellite pictures have revealed that tropical storms sometimes have an extensive cloud band extending northeastward into middle latitudes. Studies of data over the North Pacific show that this feature is the source of major heat injection from the tropics into the middle latitudes. Thus this feature may have some important part to play in the resulting middle latitude circulation and weather.

Techniques for producing 12, 24 and 36 hour cloud cover forecasts using satellite pictures as the initial cloud data were perfected in time to use these forecasts experimentally in support of the Apollo 15 mission.

Data analysis techniques were developed to assist in determining distributions of sea surface temperature and sea ice. Methods for correcting scanning radiometer data for atmospheric attenuation and for filtering system noise were tested and experimental global maps of sea surface temperature produced.

Methods of monitoring polar ice packs have been improved by displaying composite minimum brightness charts in five gray tones which correspond to five categories of ice concentration and condition ranging from compact, snow-covered pack to very open pack or ice free.

Near-infrared imagery obtained from Nimbus 3 high resolution data shows that thawing ice packs have little or no reflectivity in this spectral interval. Early detection of melt periods of sea or lake ice could result from monitoring in the visible and near-infrared bands.

Thermal infrared measurements are being evaluated to determine their usefulness for snow mapping and for determining snow surface temperatures. A means has been found for detecting thaw conditions of snow fields. When the snow cover is dry, it is bright in both the visible and the near-infrared parts of the spectrum. When the snow cover is wet, the reflectivity drops to low levels in the near-infrared but remains fairly high in the visible band.

**International Cooperation.**—Worldwide availability of Automatic Picture Transmission (APT) pictures and the experimental semioperational transmission of a variety of satellite products through the ATS spacecraft continued throughout the year. There are now about 500 APT stations located in 94 countries and trust territories.

The NESS provided training and study facilities for Brazilian meteorologists and briefings for many other foreign scientists. Through the auspices of the World Meteorological Organization's (WMO) Voluntary Assistance Program, the NESS furnished a training mission to Thailand, Nepal, Zambia, and Somali. The NESS also participated as part of the U.S. delegation to the Sixth Congress of the WMO.

The NESS participated in the U.S.—U.S.S.R. bilateral negotiations on peaceful uses of outer space. As

an outgrowth of the U.S.—U.S.S.R. agreement for cooperation in space science and applications, the NESS was actively represented in the negotiation of the basic bilateral agreement, and on the Joint Working Group on Meteorological Satellites and the Joint Working Group on the Natural Environment. These groups developed tentative cooperative experiments using satellites and other facilities of both countries, including acquisition and exchange of data.

**Washington-Moscow Data Exchange.**—The U.S. and U.S.S.R. have exchanged satellite data routinely over a direct circuit since September 1966. In 1971, this flow of information was virtually uninterrupted except for brief periods when the circuit was not operational for technical reasons. The U.S. began transmission of direct readout and stored scanning radiometer data for the first time during the middle of the year. The U.S.S.R. continues to provide television and infrared data from the Meteor series of satellites. Meteors 7, 8, and 9 were launched this year. At year end, data were being received from Meteors 8 and 9 and from Meteor 5 launched in a prior year.

**National Weather Service.**—The National Weather Service (NWS) both serves and is served by the aeronautics and space program. Through its widespread observations and forecasting network it provides direct services to civil and military aviation, and through its Space Operations Support Division it provides specific weather services to the space program. The NWS research programs are aimed at improvement and enlargement of all these services. The aeronautics and space program provides benefits to the NWS with data gathered by aircraft and spacecraft, and by rapid data relay through spacecraft. The NWS participates in the planning of spacecraft data gathering and dissemination systems, and in the enhancement of the usefulness of weather data gathered by satellites.

**Snow Mapping by Satellites.**—NOAA satellite photographs of snow fields were used by the River Forecast Centers in the preparation of river and flood forecasts. The products provided by the National Environmental Satellite Service permits more timely and accurate analysis of the areal extent of snow cover. This information when augmented by ground reports of water equivalent of snow is important to accurate predictions of potential flooding and water supply forecasting.

**Collection and Relay of Data by Satellites.**—Data relay equipment on the ATS 1 satellite permits collection of information from instrumented, unmanned observation sites. Because this pilot program has proven successful, sites have been selected for hydrologic data collection platforms (DCP) of river and rainfall stations to be used with the Geostationary Operational Environmental Satellite (GOES) sys-

tem to be initiated in 1973. The Columbia Basin of the Pacific Northwest was chosen as the location for the 15–20 prototype DCP's because of extensive inter-agency prediction and monitoring activities.

Special efforts toward full use of geostationary weather satellite pictures have been made at the National Hurricane Center, Miami, and the National Severe Storms Forecast Center, Kansas City. The system has been in operation for a full year during which time procedures have been developed to incorporate the new pictures into analysis and forecasting techniques. The photographing satellite was placed at the most favorable positions for viewing mid-continent severe storms during the spring, and then moved to look at hurricane areas during the summer and fall. The temporary malfunction of this satellite during the hurricane season served to point up our dependence on this new observation tool.

***Satellite Imagery Distributed by Facsimile Circuit.***—

Pictures of cloud systems over the earth, taken by polar-orbiting weather satellites, are distributed to NWS forecast offices over NWS facsimile communications systems. These include pictures made by the Automatic Picture Transmission (APT) system, which can be received directly from the satellite when necessary, and the Advanced Vidicon Camera System (AVCS) and large area mosaics of cloud imagery. A different kind of "look" at the earth cloud cover is supplied by infra-red sensors on the weather satellites, and during 1971 NWS initiated real-time communication of this additional analysis tool to our forecast offices.

***Remote Sensing of the Water Equivalent of Snow.***—

Techniques for remote measurements of the water equivalent of snow cover from sensors aboard aircraft have shown great promise in initial testing. The sensing technique is based on change in attenuation of natural earth-emitted gamma radiation due to variations in the water equivalent of snow. The method was used on a limited operational basis in the winter of 1971. The feasibility of wide operational application in river forecasting is presently being determined from research results.

***Meteorological Support to Space Operations and Test Facilities.***—

The NWS through its space operation support division continued its guidance to several NASA Programs. In the manned space flight area the 1971 support covered two lunar flights. Weather was of real concern at the time of the Apollo 14 launch on January 31, since the Kennedy Space Center was experiencing rapidly moving clouds and numerous showers. On the basis of a short-range forecast the space vehicle successfully passed between the thick clouds, avoiding the danger that it might trigger a damaging lightning discharge. There were no serious forecasting difficulties for the launch and North Pacific Ocean

landing of the Apollo 15 flight, on July 26 and August 7, respectively, but there was an unusually high frequency of thunderstorms in the Kennedy Space Center area during the 2-month checkout period. As a result of their forecasting and warning assistance, the NWS team at the Kennedy Space Center received a NASA Group Achievement Award "for exceptional performance of duty during the checkout and launching of Apollo 15."

***Forecasting for Earth Observations Aircraft Flights.***—

The NWS Spaceflight Meteorology Group provided almost daily forecast support to the NASA Earth Observations Aircraft Program and has made studies of weather as it may affect future earth-viewing satellite programs.

The NWS unit at the NASA Wallops Station supports a variety of space projects. One significant NASA test, the Planetary Atmospheric Experiment Test of June 20, required forecasts, meteorological rockets, and shipboard observations near Bermuda. Another major support effort of the Wallops team—that for the cooperative Germany-United States Barium Ion Cloud experiment, involved surface and upper air observations and forecasts for several sites in the Southwestern United States and in South America. A clear view of the 20,000 mile high cloud was successfully forecast for all primary observatory sites.

Units of the NWS at San Nicolas Island, California, and Barking Sands, Hawaii, assisted in the weather support for the Navy Pacific Missile Range. Also the NWS furnished the full weather observing and forecasting service for the Army Safeguard System Command at the Kwajalen Missile Range.

***Support to World Meteorological Organization.***—

NWS technicians completed the installation of nine APT ground receiver stations in foreign countries and provided training in satellite picture interpretation as part of U.S. support to the World Meteorological Organization Voluntary Assistance Program. Additionally, APT systems were purchased and arrangements made for their installation in six more countries in 1972.

***Utilization of Aircraft.***—Meteorologist-pilots of the quality control staffs at NWS Headquarters fly small single or twin-engine aircraft (either rented or privately owned) in connection with quality control duties. These flights permit in-flight monitoring and evaluation of NWS furnished aviation weather services; they also are used as a means of travel for station visits and on-station services evaluation.

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 NWS products.

***Services to Aviation.***—Specialized weather information is provided to pilots, controllers, and aircraft op-

erators to promote efficiency in aviation activities. This information is in the form of observations, forecasts, warnings, and pilot briefings. In addition, weather consultation and guidance are provided to assist the efficient flow control of the Air Traffic Service. Observations are made at 954 locations; many by other Government agencies, airlines, and airport personnel. Terminal forecasts are made for 427 airports, generally every 6 hours. Area forecasts and in-flight advisories are also provided. Forecasts for international aviation covering all of the Northern Hemisphere and most of the Southern Hemisphere are also provided in facsimile and/or digital forms, the latter being used extensively in computer flight planning by the airlines.

Pilot weather briefings are available through 269 NWS offices, plus 327 FAA offices and 215 unmanned FAA facilities. About 2 million briefings are provided annually by the NWS and about 13 million by the FAA.

**Environmental Data Service (EDS).**—The Environmental Data Service collects, processes, archives, publishes, and disseminates environmental data and information gathered on a global scale, providing a single source service, readily accessible to specialized and general user groups. EDS maintains data centers for oceanographic, meteorological, aeronomic, geomagnetic, and seismological data, and provides administrative support for corresponding World Data Centers—A, which receive data from cooperative investigations and other international sources. In addition, it maintains an Environmental Science Information Center, the NOAA focus for scientific and technical information, publications, and library services. EDS also sponsors and conducts research and development activities to improve its performance of those functions and coordinates with world scientific organizations our Nation's international activities in the data and information management areas of NOAA responsibility.

**The National Climatic Center (NCC).**—The NCC at Asheville, N.C. processes, publishes, distributes, and archives surface and upper air meteorological data, including certain satellite data. Both the raw and processed data from the National Weather Service and its cooperators—the National Environmental Satellite Service, the Air Weather Service of the U.S. Air Force, the Naval Weather Service Command and foreign meteorological services—are archived at the NCC.

Accomplishments at the NCC relating to aeronautics and space activities during 1971 include:

1. Computation of tropical cyclone strike probabilities for the NASA installations at Houston, Texas; Mississippi Test Facility at Bay St. Louis, Mississippi; Cape Kennedy, Florida; and Wallops Island, Virginia. These data were published in NASA CR-61355, "Atlantic Tropical Cyclone Strike Probabilities (For

Selected Stations and the Month of September)" which also include a statistical climatology of tropical cyclone movements in the North Atlantic Ocean, Caribbean Sea and the Gulf of Mexico.

2. Compilation of surface climatological information for 20 selected stations to aid in the site selection of the space shuttle launches. These data were published in NASA CR-61342, "Surface Climatological Information Twenty Selected Stations for Space Shuttle Studies."

3. The data summary and analysis programs designed to furnish up to date statistics on peak surface winds and thunderstorms at Cape Kennedy and serially complete upper air wind data for Cape Kennedy, Florida and Vandenberg AFB, California were continued.

4. In cooperation with the Naval Weather Service Command, the second and final volume of upper air climatology of the Northern Hemisphere was published in NAVAIR 50-1C-59, "Selected Meridional Cross Sections of Heights, Temperature and Dew Points of the Northern Hemisphere."

5. Efforts to reduce the wind and thermodynamic data collected on the 150-meter instrumented tower at the Merritt Island Launch Area, Cape Kennedy, Florida were continued.

6. Analysis of atmospheric conditions relating to the development of a method for interpreting measurements of aircraft flyover noise was carried out in a NASA-FAA cooperative effort. The analysis is in the process of publication.

7. Cloud analyses from the facsimile charts transmitted on the National facsimile circuit are being coded and punched into cards for use in a cooperative NASA-NOAA research effort. Some of the results are published in "NASA-Technical Note D-5631."

8. The NCC continued its efforts in the processing, publication, and distribution of the High Altitude Meteorological Data received from the Meteorological Rocket Network (MRN) and the EXAMET Net and participating foreign countries. These data are published for the WDC-A for Meteorology and Nuclear Radiation. Data for the months May 1969 through February 1970 were published in 1971.

9. The last three volumes on the Upper Air Climatology of the Southern Hemisphere were produced in cooperation with the Department of Defense and the National Center for Atmospheric Research (NCAR), and were published during 1971. The titles of these volumes are: Vol. II "Temperatures, Dew Points, and Heights at Selected Pressure Levels"; Vol. III "Vector Mean Geostrophic Winds (Isogon and Isotach Analysis)"; Vol. IV "Selected Meridional Cross Section of Temperature, Dew Point and Height (Cross Sections at 30° Intervals Around the Hemisphere)."

In addition to the above, satellite data achieved at the NCC provide an important contribution to the global Basic Data Sets which have been organized for research purposes by the NCC. This program, under the auspices of the Global Atmospheric Research Program (GARP), has assembled the most complete meteorological collection in existence for one winter month (November 1969) and one summer month (June 1970). ATS cloud and wind data as well as SIRS data provide unique and otherwise unobtainable information over large ocean areas.

***The Aeronomy and Space Data Center (ASDC).***—

This center archives monitoring type solar-terrestrial data recorded by satellites and space probes. The Center is the primary source to scientists for the ionograms taken by the topside ionosonde satellites. In addition, several solar parameters (protons, X-rays, and solar wind) measured by satellites and space probes are archived and also published monthly in *Solar-Geophysical Data*, to provide the international scientific and technical community with data values for understanding many solar-terrestrial relationships. These are the only such data published routinely on a reasonably rapid schedule, some even in the first month after observation.

Analyses of satellite and space probe measurements are included in special data compilations for times of unusual solar-geophysical activity. These are published in the *Upper Atmosphere Geophysics Report* series of the collocated World Data Center A. The data catalog, also issued in this series, specifies which of the holdings in the field of solar-terrestrial physics are from satellite and space probes.

Until July 1971 the ASDC had the responsibility for processing, scaling, and archiving of solar flare patrol films and solar radio noise data obtained at special patrol observatories at Boulder, Colorado, Carnarvon, Australia, and the Canary Islands. These sites are spaced in longitude to normally keep the sun under watch for a full twenty-four hours each day. Their operation was part of a contract program between the NASA Manned Spacecraft Center and the Space Environment Laboratory of the NOAA Research Laboratories. The program produces a highly homogeneous set of quality controlled data in support of the Apollo space missions for the detection of hazardous solar particles.

***The National Geophysical Data Center.***—NGDC digitizes many magnetograms for use by NASA scientists; in particular, for comparison with their satellite magnetic field measurements. These digitized magnetograms are also used to prepare indices which are, in turn, most valuable in correlation studies with satellite magnetic field data and in interdisciplinary space studies. Hundreds of observatory years of data

are furnished annually to space researchers throughout the world.

The National Geophysical Data Center also maintains a file of magnetic survey data which it uses to provide magnetic declination information for the hundreds of U.S. aeronautical and airport charts which are printed or revised each year. Mathematical models of the earth's magnetic field have also been distributed by NGDC to numerous airlines, airports, and other groups concerned with using automated techniques for deriving magnetic declination information.

***The National Oceanographic Data Center.***—NODC is actively involved with three types of oceanographic data collected by aircraft and satellites: aircraft expendable bathythermograms (AXBT) and sea surface temperature determined by airborne radiation thermometry (ART) or by satellites.

NODC has completed development of a processing system for certain types of AXBT's and has begun digitization of the approximately 5,000 observations presently in the archives.

Storage and retrieval criteria for ART's have been established by the NODC, but at present no data are available in the required digitized mode.

A format and accessions system for NOAA satellite-sensed sea surface temperature data has been established. Routine storage at EDS' National Climatic Center of daily global sea surface temperature data should begin by mid 1972.

***The Laboratory for Environmental Data Research.***—LEDR is exploring climatological applications of meteorological satellite data as follows:

1. Monthly cloud cover amounts are being estimated from meteorological satellite data for tropical areas of the Pacific and Atlantic Oceans. Long period variations in cloud amount in these ocean areas, and the interocean cloud cover variations, are being studied because the amount of cloud cover is closely related to the characteristics of the general atmospheric circulation.

2. Standing waves in the atmosphere induced by orographic features are being studied with seasonally averaged pressure-heights derived from meteorological satellite radiometric data. The standing waves contribute significantly to observed mean vertical pressure-height distributions and therefore are probably closely related to weather variations in persistent areas of cyclogenesis. A better understanding of standing waves in the atmosphere will probably lead to a better understanding of the general atmospheric circulation.

***Environmental Research Laboratories.***—The Environmental Research Laboratories, (ERL), with headquarters in Boulder, Colorado, conduct the fundamental investigations needed to improve man's understanding of the physical environment. Ten laboratories

and two centers conduct research in the various scientific disciplines required in support of NOAA missions.

**Space Environment Laboratory (Boulder).**—The NOAA Space Environment Laboratory (SEL) provides services and conducts research in solar-terrestrial physics to develop technology required to monitor the state of the earth's environment and to forecast geophysical effects produced by solar disturbances. Experimental, observational and theoretical research is directed towards the understanding of the physics of solar flare development and other solar activity, and the manner by which the solar produced electromagnetic and particle radiations affect the magnetosphere and ionosphere of the earth.

Services performed for NASA and other agencies include:

- The operation of SPAN (Solar Proton Alert Network), a network of four stations spaced around the world to permit continuous solar observations by optical and radio methods.
- Support of the Apollo 14 and 15 missions, with respect to solar disturbances, was provided by SEL personnel who manned the Space Radiation Console at the Manned Spacecraft Center in Houston, Texas, and by special forecast and monitoring efforts.
- Operation of the Boulder Telemetry Station to obtain data from the ionospheric sounding satellites Alouette 1, Alouette II, ISIS 1, and ISIS 2.
- Development of techniques for forecasting the position on the sun, and time, of solar flare eruptions to support the Advanced Telescope Mission (ATM) of Skylab. These predictions, if successful, will enable astronauts to point high resolution optical instrumentation in order to record the early development of flare activity.

A number of experimental programs make use of satellite and rocketborne measurements.

- Observations of energetic charged particles by a rocket launched at high latitudes suggest these particles were accelerated close to the earth by an electrostatic field directed along a geomagnetic field line. This result has implications for theories of charged particle behavior in the geomagnetic field.
- Low energy particle data from the satellite OGO F-15 are under analysis with improved time resolution. These results will improve understanding of aurorally associated charged particle behavior.
- Particle and magnetic field data are also obtained on an operational basis from the geostationary satellite ATS-1.

The SEL is responsible for the design and construction of the ATS-F and -G radio beacon receiving sta-

tion and for design specifications for the spacecraft transmitter. This system will provide improved measurement of electron density, integrated over the path, in the ionosphere and magnetosphere. A prototype version of the ground receiver has been constructed and is under test. Final design plans will be made available, internationally, to those groups desiring to participate in cooperative studies using the ATS radio beacons.

A special report on effects of solar disturbances on high latitude aeronautical communications was compiled for the SST panel of the International Civil Aviation Organization. In this report the state of present knowledge on the subject was assembled in order to estimate the extent of communication problems that may arise during periods of high solar activity.

Low energy solar protons, detected by particle detectors on the NOAA meteorological satellites, were found to occur at latitudes lower than anticipated by present theories of particle behavior in the earth's magnetic field. An explanation for the observation of these particles was made suggesting a diffusion process during magnetic storms to be a plausible mechanism.

The SEL is developing instrumentation for a number of space experiments to be launched at future dates. These include:

- Particle and radiometric instrumentation for rockets to be launched in Norway,
- Energetic particle experiments for IMP H and J,
- Particle, X-ray, and magnetic field sensors for operational space environment monitoring, and for research purposes, to be included in the geostationary meteorological satellites (SMS/GOES) under development for NOAA by NASA,
- Particle instrumentation for ATS-F and -G.

Theoretical studies were made of the earth's magnetosphere and its interaction with the solar wind (a continuous, but variable, stream of particles flowing away from the sun) in order to understand the manner in which solar flare energy produces the various geophysical effects observed at and near the earth. In one recent study, the shock wave produced by a flare, its propagation through the solar wind, and its interaction with the magnetosphere was modeled numerically. The complicated dynamical behavior was made visible by means of computer produced motion pictures. Plasma and magnetic field data from the spacecraft Pioneer 7 interplanetary shock observations, were used to compare with the theoretical computations.

Model magnetospheres of several of the outer planets—Jupiter, Saturn, Uranus, Neptune and Pluto—were computed for NASA. These computations, which incorporated solar wind parameters, and

the best available data and theoretical deductions pertaining to the planets, will provide information for design of spacecraft for planetary exploration.

**Aeronomy Laboratory (Boulder).**—Laboratory measurements of the rates of ion-molecule reactions relevant to the upper atmosphere have continued, with some emphasis on the complex clustering reactions that take place at altitudes below about 85 kilometers. Recent progress has included the first definitive measurement of the electron affinity of  $\text{NO}_3$ , believed to be the dominant species of negative ion in the lower ionosphere. The program is currently being extended to allow investigation of many free-radical reactions important in air-pollution episodes, exploiting new technology opened up by development of the spin-flip infrared laser.

Further direct rocket measurements of atomic-oxygen distribution in the upper atmosphere have been carried out, using a thin-film detector developed in the Aeronomy Laboratory. The technique has aroused considerable interest, and programs involving its use are now being planned by several groups in this country and abroad.

Radar studies of the small-scale structure of the ionosphere during auroral displays are being carried out in cooperation with the Space Environment Laboratory. These studies involve use of a 50-MHz radar located at Anchorage, Alaska, and a portable doppler spectrum analyzer with an on-line computer. Preliminary experiments have yielded much more insight into the mechanisms that give rise to auroral 'turbulence' in the ionosphere than has previously been obtainable. The results will have important practical consequences for radar and communications operations in the Arctic regions.

The theory of plasma resonances is being advanced by results of a recent rocket experiment involving an improved ionospheric topside sounder. Analysis of the frequency spectrum of the received signal confirms the wave propagation characteristics of the resonant-like behavior. In addition to their contribution to basic plasma physics, the resonances may also be used as a tool for accurate measurement of magnetic field strength and electron density and, most importantly, electron temperature.

**Atmospheric Physics and Chemistry Laboratory (Boulder).**—An analysis of the Apollo 12 lightning strike has shown that the launch vehicle itself triggered the lightning by causing sufficient concentration of the electrical field at its tip to initiate a lightning discharge.

An investigation to determine the feasibility of triggering lightning by small rockets to discharge electrified clouds immediately prior to Apollo or other space vehicle launch, has produced the following major results:

- A theory has been developed which predicts under what conditions lightning will be triggered by a specified rocket;
- Field experiments have been carried out and 20 lightning flashes have been triggered by a Folding Fin Aircraft (FFA) rocket;
- New instruments developed for these field tests include a lightning triggering and field measuring payload for the FFA rocket, and airborne electric field measuring system, and a real time lightning plotter which plots the positions of lightning discharges occurring within a radius of about 48 kilometers.

Outstanding results of the high altitude water vapor and radiometric measurements from jet aircraft platforms are as follows:

- Flights around individual large thunderstorm anvils have shown that these storms may inject several times as much water vapor into the stratosphere as exists upstream from the storm. Further studies are needed to ascertain the residence time of this injected water vapor after storm decay. This problem is related directly to SST operations.
- Contrails in heavy jet traffic corridors decrease the mean local surface temperature by only 0.15C. The global change is negligible.
- Observations of changes in stratospheric water vapor content over extended jet aircraft traverses have been made from the NASA Convair 990 aircraft. These measurements permit an analysis of the spatial variations of water vapor which is not possible by balloon probes.

A theoretical study has been completed on the problem of SST emissions and resultant modification of the stratosphere.

**Atlantic Oceanographic and Meteorological Laboratories (Miami, Fla.).**—AOML conducts a broad research program in marine geology and geophysics, physical oceanography, sea-air interactions, and hurricane research and modification.

Monitoring and analysis of the Gulf Stream and the Loop current in the Gulf of Mexico have been carried out using the high-resolution infrared imagery available from ITOS and Nimbus IV. These studies support and extend the classical surface and aircraft observations and give an overview of meanders and instabilities along the northwest edge of the Stream, an item of interest to fishing and shipping activities.

A laser sea-surface profilometer has been flown into both tropical storms and northern disturbances aboard RFF aircraft, and ocean wave spectra obtained under dynamic, evolving wind conditions. An understanding of the generation of waves by high winds is required for oceanic and atmospheric monitoring and predic-

tion, as well as for research into the nature of the interactions of these two fluid envelopes.

Analyses of weather satellite data have revealed that solar energy input to tropical regions is considerably higher than thought earlier, thus stimulating a search for mechanisms that can transport this extra energy poleward.

**Earth Sciences Laboratories (Boulder).**—Construction began on a magnetometer to be used as a space environment monitor on the NOAA geostationary satellite SMS/GOES. In preparation for the measurement, automated geomagnetic data analysis techniques are under development in the Boulder Laboratories.

In a joint effort with NASA, NOAA is using computers to process geomagnetic analog records from worldwide magnetic observatories, and geomagnetic data collected by satellites and space probes.

Developmental work continued on modifications to the International Geomagnetic Reference Field. This mathematical model of the earth's magnetic field is used as a common base by scientists worldwide in studies of related atmospheric, ionospheric, and outer space parameters. In collaboration with NASA, synthesis programs for spherical harmonic models of the main geomagnetic field were tested. Studies were made to compare magnetic chart models developed from ground data with those developed from satellite data, and the feasibility of using satellite data in the production of world magnetic charts was evaluated.

Plans were developed for broadcast of the NBS originated time codes by the NOAA SMS/GOES geostationary satellite as timing information for seismological observatories supported by NOAA.

**National Severe Storms Laboratory (Norman, Okla.).**—In a cooperative program, NSSL, NASA, FAA, and USAF Air Weather Service have been studying the distribution of cloud tops extending above 12 kilometers, the probability of occurrence of turbulence above severe storms, and the horizontal temperature gradients above those storms. This study aims to improve safety of flight in the vicinity of thunderstorms. Satellite data are used to aid correlation of radar echo and weather characteristics, to identify cloud and storm systems in their incipient phases, and to estimate the role of meteorological parameters in storm development. Analyses of satellite cloud photographs indicate regions of vertical motion in the lower troposphere and are being increasingly used with NSSL surface network and radar data for the study of severe storms.

**Air Resources Laboratories (Silver Spring, Md.).**—Studies of the effects of the atmosphere on the sonic booms produced by supersonic aircraft have continued under the sponsorship of the FAA. Studies were made near Las Vegas, Nevada, and in central Idaho to de-

fine the structure of amplified booms resulting from slightly supersonic and transonic flight, and influence of atmospheric conditions on such booms.

There has been a noticeable increase in the amount of high cloudiness at seven weather observing stations in the U.S. during the late 1960's. Many of these stations are located near major commercial jet-aircraft flight tracks and the increases in cloudiness correlate with the increased consumption of jet fuel. These data suggest that jet contrails may increase the amounts of high cloudiness.

**Research Flight Facility (Miami, Fla.).**—In conjunction with the FAA and NHRL the RFF performed a contingency program to determine the operational capability of the Omega navigation system for civil aviation. During the program the RFF recorded Omega phase data and processed these data for analysis of the phase variation of the Omega signal, and of the frequency difference as derived from the two basic frequencies. Additionally the RFF performed flights to evaluate the performance of the Omega system during periods of precipitation, and static conditions.

**National Ocean Survey.**—The National Ocean Survey (NOS) plays a key role in the management and use of the national airspace through the publication of aeronautical charts. The basic programs of NOS include the operational use of satellites for geodesy and precise navigation, research to determine the feasibility for using satellite techniques to perform assigned tasks, and operational aerial photography for charting and coastal mapping.

**Aeronautical Charts.**—Advancing technological developments for the management and use of the National Airspace System placed increasing demands on the NOS for aeronautical charts and navigational information.

At the request of the Federal Aviation Administration, a Controller Chart Supplement was prepared for computer processing and 28-day updating. This contains an Airway Fix File listing each airway from terminal to terminal, and the geographic position of each fix along the airway. These data are an important aid to air traffic control and are the beginning of essential input to automation in the control tower and in-flight navigation systems.

This introduction of Area Navigation techniques required new chart graphics. A new series of High Altitude Enroute Area Navigation Charts was first published in April 1971. Instrument Approach Procedures based on Area Navigation were added to the chart inventory.

A milestone of 1971 was the completion of the Sectional Aeronautical Chart series to common specifications for both civil and military aviation use. The last chart, Seattle, was published in July.



**Geometric Satellite Triangulation.**—Data acquisition for the North American Densification Program of satellite triangulation was completed at the following stations: Shemya, Cold Bay, and Pt. Barrow, Alaska; Moses Lake, Washington; Valkaria, Florida; Cambridge Bay and Whitehorse, Canada; Bermuda; and Puerto Rico. At yearend, field teams were conducting observations in the United States, Canada, and Greenland. This final phase of field operations will terminate in April 1972.

Computation and analysis for the Worldwide Program of Geometric Satellite Triangulation continued during the year. Publication of results is scheduled for mid-1972. International acceptance of this Program as a unified reference system relating all major land masses to  $\pm 10$  meters is a primary goal.

Investigations are being conducted into the use of Doppler satellite tracking methods that have a potential utilization within the NOS. As part of these studies, cooperative field operations with the Department of Defense are in progress to test the geodetic positioning capabilities of a new version of Doppler tracking instrumentation. Further evaluation of satellite navigation receivers was also made.

**National Data Buoy Project (NDBP).**—This project was established for the purpose of developing a national capability to deploy and operate networks of automatic buoys to retrieve useful information describing the marine environment on a reliable, real time basis. The basic concept of the National Data Buoy System involves the use of a number of buoys, of one or more types, moored or drifting in the deep ocean in a systematic array. The buoys will be equipped with sensors to measure environmental parameters and will use direct or satellite radio links to transmit the coded data to shore stations for dissemination to data processors and users.

In 1971, the NDBP progressed through the preliminary and contracting stages of procuring data buoys of various designs and with associated instrumentation for use in the Engineering Experimental Phase (EEP) of the program. The EEP will entail intensive critical analysis of the hardware under consideration for use in the resulting National Data Buoy System. This year was, primarily, a time of procuring hardware for test and evaluation, preparing for the deployment of developmental hardware, and the continued evaluation of data needs, uses and benefits.

**National Marine Fisheries Service (NMFS).**—The National Marine Fisheries Service plays a major role in the development and utilization of national fishery resources. NMFS vessels, laboratories, and offices located throughout the nation are involved in this mission. The mission is to discover, describe, develop, and conserve the living resources of the oceans, particularly those that affect the economy, food sup-

plies, and recreation of the United States. To this end the NMFS conducts biological and ecological research on the living marine resources and their environment and analyzes the economics of both commercial and recreational aspects of fishing operations. It develops methods for improving catches and the products through technological products. NMFS is deeply involved in the environmental aspects of the oceans and estuaries through research on, and by reviewing the effects of, pollutants and development programs on marine resources. An extensive aquaculture program is carried out, particularly in salmon under the Columbia River Fishery Development Program. A joint enforcement and surveillance operation is conducted in conjunction with the Coast Guard both in territorial waters and in the high seas on both foreign and domestic fishing fleets.

**Remote Sensing Program.**—The marine environment determines the activity and movement of ocean creatures. In the past, measurements of the marine environment were of necessity limited to those that could be acquired by ships and shore stations. However, the development of remote sensors has made possible a more efficient and effective method of acquiring detailed, timely measurements of certain parameters over large areas of the ocean. The NMFS, through an agreement with NASA, is carrying out a program to assess the value of remote sensing to its mission. This is being done at the NMFS Remote Sensing Program at NASA's Mississippi Test Facility.

During this past year, the applicability of spectrometers and image intensifiers to fisheries has been extensively tested. A 25,000-gallon-live-fish test tank was built at MTF and various species and concentrations of fish were studied with the spectrometer. The instrument was then flown over schools of fish in the Gulf of Mexico and off California. Preliminary data is not encouraging, but the analysis is continuing.

Low-light-level image intensifiers have been flown over calibration targets at MTF and over the Gulf of Mexico and waters off Oregon and Washington. The instrument, which magnifies the light given off by minute organisms in the presence of fish, has definite promise as a fisheries tool. Major drawbacks are its requirements for clear, dark nights.

Airborne photography techniques are in a continuing state of development with present emphasis on selecting the proper types of films and filters for each need. Lasers will join the testing program during this coming spring.

A joint program between NASA and NMFS related to the development of instrumentation and sensor systems to gather data from spacecraft during the proposed Earth Resources Technology Satellite (ERTS) and Skylab (EREP) programs has been proceeding rapidly. Two NMFS proposals for ERTS/EREP were

submitted and have been selected by NASA for funding. The experiments will study the Mississippi River plume and eddy currents associated with islands in the Caribbean.

NMFS also is utilizing surface temperature patterns of the oceans from infrared data obtained by NOAA's Environmental Survey Satellites as part of a general program relating space-acquired oceanic data to the NMFS requirements relating to assessing, monitoring, and managing marine resources and their environment.

### Office of Telecommunications

The Office of Telecommunications is responsible for an extensive program of telecommunications services, economic and policy analyses, and technical and analytic support for the Office of Telecommunications Policy (OTP) in the Executive Office of the President. The Office of Telecommunications operates as a primary unit in the Office of Assistant Secretary of Commerce for Science and Technology.

Office of Telecommunications studies have practical applications to aeronautic and space technology in areas of navigation, communication, remote sensing, and technical input to support policy considerations in frequency assignments. Work during 1971 included:

**Radio Navigation Systems.**—Office of Telecommunications (OT) is evaluating features affecting the accuracy of Loran A, C, and D navigation systems. These systems operate primarily in the medium frequency band (1900 kHz for Loran A) and the low frequency band (100 kHz for Loran C and D). They are pulsed systems, primarily using ground wave propagation. Over sea water accuracies of a few hundred feet are attainable. Over rough or irregular land however, the accuracies are greatly reduced and errors of a few thousand feet may be experienced. Evaluation of methods of predicting or reducing these errors is being continued.

**Compatibility of Aircraft Collision Avoidance and Radio Altimeter Systems.**—OT has investigated the practicality of sharing the 1600 MHz aero navigation band between collision avoidance systems and radio altimeters. Radio altimeters operating in this band are very common. Collision avoidance systems, which offer great potential for avoiding mid-air collisions, are new and have, as yet, received little use. The investigation shows that there will be major problems in sharing the same band on the same aircraft since pulsed altimeters may prevent the collision avoidance system from giving the proper warnings when appropriate. The problem may also occur even when the two systems are on different aircraft in proximity to each other.

**Radio Channel Requirements for Air Traffic Control.**—OT has examined air traffic control require-

ments for radio channels. The growth of air traffic in the last few years suggests that in the near future many more radio channels may be needed than are currently available. This projection is based on the assumption that each aircraft talks continuously to its controller and that the aircraft are located at the worst points from the view of causing interference to each other. The recent work attempts to take a more realistic view of the situation by considering the intermittent nature of the communication, and by taking account of the fact that the aircraft locations in the service volume are statistically distributed. Models have been developed which show that these factors will somewhat reduce the need for more channels.

**Use of Microwave Line-of-Sight Links for Transmitting Air Traffic Control Radar Data.**—OT has shown that outages which occur in the microwave links used to transmit air traffic surveillance radar data to controllers can be greatly reduced by using space (or frequency) diversity, without requiring higher transmitter power or more but shorter communication links.

**Improvement of Instrument Landing Systems.**—Aircraft instrument landing systems are vital for allowing landings to occur in a fog or heavy rain when the strip cannot be seen. Existing and new systems can yield inferior results because of reflections from buildings and because of atmospheric effects. OT is working on methods to reduce reflection effects, and has examined some of the problems which are involved in going to frequencies as high as 15 GHz to obtain higher precision. The conclusions are that for greatest reliability in heavy rain, a frequency less than 6 GHz should be used, but within 1-2 miles of touchdown a frequency as high as 15 GHz could be used to provide precise runway alignment or flareout information.

**Satellite Communications.**—OT is working on several problems associated with satellite communication systems. These involve interference between satellite and terrestrial systems sharing the same band, and questions concerning the use of very wide band digital transmission through the atmosphere.

Work has been done in methods for estimating the interference caused by rainfall occurring in a common volume visible from both satellite earth stations and terrestrial stations. The work has been both experimental and analytical and was used as the basis for international regulation in this area. Other completed work has produced methods for estimating the interference between satellite and tropospheric scatter communication systems.

Measurements have also been made of the electromagnetic environment of proposed earth terminal locations near large metropolitan areas for the NOAA Geostationary Operational Environmental Satellite (GOES) system.

***Ionospheric Modification.***—OT has completed a very high power (2MW–CW) high frequency radio transmitter and directive antennas at Platteville, Colorado. These are being used to examine the effects of high power electromagnetic fields on the D, E, and F regions of the ionosphere. Experimental observations indicate that the transmissions cause major modification in the ionosphere. Electron density profiles and collision frequencies are changed and large irregularities are produced. Many of the results are totally unexpected and when explained will contribute significantly to ionospheric theory and the theory of plasmas.

***International Cooperation.***—OT staff participated in U.S. National Committees of the International Radio Consultative Committee (CCIR) and also provided the chairmen of three of these committees. Staff also contributed to the work of the International Telegraph and Telephone Consultative Committee (CCITT) and the Scientific Committee for Antarctic Research (SCAR). Contributions to the World Administrative Radio Conference held in 1971 were embodied in the revised regulations for space systems which are now being promulgated. Other international bodies that staff has participated on are the International Radio Scientific Union (URSI), the International Union of Geodesy and Geophysics (IUGG), the NATO Advisory Panel on Radiometeorology, and the International Committee on Solar Terrestrial Physics.

### **Maritime Administration**

The Maritime Administration has completed the first phase of a program directed towards the use of synchronous satellites for improved navigation, communication and surveillance of commercial ship operations. The results of the initial phase indicate significant cost and operational advantages can be obtained by implementing this program.

The recent allocation of the 1971 International Telecommunications Union World Administrative Radio-frequency Conference on Space Techniques of 15 MHz in the "L" band (1600 MHz) region for exclusive maritime mobile satellite application supports the direction of the Maritime Administration program. Experimental communications and position determination studies undertaken by the Maritime Administration have previously proven the technical feasibility of using "L" band systems for commercial maritime applications.

The current second phase of the Maritime Administration program calls for the development and fabrication of ten shipboard transmitting and receiving systems to be operated by ships of opportunity in conjunction with a shore-based Maritime Coordination Center using current NASA ATS 1, 3, and 5 satellites. This Center will have the capability of providing

realistic data relating to maritime traffic advisory/control as well as facilitating accurate navigation and reliable communication services.

### **National Bureau of Standards**

The goal of NBS is to strengthen and advance the Nation's science and technology and to facilitate their effective application for public benefit. In working toward this goal, the Bureau pursues a wide range of activities, including many projects in space and aeronautics, in its three major institutes: the Institute for Basic Standards, the Institute for Materials Research, and the Institute for Applied Technology.

#### **Institute for Basic Standards**

***Lunar Ranging Analysis.***—Apollo 11 and 14 missions placed retroreflector packages on the moon for determination of the rotation, polar motion, and large scale crustal movements of the earth as well as data on the lunar orbit and its librations. NBS is participating in the Lunar Ranging Experiment Team which advises NASA on the conduct of the experiment and performs analysis of the ranging data. Major progress was made this year in analyzing the difference between calculated and observed ranging distances to the retroreflectors. Improvement in the models used in calculations has resulted in fits of 15 meters accuracy, compared with initial range uncertainties of roughly 300 meters. NBS work supplements the primary analysis being performed at the Jet Propulsion Laboratory and the University of Texas.

***Astrophysics of Stellar Atmospheres.***—NBS scientists conduct theoretical studies of stellar atmospheres and particularly of the solar atmosphere. These studies are complemented by an observational program carried out jointly with the University of Colorado and Sacramento Peak Observatory. Specific efforts this year included solution of the radiative transfer problem in extended, spherical gaseous systems, a problem which has been outstanding since the early 1930's. Application of this solution to Rayleigh scattering spherical systems has shown that the degree of polarization of the radiation escaping at large angles to the normal will be close to unity, a fact of considerable interest in the interpretation of certain eclipsing binary stars. Also solved this year was the problem of nonradiative transfer of energy by the drift of excited atoms which accompanies ordinary radiative transfer. NBS completed formulation of a new approach to the structure of stellar atmospheres, wherein nonequilibrium departures from the classical atmosphere are described in terms of population and transfer effects. In cooperation with scientists from Harvard and the California Institute of Technology, theoretical calculations are being compared with data from the 1970 solar eclipse

in order to determine a new model for the solar chromosphere.

**Microwave Spectroscopy.**—NBS work in microwave spectroscopy is used by radio astronomers in identifying observed emissions from molecules in interstellar space. This year NBS laboratory measurements led to positive identification of methyl alcohol, which had been observed and misinterpreted, formamide, and cyanoacetalene. The latter measurements were an order of magnitude better than previously available values, allowing identification of Doppler shifts for accurate location of the molecules in moving clouds; this will allow correlation with other molecules and investigation of the chemical dynamics of those clouds. Data on various isotopic forms of hydrogen cyanide have been accurately measured and are being used as references by radio astronomers. The NBS measurements on thioformaldehyde, published last year, were used to make astronomical searches for that molecule; the fourth attempt, at the Parkes Observatory in Australia, was finally successful this year.

A radio astronomy data center has been formed to critically evaluate both laboratory data and observations on all 20 molecules that have been detected in interstellar space. Formamide, formaldehyde, thioformaldehyde, and methyl alcohol were completed this year.

**Calculations of Energy Deposition.**—NBS has developed computer programs, under NASA sponsorship, that use Monte Carlo techniques to calculate energy transport and deposition. Three dimensional luminosity patterns for natural and artificial auroras were calculated and corroborated by comparison with observations. The same calculation techniques were used to evaluate response functions of sodium iodide detectors carried on the Apollo 15 mission. NBS is participating in the analysis of the lunar gamma ray data obtained on that mission.

**Laboratory Astrophysics.**—NBS conducts extensive research programs in atomic and molecular physics and the interaction of radiation with atomic and molecular systems. Much of this work is in direct support of investigations of stellar and planetary atmospheres. Integrated theoretical and experimental efforts include collisional excitation, dissociation, and ionization studies; radiative transfer and radiative dissociation measurements; and spectroscopic work in the microwave, infrared, visible, and ultraviolet regions of the spectrum. Specific achievements included measurements of cross sections for dissociation of negative ions of oxygen molecules, cross sections for hydrogen ion dissociation, determination of excitation cross sections for the Fraunhofer lines of sodium and calcium and line broadening parameters for the calcium H and K lines. Infrared, visible and ultraviolet spectroscopic studies included investigation of dimers of water and other molecules of

possible importance in planetary atmospheres and measurement of parameters of molecules of importance in the sun and interstellar space such as water, carbon monoxide, and thioformaldehyde.

Careful experimental determination of Stark shifts in the Balmer lines in hydrogen may modify the currently held theories of white dwarf stars. The new values are larger than previous measurements, reducing the amount of the observed red shifts that can be attributed to gravity. The magnitude of the red shift due to gravity is used to calculate the mass of these stars.

**Cryogenic Data and Engineering Support.**—NBS provides basic data and engineering services to NASA, the Defense Department and aerospace contractors for cryogenic systems used in spacecraft for fuel cells and propulsion fuel storage. Work proceeds on thermodynamic, electromagnetic, and transport properties of cryogenic fluids, mechanical and thermal properties of materials at cryogenic temperatures, measurement techniques and instrumentation, and safety procedures and standards. For example, NBS is providing consultation and advisory services to the joint NASA-AEC Space Nuclear Systems Office and its contractors—the Aerojet General Corporation and General Dynamics/Fort Worth Division—in support of the NERVA nuclear rocket engine program. Another NBS project is to develop, under NASA sponsorship, the technology for handling slush hydrogen as a space vehicle fuel.

**Calibration and Measurement Services.**—NBS develops basic measurement techniques and provides calibration services for NASA, the Defense Department, and industry. Many of these services are in direct support of NASA and Defense Department aerospace activities in the areas of communications, optical systems, temperature measurements, and mechanical measurements. Specific services included antenna standards, electromagnetic radiation shielding tests, development of noise sources for microwave telecommunications and radar system calibrations, load cell calibrations for rocket engine thrust measurement, fatigue studies of sealing type aircraft fasteners, studies of mechanical properties of composite materials for aerospace applications, high temperature thermocouple evaluation and calibration, development of a wall stabilized arc for ultraviolet radiometric calibrations for the Apollo Telescope Mount Space Station (Skylab), development of vacuum ultraviolet transfer standards, and far ultraviolet and x-ray calibrations of detectors for astronomical observations by balloon, rocket, and satellite.

#### **Institute for Materials Research**

**Specular Spectral Reflectance Standards.**—NBS has developed a set of specular spectral reflectance standards for calibration of reflectometers used to evaluate

thermal radiation properties of materials. Knowledge of these reflection properties is essential to balancing spacecraft heat loads.

**Chemistry of the Stratosphere.**—The possible chemical reactions between the exhaust gases of high flying aircraft and the natural constituents of the stratosphere have been surveyed by NBS. Photochemical processes control the composition of the stratosphere. They are responsible for formation of the ozone layer that filters out harmful ultraviolet radiation. Exhausts from high flying aircraft will introduce small quantities of chemicals, such as water, carbon dioxide and the nitrogen oxides, that might react with ozone and change the ozone shield. Data on speeds of these chemical processes are needed in models that can predict the chemical dynamics of the stratosphere. NBS is preparing a summary of the best available values for rates of these reactions, has identified systems on which experiments must be made, and is undertaking studies to obtain needed data not currently available.

**Thermodynamic Properties of HNS.**—Results of NBS studies of thermodynamic properties of hexanitrostilbene (HNS) have found application on the Apollo missions. This explosive substance is used in the landing gear of the Apollo Lunar Lander and as a source of shock waves for seismic studies. It has very good keeping qualities for the hostile environment of the moon because of its stability and very low vapor pressure. The enthalpy of combustion and enthalpy of formation necessary for predicting its explosive properties were determined at NBS.

**Analysis of Apollo Lunar Samples.**—Several specimens collected on the Apollo 12 and 14 missions were analyzed at NBS in cooperation with NASA-Goddard, using electron microprobe equipment and techniques specially developed at NBS. These procedures provided important information on the identity and distribution of mineral phases in the specimens.

Analyses for some 12 elements on the same sample have been completed with precise and accurate isotopic ratios and assays having been obtained. Important results to date indicate that those elements which show constant isotopic ratios in terrestrial materials also do so in the lunar materials examined. Confirmation has been obtained of an older component in lunar soils which gives apparent lead-uranium ages of 4.88 billion years. As found previously, rubidium-strontium ages in the soil tend to be distinctly younger.

Mossbauer spectroscopy was applied to the determination of site occupancy factors in certain lunar minerals through cooperative work by NBS and NASA Goddard. Apollo 12 powdered samples were separated into a variety of crystal phases and samples of orthopyroxenes and pigeonites were studied by Mossbauer spectroscopy. This technique appears to be the best

available for determining site occupancy in this type of material.

Metallic inclusions and other metal particles in Apollo 12 lunar soil were studied cooperatively by scientists from NBS, Lehigh University and NASA. The microstructure and chemical differences between metals of lunar and meteoritic origin found in Apollo 11 and 12 soil samples was investigated. Samples of meteorites from Meteor Crater, Arizona were included to compare their microstructure with that of meteorites found on the moon. A criterion for determining whether metal in the lunar soil was indigenous or of extra-lunar origin was developed. This criterion has been applied successfully to Apollo 12 and Apollo 14 specimens.

**Effect of Zero Gravity on Crystal Growth from Melt.**—In zero gravity temperature gradients in a melt would not be expected to create convective flow. This condition may then make it possible to produce more perfect single crystals. NBS scientists have developed a method to study the degree of perfection in single crystals by means of dynamical diffraction of X-rays. At the request of NASA this method is being applied to melt grown single crystals to determine crystal perfection under various conditions of liquid flow in the melt.

### **Institute for Applied Technology**

**Evaluation of Battery Cell Separator Materials.**—NBS is developing test procedures and techniques for NASA for evaluation of polymeric separator materials for nickel-cadmium batteries used as power sources in space applications. Some of these separator materials have failed in operation before completing their designated cycling times.

**Aerospace Fire Safety.**—NBS is charged with developing the fire safety portion of the NASA Aerospace Safety Research Data Institute on-line information storage and retrieval system. Reports, journal articles, and other documents related to aerospace fire safety and hazards have been evaluated, catalogued, abstracted, indexed, and reviewed. A state-of-the-art report is being prepared on fire extinguishment in oxygen enriched atmospheres under normal and reduced gravity and for both hyperbaric and hypobaric conditions.

NBS has in the past performed experiments on fire growth in model enclosures and made extensive investigation of smoke and gases produced by aircraft interior materials. These data are helpful in evaluating potential hazards of various materials, but the complex phenomena of flashover as it might relate to aircraft cabins is not well defined. Flashover appears to involve gas phase combustion reactions from the products of thermal decomposition of solid organic materials within the cabin enclosure. NBS is using carefully designed laboratory models to analyze the flashover problem and

to obtain precise quantitative data on combustion products and reactions.

**Telemetry-Transistor Wire Bond Reliability.**—NASA-Marshall Space Flight Center recently requested NBS assistance in the identification and correction of the mechanism of wire bond failure in a transistor used in a telemetry application. Failures occurred after about 1000 operating cycles in many samples; some were not so affected. NBS investigations suggested that control of wire bond loop height should reduce the thermal and mechanical effects leading to the failures. Successful implementation of these controls by the device manufacturer has reduced the failure rates as shown by tests underway at NASA where, at last reporting, devices had passed 41,000 cycles without a failure.

**Semiconductor Nuclear Radiation Detectors.**—NBS has assisted NASA-Goddard Space Flight Center in pre-flight testing of commercial semiconductor nuclear radiation detectors intended for experimental applications on IMP and Pioneer space packages. Studies of long-term damage effects on detectors by nuclear radiation of the type found in trapped planetary radiation

belts and nuclear power sources have been performed for NASA Goddard. It has been shown that some types of damage effects can be minimized by keeping the detector constantly under an applied electric field. Measurements are also underway to determine the possible effects of chemical reaction products from spacecraft control thrusters on semiconductor performance and life characteristics. The end purpose of these various measurements is to improve existing methods of predicting long-term performance of semiconductor nuclear radiation detectors in space in order to aid in detector selection for the Grand Tour mission.

**Aircraft Landing Instrumentation.**—Under support by the Naval Air Systems Command, NBS is developing and improving instrumentation to aid in aircraft landing: instrumentation for measuring and displaying wind speed and direction to assist in the control of carrier-launched aircraft; instruments for measuring atmospheric haze at airports by means of a pulsed-light backscattering principle; and a see-through sighting and indicating console to present the carrier-deck landing officer with simultaneous visual and digital information needed in his control of approaching aircraft.

XII



## United States Information Agency

### Introduction

The U.S. Information Agency maintained a high level of activity in projecting United States space operations and accomplishments during 1971. In carrying out NASA's public information functions overseas, Agency officers noted that the demands of foreign audiences for information, which had slacked off somewhat in earlier Apollo missions, again rose to a peak with Apollo 15. USIA was already directing its efforts towards telling the story of Skylab and the space shuttle, the manned programs which would follow Apollo in the seventies. The practical benefits of space exploration, and the ways in which these affect man on Earth continued to be stressed. So were NASA's cooperative arrangements with the U.S.S.R. to develop a mutually compatible docking system.

The Agency initiated and assisted in a five-country Presidential good-will tour of Europe, carried out November 6-21 by the Apollo 15 crew. Unlike previous astronaut tours, this one focused chiefly on the scien-

tific results of the mission, which had been extraordinary. To convey these to the scientific community, round-table sessions with up to two dozen of the most eminent scientists from the disciplines supporting lunar exploration, were convened. After a slide presentation, the lunar explorers were questioned first-hand on their findings by geophysicists, cosmologists, physiologists, geologists, astronomers, and lunar rock experimenters who were seated with the crew. The astronauts gave such a presentation at Cambridge University and before the Royal Society in London, before the Academy of Engineering in Stockholm, and before selected scientists in Munich, Milan, and Paris. The crew also addressed university audiences, held press conferences, and appeared on national television in England, Sweden, Germany, Italy, and France. It was one of the most successful of astronaut tours, and the appearance of the crew before the assembled scientific community of European countries was a measure of how far scientific exploration under Apollo had come.

## Radio

The 10th anniversary of the United States in space was commemorated in a special Voice of America documentary narrated by Alan Shepard. USIS posts in 45 countries ordered the feature for placement with local radio stations. Another VOA English special, "The First 'A' in NASA," reported on aviation research projects carried out by the Agency.

English and language services broadcast and distributed for local placement a wealth of interviews with scientists and engineers involved in the space program. The Bulgarian Service interviewed a California physicist on Apollo 14 instrument design while VOA Mandarin invited five Chinese-American scientists to participate in its broadcasts. Professor Hermann Oberth, the distinguished pioneer rocket scientist of West Germany, commented on the importance of lunar exploration for a Romanian broadcast, and Dr. Wernher von Braun discussed space plans for the seventies in an English science series.

The U.S.S.R. Division gave full play to the Lunar Science Conference in Houston and to developments in U.S.-Soviet space cooperation. Russian broadcasts in April offered comments by NASA Acting Administrator George Low, Manned Spacecraft Center Director Robert Gilruth and Astronaut Neil Armstrong. Astronaut Edwin Aldrin also joined VOA's Russian language correspondent at the mike during Apollo 14 to recall his pleasant association with Soviet cosmonauts Nikolayev and Sevastyanov and to acknowledge the congratulatory message from Soviet cosmonauts.

All VOA services carried world reaction to the tragedy of the Soyuz 11 cosmonauts and provided a constant flow of features and news reports on other significant space developments. The Mariner-9 voyage to Mars, the Earth Resources Technology Satellite, and Skylab were all treated by the Voice.

The Voice provided fullest coverage of the Apollo 14 and 15 missions to world audiences. This included pre-flight interviews with the astronauts and key members of mission control, live broadcast of the flights with commentary by Astronauts Edwin Aldrin and Fred Haise, and extensive follow-up on the scientific achievements of the missions. Special broadcasts in Chinese, Russian, Spanish and Portuguese reported live on major flight events while all 36 language services carried full news reports and features on flight progress along with on-the-scene news from VOA's multi-lingual correspondent teams at Cape Kennedy and Houston. VOA Spanish and Portuguese broadcasts of the Apollo 14 missions were relayed by 1,017 stations in 16 Latin American countries, reaching an estimated 35 million listeners.

### Press and Publications

The two Apollo flights in 1971 received special attention from the Agency's press and publications service.

Special feature packets of articles on the scientific importance of the missions, backgrounders on the astronauts, explanations of the ALSEP packages and Lunar Rover—all accompanied by appropriate photographs and drawings—were on the desks of editors, science writers and radio and television space specialists well before launch. USIA reporters filed wireless stories from Cape Kennedy and Houston during the flights and followed up with post-flight analyses of moon rocks and other data obtained by the missions.

Responding to a need for material on U.S. space plans for the future, USIA writers produced a variety of stories on Skylab, the space shuttle and the planetary Grand Tour proposed for late in the decade. Mariner 9 was the subject of numerous wireless file items and features, while the Agency expedited shipment of the pictures taken by the Mars orbiter to all posts as they became available. Other subjects treated included the INTELSAT Agreement, plans for educational TV satellites and the Earth Resources Technology Satellites.

U.S.-Soviet cooperation in space was treated in stories based on talks at Moscow and Houston and interviews with the NASA officials involved. USIA press materials also noted many examples of cooperation between NASA and other countries, such as the distribution of lunar samples for investigation by foreign scientists, and NASA's role in providing rocket boosters and other assistance for the Italian San Marco project.

USIA's Russian-language *America Illustrated* magazine carried a variety of features and photographs on space, including "The Giant Harvest from Space—Today and Tomorrow," "Moon rocks—What Scientists are Learning from Them," "The Great Promise of Zero G" (on the potential for manufacturing in space), stories on Apollo 14 and 15, and a feature on TV coverage of lunar exploration.

Articles on the future of the space program, the promise of space, lunar rocks and space-age communications appeared in *Topic* and *Al Majal*, the Agency's magazines for readers in Africa and the Arab world. These and other space stories were used by Agency periodicals in Britain, India, Pakistan, Iran, Yugoslavia and East Asia.

In pamphlets, the Agency's major effort was a 24-page, color-illustrated publication, "America in Space: The 1970's," which featured an interview with Wernher von Braun on space travel in the seventies. Soon after the missions USIS posts abroad were distributing leaflets on Apollo 14, and an Apollo 15 pamphlet, "Three Days on the Moon."

### Motion Pictures and Television

Overseas viewers continue to exhibit the greatest interest in new films and television programs on space.

USIS posts requested 28 language versions and 491 prints of the NASA Apollo 14 half-hour color documentary adapted by USIA. The Apollo 15 film is meeting a similar response. Older space films including the Agency's special film on the first moon landing, "The Infinite Journey," and "Project Apollo," and NASA films on Apollo 8-through-14 missions were used repeatedly during Apollo 15 on foreign TV and in direct projection screenings. A tally shows that space films provided by USIA have now been shown in 150 countries.

The number and type of USIA satellite-beamed television programs grew considerably. Twenty-three programs were transmitted abroad via satellite. The Agency initiated a monthly discussion series on various aspects of U.S.-Japanese relations that were seen widely in Japan. Two pilot programs, one featuring an interview with Dr. von Braun, were broadcast to Argentina. A test program was transmitted to the new receiving station in Morocco. A USIA special program inaugurated the Congo, Kinshasa, receiving station in June. The monthly satellite show to Brazil, "First Friday," included interviews with Astronaut Edwin Aldrin and Dr. von Braun.

The Agency continued to distribute NASA Aeronautic and Space Reports and film clips to USIS posts for use in telecasts and newsreels abroad. USIA's Science Report, sent to 78 countries monthly for use on television and in schools, featured Apollo 14, the Lunar Science Conference, Mariner '71 and Apollo 15. A half-hour documentary "Windfall from Space," describing the practical results of space exploration, was produced by USIA for Latin America but distributed world-wide to help meet the need for material on the benefits of space exploration. Another documentary, acquired from NASA, "Seeds of Discovery," telling the story of various scientific discoveries that made the space program possible, has been adapted into four language versions at the request of USIS posts overseas. In addition to acquiring and distributing NASA films, USIA maintains a film library in Rome stocked with NASA films for loan to universities, schools and television stations in Europe.

During Apollo 14 and 15, representatives of the Agency's motion picture and television division assisted foreign TV producers and newsmen from 19 countries at Cape Kennedy. Commentaries and interviews were filmed for use on the newsmen's home TV stations. This Agency service is provided for those foreign media who do not have camera and sound equipment at the scene.

### Information Centers and Exhibits

USIA space exhibits continue to be in demand at fairs, museums, and universities and schools. With the cooperation of the Smithsonian Institution the Apollo

10 and 12 Command Modules, the Gemini 12 spacecraft and other assorted space artifacts have been widely toured and displayed. Reports from USIS posts attest to the tremendous impact of flight-tested hardware as exhibit items. The six small moon rock specimens on loan to the Agency from NASA had been viewed by almost 7 million people in 14 countries during the first half of 1971 and were reserved for showings as much as six months in advance.

The exhibit, "Man in Space," at the Belgrade Cosmos Space Fair was the largest and most complete of the 1971 U.S. space exhibits, and possibly the finest space exhibit yet seen abroad. Featuring the Apollo 12 Command Module, full-scale models of the Lunar Rover, the Skylab living quarters, and other space items, the exhibit used special design, lighting and sound to create a space-like environment which obviously fascinated viewers. The presence of Astronaut Thomas Stafford lent added interest.

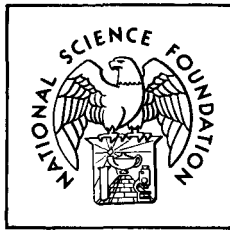
In late October the Apollo 10 Command Module completed a 10-city tour of the United Kingdom. Accompanied by display panels and a 40-frame exhibit of postage stamps issued by foreign countries in honor of the U.S. space program, the Command Module was viewed by more than 277,000 persons.

The U.S. exhibit at the Kinshasa Trade Fair told the story of space satellite communications to some 307,000 visitors. Full-scale mock-ups of the Lunar Rover and part of Skylab were displayed at the German Industries Fair in West Berlin and at the Budapest and Plovdiv International Trade Fairs. Staged on a somewhat smaller scale, eighteen Agency traveling space exhibits circulated among posts in five world areas. The exhibits included 1/3-scale models of the Apollo Command and Lunar Modules, a life-size simulated space suit worn by a manikin, an 8-foot Saturn V model, space photos, a panel exhibit on "Space Benefits," a Telstar satellite model and a stamp exhibit entitled, "Africa Honors Apollo."

On July 26, when Apollo 15 lifted off the pad, the Netherlands' Minister of Education officially launched the "Moonrock Express," a space exhibit train that was to tour 36 Dutch cities. The train, carrying a moon rock, numerous space artifacts, models and photographs, attracted visitors from all walks of life, but was particularly welcomed by teachers and their school classes. By the end of the year the Moonrock Express tour had been extended to German cities, and plans were in preparation for tours of parts of Italy and Switzerland.

During 1971 USIA published translations of 11 books on space, in Burmese, Spanish, Thai, Bengali and Portuguese, which totaled 46,000 copies. In response to world-wide field requests the Agency has distributed 15,000 copies of its space science reader "The Apollo Story: Footprints on the Moon," used for English teaching.





### Introduction

The National Science Foundation contributed to the support of aeronautics and space sciences through a number of its programs in 1971, principally individual research projects, the polar research programs, and a variety of educational programs including institutes and fellowships. Most of the research work supported by the Foundation in the aeronautics and space sciences is carried out by investigators affiliated with U.S. colleges and universities, many of whom use the specialized facilities available at the national research centers or the unique facilities of the Antarctic continent.

**Solar-Terrestrial Research Program.**—The outer reaches of the solar atmosphere, the interplanetary plasma, and the earth's magnetosphere are concerns of solar-terrestrial research. The normal sun continuously forces out from its surface a flow of charged particles—the Solar Wind. Intermittently, much smaller numbers of particles in disturbed solar regions are accelerated to high energies, by mechanisms not yet understood, and are spewed into space. A large part of the program is devoted to these particles and their interactions. Optical and radio studies of the dynamics of the atmosphere are supported. Investigations of the Solar Wind which use cosmic rays as a probing tool are funded. Observational and theoretical research on the interaction of the Solar Wind with the earth's magnetosphere and the atmospheres of other planets are sponsored. Major attention is also devoted to the earth's magnetosphere and particles in it. Trapping and release of particles, wave-particle interactions, currents and magnetic fields, are all associated with spectacular aurora, magnetic storms, interference with radio, long-line telephonic communication, and with surges on large power networks. Progress was made during the year on the study of the structure and stability of the magnetosphere and the trapping and release processes.

**Aeronomy Program.**—The region from the stratosphere to the magnetosphere on the earth and other planets is generally associated with Aeronomy. The Foundation supports theoretical, and field studies of aurora and laboratory studies of the interactions taking place in aurora. The most powerful single tool for studies of the ionosphere, located in this same

altitude region, is the incoherent backscatter radar. Studies of this region, of importance to radio communication, have been supported in tropical, subtropical, temperate and polar latitudes with this tool. The chemistry and physics of the ionosphere is complex, and each latitude region has distinctive features not yet clearly understood. For instance, the need for understanding neutral winds at altitude near 100 km is now becoming plain from radar backscatter and other studies. A three-prong attack—theoretical, observational and experimental—on problems of the normal ionosphere is funded. In the upper atmosphere of the earth, minor constituents play an important role—ozone in the stratosphere and nitric oxide in the D region. Modification or destruction of such constituents or the addition of others could conceivably have far reaching consequences. Studies of chemical reactions of possible importance in the upper atmosphere are supported. Tests of our understanding of the earth's atmosphere can be applied in the atmospheres of other planets, but for such tests data on the other atmospheres are required. A highlight of the year was the success of an observation of a star occulted by Jupiter giving information on the atmosphere of Jupiter.

**Meteorology Program.**—In meteorology, a wide range of investigations into the dynamical behavior of the atmosphere are supported. Our understanding of the formation of clouds and precipitation, and the air motions which accompany these processes, has been increased through a balanced program of laboratory experiments in the areas of fundamental cloud physics and numerical simulation of the clouds themselves by digital computer. Theoretical studies of clear air turbulence and of motions forced by airflow over surface topography have continued through the year. Studies of atmospheric motions on a larger scale have as their goal the building up of a reservoir of fundamental knowledge and technique that can be drawn upon to improve weather forecasting. Studies of this nature over the past year fall into the areas of diagnostic studies of actual weather situations, laboratory experiments in rotating fluid tanks, and numerical simulation by digital computer of large-scale weather patterns.

An exciting new area has been that of remote sensing. The continued development of lidar techniques and their employment in the field promise increased

understanding of the transport of water vapor from one place to another as well as of the formation and optical properties of haze and other particulates suspended in the atmosphere. The possibility of remote detection and subsequent tracking of severe storms and tornadoes by the monitoring of electrical and acoustic emissions has been raised as a result of several field studies made during the year.

**National Center for Atmospheric Research.**—During 1971, the National Center for Atmospheric Research continued its studies of the sun, the interplanetary medium, and the earth's atmosphere. A major portion of the observing resources of the High Altitude Observatory (HAO) of NCAR are devoted to measurement of solar prominence magnetic fields, which are important to all forms of solar activity. In solar-terrestrial physics, high altitude tidal winds and their interactions with the earth's magnetic field were also studied. Studies of the solar T-corona, which represents the thermal radiation of vaporizing particles precipitated into the neighborhood of the sun, suggest that these particles are composed of pyroxine or olivine. A detailed analysis, now in progress, of observations made at the 1970 total solar eclipse, should lead to an integrated model of the interplanetary particles including their mineralogical content.

The Apollo Telescope Mount (ATM) coronagraph, developed at NCAR with NASA support, is presently being integrated into the Skylab Program. One model of this instrument is now undergoing tests in Houston, while the actual flight unit is being integrated at the Marshall Space Flight Center in Huntsville, Alabama. NCAR has recently let a subcontract, under NASA funding, to the Ball Brothers Research Corporation to study the development of a rapid-response coronagraph, which would be included in the Skylab program.

An improved rocket-borne cryogenic sampler, which uses neon as the cryogen, is scheduled for launch in mid-December, 1971. It will bring back a whole-air sample from an altitude of 40–50 km for laboratory analysis. In cooperation with the Air Weather Service, NCAR has made a series of stratospheric flights to determine the concentration of sulfuric acid particles at levels of 20 km or higher. Data from these recent flights indicate that the number of particles in the sulfate layer has returned to a level approaching those of ten years ago. The increase in such particles in the past decade was probably attributable to the volcanic activity during that period. A somewhat surprising result has been the very large amount of nitric acid vapor in the stratosphere, which on occasion exceeds the concentrations of sulfate. Concentrations of a number of other trace constituents in the stratosphere, such as calcium, magnesium, sodium, chlorine and bromine, have also been determined. In cooperation with the AEC and the Air Force, NCAR personnel are presently engaged in a series of flights roughly along the

80th meridian from Argentina to Alaska which provides a unique opportunity to obtain a meridional distribution of stratospheric particles.

Advances in NCAR's lidar program have made it possible to obtain fairly regular observations of particles from the ground throughout the stratosphere, up to 50–60 km. An upward directed dye laser, installed in an aircraft in a joint effort with the University of Wisconsin, has permitted a survey of the distribution of particles up to about 30 km over a wide range of latitude. A joint project involving scientists from NCAR, the University of Michigan and the University of Wisconsin, using observations from NASA's OAO satellite, has produced new information on the distribution of ozone and molecular oxygen in the 60–200 km altitude range. Using the OAO-2 data on the occultation of stellar ultraviolet light, we have obtained high vertical resolution number density profiles of molecular oxygen in the 100–200 km altitude region. This experiment has shown the feasibility of obtaining high quality data on the composition of the upper atmosphere from polar orbiting satellites.

Work continues in developing worldwide observation networks, utilizing superpressure balloons and buoys which are interrogated by satellites. The Tropical Wind, Energy Conversion and Reference Level Experiment, (TWERLE), a joint experiment with NCAR, the University of Wisconsin and NASA-Goddard, funded by NASA, is an experiment using constant density superpressure balloons and a Nimbus-F satellite for data handling. The purposes of the experiment are: (a) to investigate upper tropospheric winds in the tropics; (b) to measure, as directly as possible, the conversion of potential to kinetic energy; and (c) to test a method of providing reference-level measurements which, when linked to infrared measurements from satellites, can provide at mid-latitudes a three-dimensional temperature-pressure field analysis.

**Astronomy.**—The discovery of new interstellar molecules has continued at a high rate with most of them found in the radio source near the center of our Milky Way galaxy. In some cases the molecular lines are anomalously strong in comparison with laboratory spectra and an interstellar maser action has been proposed as a mechanism to explain the enhanced line strengths. For the first time molecules were detected in a galaxy outside our own by a university group. Radio astronomers are now beginning to use the recently found line of formaldehyde for the mapping of spiral arms of our galaxy and the detection of large scale structure and rotation patterns. Formaldehyde offers better resolution, permits probing the conditions in interstellar dark clouds and the investigation of isotopic abundances of carbon and oxygen. Certain organic molecules, already detected in interstellar dust and gas clouds, are precursors to amino acids which

have been found in meteorites; but the connection, if any, between these phenomena is not yet understood.

**National Radio Astronomy Observatory (West Virginia and Arizona).**—The National Radio Astronomy Observatory (NRAO) maintains three major radio telescope facilities at Green Bank, W. Va. These include a three-element array of 85-foot diameter telescopes used as an interferometer; a 140-foot diameter fully steerable telescope; and a 300-foot diameter transit telescope. A 36-foot diameter millimeter-wavelength telescope is maintained at Kitt Peak, Ariz. There is heavy demand for observing time with these instruments by visiting radio astronomers and staff members of the observatory for a wide range of radio astronomy. The new surface for the 300-foot telescope extends the frequency coverage three fold and the provision of a travelling box for the feed near the focus permits longer integration times with this transit instrument. New improved receivers have been constructed with emphasis on spectral line work. A notable result during the year was the first detection of radio emission from a normal star, other than the sun. The red supergiant star Antares, a first magnitude star in the summer sky, was detected in the 11 centimeter wavelength range. In addition, several bright novae observed in the past few years were found to be emitting radio waves in the same range.

**Kitt Peak National Observatory (Arizona).**—Research is carried on in three principal fields—solar, stellar, and planetary sciences. In addition, major efforts are directed towards the design and construction of auxiliary instrumentation for use on telescopes and rockets. The observatory maintains seven telescopes for use of resident staff and visiting scientists: an 84-inch diameter general-purpose telescope; a remote control 50-inch telescope used mostly for photometric observations; two 36-inch photometric and spectroscopic telescopes; two 16-inch photometric telescopes; and the world's most powerful and versatile instrument for the study of the sun's surface and atmosphere—a 63-inch aperture solar telescope. A new 150-inch telescope is expected to be in operation in 1972. Instruments at both Kitt Peak and its sister observatory in the southern hemisphere on Cerro Tololo are used to study the composition and characteristics of stars within our own galaxy as well as of distant galaxies and objects in remote regions of the observable universe. The unique solar telescope facility has been particularly useful in the study of physics of the outer layer of the nearest star, our sun, and has resulted in a better understanding of solar-terrestrial relationships. The rocket program has contributed to the solution of important problems concerning the chemistry and dy-

namics of planetary atmospheres and stellar ultraviolet and x-ray sources. Using facilities at Kitt Peak, a staff member of the observatory found in 1971 the largest red shift yet observed, 80% of the velocity of light, for the quasi-stellar object 4C05.34. In its spectrum there is evidence of several intergalactic gas clouds lying between this distant object and the earth, from the several absorption line patterns observed.

**Cerro Tololo Inter-American Observatory (Chile).**—Six telescopes were in operation during the year and available to scientists and students with observing programs, with the largest a 60-inch reflector used in a wide variety of investigations including low- and high-dispersion spectroscopy, photometry, and wide-field photography. A 150-inch telescope is under construction and should be ready for use in 1973. This instrument is similar to the one under construction at Kitt Peak and is being jointly funded by the National Science Foundation and the Ford Foundation. Visitors and staff are conducting programs of research in photometric, spectroscopic, and photographic observations of the moon, planets, asteroids, stars, pulsars, gaseous nebulae, clusters, quasars, and galaxies, many of which are visible only from the southern hemisphere.

During the favorable opposition of Mars in August, Kitt Peak staff made high dispersion spectroscopic observations at CTIO for mapping the topography of Mars, supplementing the parallel radar observation by other astronomers. The excellence of the site for infrared observations has encouraged such work on southern hemisphere objects, including the flaring object Eta Carinae. Eta Carinae was the second brightest star in the sky during the nineteenth century but now has faded to be barely visible to the naked eye. Its present infrared output however, ranks it as the brightest object in the wavelength range, outside the solar system.

**National Astronomy and Ionosphere Center (Puerto Rico).**—The Arecibo facility was officially designated as a national center on October 1, 1969. A 1,000-foot diameter telescope is available to scientists and students throughout the United States. This unique facility consists of a fixed horizontal spherical antenna with an antenna beam that can be moved to angles of 20° in any direction. Radar research at the Arecibo Observatory has provided high spatial resolution maps of the moon and nearer planets, which are of great importance to space missions. Improved time resolution in the observation of pulsars, interpreted as rapidly rotating neutron stars of high magnetic field, have resulted in a better definition of detail for these phenomena. A particularly interesting pulsar (CP0950) frequently, though irregularly, emits a remarkably strong pulse of less than seven millionths of a second and at such times is momentarily by far

the strongest radio source in the sky and detectable on an ordinary television set.

**Engineering Division.**—The Engineering Division supports a broad spectrum of research programs related to aeronautics and space activities. In general, space related research support is provided in rarified gas dynamics, plasma dynamics, lasers and heat transfer which are fundamental to space-vehicle and space-communications applications. Support is also provided in earth-based problems and aeronautical applications such as wind effects on structures, unsteady wakes, transition and turbulent boundary-layers, dispersion of pollutants in urban areas, just to mention a few.

Fundamental areas of research supported include the effects of free stream turbulence on the drag of blunt and bluff bodies, experimental determination of molecular nonequilibrium parameters, and the structure of free turbulent vortex decay and breakdown. Specific engineering investigations have been undertaken in building aerodynamics such as the effects of tornado or wind loadings on structures, high efficiency jet separation processes, and solid particle dispersion in the lower atmosphere. Research is also supported in direct energy conversion including thermionics, thermoelectrics, and magnetohydrodynamics. If the efficiency of these processes can be improved, alternate sources of energy may be possible.

**Mathematics.**—Research in mathematics includes a wide range of projects which support aeronautics and space activities. The development of fundamental mathematical methods provides techniques for the construction and manipulation of abstract models leading to the solution of particular problems in these fields. Both analytical and numerical methods are being investigated. Control and optimization theory find many applications to atmospheric and space flight. Studies are being conducted in stellar dynamics which include stability of stellar models, dynamics of pulsating stars and the structure of isolated and interacting galaxies. Investigations of compressible flow at various Reynolds numbers have a direct bearing on aeronautics. Air traffic studies, encompassing optimal runway and gate utilization at airports, are being supported. Research on problems of celestial mechanics is underway.

**U.S. Polar Research Programs.**—In many ways the polar regions, especially the Antarctic, provide the most realistic terrestrial approximation to the conditions expected to be encountered on journeys to and occupation of the moon and the near planets. For this reason a NASA-Geological Survey team is currently using the ice free valleys in Antarctica, which compare closely with a typical Martian surface, to test instrumentation being developed for use in the Mars landing spacecraft.

There also are many scientific similarities between the polar environments and outer space. As one example, the earth's magnetic field causes a spectrometer-like action on the charged particles approaching earth from all directions. The near vertical field in polar regions permits the entry of lower energy particles than does the near horizontal equatorial field. This means the polar particle population is more like that in interplanetary space than is the equatorial population. Consequently, the ground-based NSF polar program can investigate approximately the same phenomenology as the satellite and space probe based program of NASA. Both agencies use measurements of the aurora, the geomagnetic field, the particle composition and spectrum, and the electromagnetic radiation across a wide spectral range to investigate the magnetosphere and ionosphere, how solar activity affects these regions and how they interact with and influence each other. In order that each organization may remain current on the program of the other, there are frequent formal and informal meetings between representatives of the two organizations.

**Research Applications.**—Two projects utilizing aeronautics and space technology are currently being supported by the Research Applications Directorate. The University of Michigan, Willow Run Laboratories is applying remote sensing technology to the problems of urban and regional planning. This is an effort to increase the effectiveness of public planning agencies by improving the information gathering potential via remote sensing technology using airborne imaging infrared and optical equipment, multi-spectral scanner, and side-looking imaging radar data. These data will be integrated into existing data sources of the planning agencies. The transformation of information into public policy will be studied, as well as the effectiveness of remotely-sensed data compared with contact methods on cost, technical capability, and procedural acceptability. A project at the University of Wisconsin supports investigators working with the staff of the National Center for Atmospheric Research (NCAR) on the analysis of photographs from the NASA "SMS" satellite, which will be launched in 1972. The photographs are expected to yield important information on the duration, motion, and energetics of principal storms occurring in northeastern Colorado, the experimental area for the National Hail Suppression Project administered by NCAR.

**Educational Activities.**—In Fiscal Year 1971 approximately \$1.9 million was obligated by the Foundation's three Education Divisions for activities which were related to the aeronautic and space sciences. The greatest proportion of these funds supported the training of graduate students through Fellowships and Traineeships. These funds also provide for upgrading the

aeronautic and space science subject matter background of teachers in secondary schools, colleges and universities, unusual independent study and research experiences for students and the improvement of instructional programs in these disciplines at all levels of

education. Fiscal Year 1971 funds provided for the training of 962 individuals in the aeronautic and space sciences. Over one-third of these individuals were junior and senior high school teachers of science and mathematics.

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 advisors 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.

Highlights of the work of the Academies-Research Council in aeronautics and space during 1971 include the Space Science Board's study on outer planets exploration; counselling by the Aeronautics and Space Engineering Board on the space shuttle, and on the EROS programs by the Committee on Space Programs for Earth Observation; completion of a two-year survey of the status and needs of astronomy; publication of the report, *The Atmospheric Sciences and Man's Needs: Priorities for the Future*; administration of NASA fellowships; and advisory and review work in aeronautics, space applications, and space science.

### Space Science Board

The Space Science Board is the National Academy of Sciences' principal advisory group on scientific direction of the U.S. space program and acts as Academy representative to the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU). The Board carries on much of its work through its specialized committees and panels and through groups of scientists assembled for intensive study of topics of concern and timeliness to the space program. The Board itself met four times during 1971. Briefings and discussions gave particular attention to scientific activities planned for Skylab, exploration of the outer planets, scientific results of Apollo, plans for the space shuttle, and increasing cooperation with the

Soviet Union. Close liaison was maintained with the National Academy of Engineering's Aeronautics and Space Engineering Board (see below) and with NASA's newly established internal advisory groups. As is customary, sessions were scheduled to take into account critical times in budget planning and formulation; thus the Board's views have been made available to program planners for consideration.

**Outer Planets Exploration.**—A study on outer planets exploration was conducted by the Board at Woods Hole, Massachusetts, during August 1971. Undertaken at the request of NASA, the study addressed one segment of a broader study carried out in the summer of 1970 on priorities in all areas of space research. The 1970 study, *Priorities for Space Research 1971–1980*, considered seven areas and recommended priorities within and among each: planetary exploration, lunar exploration, astronomy, gravitational physics, solar-terrestrial physics, earth environmental sciences, and life sciences. The 1971 study, *Outer Planets Exploration 1972–1985*, considered the outer planets portion of the total planetary program in light of new engineering cost studies conducted by NASA since the 1970 priorities study.

The study developed priorities at three levels of funding for missions including intermediate-lived Pioneer-level spacecraft to Jupiter and Saturn, long-lived Thermoelectric Outer Planet Spacecraft (TOPS) for Grand Tour Missions to up to five of the outer planets and beyond, and advanced-propulsion planetary missions in the 1980's. The seven major recommendations of the study were presented by the Board to NASA management in August 1971 and published in the NAS report in November 1971.

**Space Biology and Medicine.**—Increasing attention in space-planning and scientific circles has focused on the biological effects of high-energy, heavy (HZE) cosmic-ray particles as a result of observations during recent

Apollo lunar missions. Light flashes seen by astronauts at the back of their eyes are believed to be caused by the impact of these particles on the retina and proximate areas and raise the question of what hazard they might present on extended spaceflights. The Committee on Space Medicine's Radiobiological Advisory Panel is looking into this phenomenon, at NASA's request, with a view to advising the agency on policies and research in its radiobiological program. The study got under way in October and is expected to require about a year.

In March 1971, the Committee's Cardiovascular Review Panel conducted its third annual evaluation of NASA's ground-based research projects in cardiovascular physiology. Another ad hoc group reviewed primate research in May. Such evaluations of individual NASA research projects are carried out at the agency's request for use in program management.

*Gravity and the Organism*, the proceedings of an international symposium conducted by the Space Science Board in September 1967 and updated in 1970, was published in 1971 by the University of Chicago Press. The volume contains 39 contributed papers focusing on the influence of gravitation on the properties and behavior of living matter.

At year's end, the Board formed a space biology group which, together with the Committee on Space Medicine, constitutes the Committee on Space Biology and Medicine. The Space Biology Section and the Space Medicine Section will meet separately on matters related to only one or the other of the groups of disciplines involved and jointly to deal with topics of mutual interest.

*International Relations*.—The Board's formal international activities are centered in the Committee on Space Research (COSPAR). COSPAR, an inter-Union organization of ICSU, fosters fundamental research in space science through the use of space vehicles. Data and significant results are exchanged through the World Data Center system. COSPAR accepted the invitation of the U.S. National Academy of Sciences to host the 1971 Annual Meeting in Seattle, Washington, June 21–July 2. Symposia included: Results of the Total Solar Eclipse of March 7, 1970, High Angular Resolution Astronomical Observations from Space, and Dynamics of the Thermosphere and Ionosphere above 120 km. As in past years, the Board's 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 1970.

#### **Aeronautics and Space Engineering Board**

The Aeronautics and Space Engineering Board (ASEB) of the National Academy of Engineering provides advisory services to government agencies interested in aeronautical and space engineering.

Throughout 1971, the Board continued its review of the NASA space shuttle program. Special attention was given to (1) the study and analysis of alternative configurations of both shuttle booster and orbiter, (2) development of an improved, longer-term mission model, and (3) consideration of the space shuttle program as an economically feasible national program based on a fixed discount rate. As a result of its discussions on these subjects, the Board submitted its comments to the NASA Administrator for his consideration.

In the field of aeronautics, the Board created an ad hoc Study Advisory Committee on Aeronautics (SACA) which reviewed recommendations of the Joint DoT–NASA Civil Aviation Research and Development Policy Study Group (CARD). Views of the Committee were transmitted by its chairman to the Joint Study Group on those areas which the Committee believed required special emphasis in the immediate future.

The Board has established several new points of contact with other countries in an effort to improve international cooperation in the development of future aeronautical and space transportation systems. Efforts in this area will continue.

#### **Division of Behavioral Sciences**

*Committee on Vision*.—A working group on Visual Elements in Flight Simulation has surveyed research planned and in progress at Langley Research Center and Ames Research Center. This working group will make recommendations to NASA concerning its plans for determining what visual cues are necessary and sufficient in a training simulator for commercial pilots.

A working group on Ocular Effects of Microwave Radiation has recommended priorities for future research in ocular hazards of microwaves and plans to study in considerable detail problems in measuring far-field microwave radiation.

A review of the literature on orthokeratology is being written, and the final report will describe what must be known before this can be considered a useful technique to improve pilots' vision. In addition, the Committee is forming a working group to advise the Army on its program to study visual effects of drugs.

#### **Division of Earth Sciences**

*Committee on Space Programs for Earth Observations, Advisory to the Department of the Interior (COSPEAR)*.—COSPEAR and its specialized panels continue to advise the Department of the Interior on its Earth Resources Observation Systems (EROS) program. A wide range of activities within the Department is aimed at developing more effective methods for accomplishing the Department's missions through application of remote sensing, and these constitute the EROS

program. The program, in cooperation with other offices and especially in cooperation with NASA, strives for improvement of relevant technology, plans and conducts aerial and spaceflight programs to gather remote sensing data, and develops programs for data management and interpretation.

The parent Committee and each Panel (Cartography and Mapping Requirements, Geography and Human and Cultural Resources, Geology and Mineral Resources, Hydrology and Water Resources, and Oceanography and Marine Resources) meet two to four times a year to review the various facets of the EROS program. The groups' advice is sometimes given in formal recommendations by the Academy to the Director of the EROS program, but more frequently is offered informally in round-table discussion with representatives of the Department of the Interior.

The advisory role of COSPEAR is expected to expand to include additional government agencies and to address general problems in earth observations that are too broad for adequate treatment by single agencies or the specialized panels now under COSPEAR. With this new orientation and scope, the Committee's name will be changed to Committee on Remote Sensing Programs for Earth Resource Survey.

### Division of Engineering

**National Materials Advisory Board.**—The Board's general purpose is to advance materials science and engineering in the national interest. More specifically, it undertakes to define technical problems in materials and point out opportunities of national concern and relevance to government, industry, or academia. Because aeronautical and space materials and their applications challenge the most advanced capabilities of materials technology, a substantial part of the Board's attention and effort is devoted to furnishing advice to the government on its program of aerospace materials research and development.

Beryllium, a highly useful material in certain aerospace applications, still presents problems relating to brittleness and inherent anisotropy. An NMAB ad hoc Committee analyzed present and potential requirements for beryllium and recommended policy options for government action to enhance the utilization of beryllium in applications in which it would provide a performance advantage. The Committee's report, NMAB-281, was issued in October. Two other reports of NMAB studies on aerospace materials problems, issued in 1971, were: "Accelerating Utilization of New Materials" (NMAB-283), and "High Temperature Oxidation Resistant Coatings" (NAS Publication ISBN0-309-01769-6).

Several studies bearing on aerospace materials were initiated by the NMAB during 1971. Among these are: a study of testing methods useful in predicting material performance in structures and components, a study of

materials for radiation detection, and a study of problems involved in producing high-temperature-resisting metallic composites by directional solidification.

### Division of Physical Sciences

**Astronomy Survey Committee.**—The Astronomy Survey Committee has completed work on its assessment of the status and needs of astronomy. The report of the Committee outlining a ten-year program embracing both ground- and space-based studies will be available early in 1972.

The Survey was in active progress for two years, and its Steering Committee and eight panels involved over 100 astronomers who have met frequently during this period to discuss priority items to be incorporated in the final report of the Survey.

**Committee on Atmospheric Sciences.**—The Committee on Atmospheric Sciences, through reviews and studies of research and technology in the several fields of meteorology, strives to evaluate and encourage activities that will provide for a balanced national program in the science. Providing guidance and advice to the several federal agencies having responsibilities in meteorology, the Committee has recently examined and reported on the developments in basic and applied research which firmly indicate notable advances in measuring and analytical techniques. These advances suggest that the difficult problems of atmospheric dynamics, energy exchanges and transformation, and chemical and photochemical processes can now be investigated, and that techniques for precipitation augmentation and remote measurement can be utilized with an enhanced potential of reaching new levels of understanding.

A recent Committee study, *The Atmospheric Sciences and Man's Needs: Priorities for the Future* (NAS, 1971), notes that many of man's enterprises and modes of habitation throughout the world are becoming increasingly vulnerable to daily and seasonal vagaries of meteorological phenomena. The report urged that greater efforts be given to developing improved capabilities for both short- and long-term weather prediction. This task will depend increasingly on data on atmospheric temperature, moisture, and trace constituents obtained from polar-orbiting and geostationary satellites. In addition, it is foreseen that such space vehicles will be utilized to interrogate remotely placed platforms on the land, sea, and ice to obtain crucial data from areas for which information is not now obtainable through conventional means. Further, advances in techniques and understanding of weather modification have reached a point where efforts in the near future may contribute to alleviating the nation's water resource needs. Investigations of severe storm phenomena such as hail, lightning, and hurricanes indicate an increasing potential to reduce significantly

their destructive effects. The advanced models of electronic computers are critically important in current studies of weather prediction and modification: these computers permit experimental numerical studies that help to guide the conduct of field experiments which, in turn, will provide the additional observations needed for improved models of atmospheric behavior.

***U.S. Committee for the Global Atmospheric Research Program.***—The Global Atmospheric Research Program (GARP) is an international atmospheric research program being developed by many nations working together through the International Council of Scientific Unions (ICSU) and the World Meteorological Organization (WMO). The objective of the GARP is to increase understanding of the dynamical processes of the atmosphere which will lead to sound physical and mathematical bases for extended prediction of the large-scale atmospheric motions. The U.S. Committee for GARP is the principal scientific mechanism for the development of U.S. scientific objectives and plans, specifications of observational requirements, and for guidance on detailed project design and planning. The Committee serves as the communication link between the scientific community and the several government agencies involved, and is the focus in the United States for the scientific planning carried out under international auspices.

During 1971, the Committee's activities centered around the first major field program of the GARP, a tropical experiment to be carried out across the Atlantic Ocean from about 40° east to 90° west longitudes between 10° south and 20° north latitudes. This international program is known as the GARP Atlantic Tropical Experiment (GATE) and will be carried out during the summer of 1974. A second observational program on the global atmosphere is planned for 1976.

International plans for the GATE are in an advanced stage of development and relate to the utilization and deployment of ships and aircraft, polar-orbiting and geosynchronous satellites, and buoys and balloons.

The tropical regions encompass fifty percent of the earth's surface and much of this area is oceanic. Tropical phenomena and their interaction with mid-latitude atmospheric processes only recently have received increasing attention. New observations from satellites have demonstrated that the tropical atmosphere responds to and interacts with the atmospheric processes existing at higher latitudes. The nature and extent of such interaction is of great importance to atmospheric developments. Therefore, the planning for the GATE is emphasizing the study of motions which will clarify the close interdependence of convective and synoptic scales of motion which together provide for much of the exchange of heat, energy, and momentum.

A geostationary satellite located over the GATE area has been singled out as the most important element of the program. Such a satellite will provide day-and-night imaging of the tropical cloud systems that will permit decisions assuring optimal exploration and study of the tropical systems available during the period of the experiment.

***Committee on Radio Frequencies.***—The Committee on Radio Frequencies and its Subcommittees on Space Science, Radio Astronomy, and Earth and Life Sciences, serve as a channel for coordinating the knowledge and views of the U.S. scientific and engineering communities regarding the radio frequencies needed for research. Their recommendations for changes in frequency allocations for space research and radio astronomy were used in preparing the U.S. Proposals for the World Administrative Radio Conference of the International Telecommunication Union, which was held in Geneva in June 1971. Most of these recommendations in the U.S. Proposal were accepted by the WARC.

***Committee on Solar-Terrestrial Research.***—The Committee on Solar-Terrestrial Research of the Geophysics Research Board is the National Academy of Sciences' affiliate to the ICSU Inter-Union Commission on Solar-Terrestrial Physics (IUCSTP) which coordinates for ICSU on an international level solar-terrestrial research programs which cut across lines of the traditional scientific disciplines. Specifically this Committee reviews, on a continuing basis, the status of U.S. research related to solar-terrestrial problems, assists in coordinating this research with that of other countries, and provides advisory services to federal agencies concerned with domestic solar-terrestrial programs. The following studies, although dealing with ground-based research, are of direct relevance to the space program, because these ground-based observations are used in support of, and in some cases in lieu of, observations with space vehicles.

In response to recommendations of a study on *Physics of the Earth in Space: The Role of Ground-Based Research* conducted by the Committee in Aspen, Colorado, in 1969, an ad hoc panel of U.S. scientists, including a number of U.S. associate members of the Geophysical Institute of Peru, was formed to provide liaison for U.S.-Peruvian cooperation in conducting incoherent-scatter measurements of the upper atmosphere using the Jicamarca Radio Observatory in Lima, Peru.

The Aspen study also recommended that a new incoherent-scatter facility, of more advanced design than exists elsewhere, be constructed near the U.S.-Canadian border for investigation of ionospheric and magnetospheric dynamics. An ad hoc panel of the Committee conducted a feasibility study to examine the scientific need and to develop criteria for the proposed



observatory. Their report, *Upper Atmosphere Observatory—Criteria and Capabilities*, was issued by the NAS in February 1971. Based on the results of this study the National Science Foundation awarded a grant to the University of Illinois to conduct a preliminary design study. The Illinois study was completed in July. A consortium of six universities, including one Canadian institution, was formed (Upper Atmosphere Research Corporation) and has submitted a proposal to the Foundation for construction and management of the facility.

A new panel of the Committee was recently established to advise on priorities for support of ground-based observations of cosmic radiation. The panel will address questions on the relative emphasis appropriate to different types of observations, including meson telescopes and neutron monitors, and on the network of neutron monitors that should be maintained around the world in the face of decreasing funding.

In cooperation with the Committee on Atmospheric Sciences, the Committee on Solar-Terrestrial Research has formed an ad hoc panel on ozone to study the physical and chemical characteristics of the atmospheric ozone layer, including the effects of introduced matter, with a view to assessing needed research. In addition, an Academy ad hoc working group was convened in July 1971 to make a preliminary assessment of the potential effects on the atmosphere of nitric oxide from the supersonic transport, as evaluated in a recently published paper. Conclusions of this group were

provided to the National Oceanic and Atmospheric Administration in November 1971.

IUCSTP proposed in 1969, and COSPAR endorsed the next year, international cooperation in long-term magnetospheric experiments. Initial steps to organize this program, known as the International Magnetospheric Survey, were taken at the June 1971 IUCSTP meeting in Seattle. The Committee on Solar-Terrestrial Research will have a role in coordinating U.S. participation in this program.

### Office of Scientific Personnel

The Office of Scientific Personnel conducts two activities in behalf of NASA, namely the NASA International University Fellowships in Space Science and the NRC-NASA Resident Research Associateships (postdoctoral and senior postdoctoral). On August 31, 1971, there were 181 Associates on tenure.

In the NASA International University Fellowships program, jointly financed by NASA and participating space agencies of other countries, there were 52 full-year fellowships in 1970 and the same number in 1971. From September 1961, when the program began, to 31 December 1971, 322 fellowships have been granted.

The Fellowship program affords young scientists from other countries an opportunity for study and space research at leading universities in the United States. In the Associateship program, scientists and engineers of unusual ability conduct research at NASA Centers.

XV



## The Smithsonian Institution

### Introduction

The Smithsonian Institution contributes directly to this nation's aeronautics and space program through the activities of its bureaus: the Smithsonian Astrophysical Observatory (SAO), the Smithsonian Center for Short-Lived Phenomena (SCSLP), the National Museum of Natural History (NMNH) and the National Air and Space Museum (NASM).

During the past year, Smithsonian observing stations used space techniques to gather data pertinent to geophysical and astrophysical research. Smithsonian experiments aboard high-altitude balloons and satellites measured radiation from distant energy sources

screened from ground stations by the earth's atmosphere. Smithsonian laboratories analyzed both returned lunar samples and recovered meteorite specimens for new clues to the mystery of lunar and planetary evolution. And, while Smithsonian laboratories and field stations increased man's knowledge about the universe, its museums diffused and disseminated this new knowledge to the public through exhibits, displays, and special programs.

The modern Institution's concern with aeronautics and space research actually is part of a long heritage that began with Samuel Pierpont Langley, third secretary of the Smithsonian and founder of its Astrophysical Observatory. Langley was both a pioneer

in manned air flight and one of the first scientists to study systematically the relationship between solar and geophysical phenomena.

In 1890, Langley called his innovative research "the new astronomy"; today, the Smithsonian Institution's innovative and dynamic research in space sciences could rate the same title.

### Smithsonian Astrophysical Observatory

The leadership of the Smithsonian Astrophysical Observatory (SAO) in world science was demonstrated this year by innovative and vital contributions to the fields of earth physics, lunar investigation, space observations, and high-energy astronomy.

For example, SAO played a central role in two of the most intense programs ever undertaken to study the earth as a planet. The analysis of lunar samples in SAO labs has provided one of the cornerstones for a new concept of planetary evolution. Similarly, the massive statistical data on ultraviolet stars obtained by SAO's Telescope experiment is being used to establish new models of theoretical stellar atmospheres. And, the development of a new and improved gamma-ray detector for balloon and satellite use promises to be an important advance in high-energy astronomy.

**Earth Physics.**—The Smithsonian Astrophysical Observatory operates a worldwide network of satellite-tracking stations in support of both special missions and general research in geophysics, geodesy, and atmospheric physics. At five of these stations, Baker-Nunn cameras are coupled with special laser ranging systems. Cooperating foreign agencies provide additional lasers at other Baker-Nunn sites.

Because of this network's global distribution and tracking precision, SAO served as one of the major subcenters for the International Satellite Geodesy Experiment (ISAGEX). This 8-month satellite observing program for dynamic geodesy was coordinated by the French space agency, CNES, and involved 18 countries operating 14 laser and 30 cameras sites. In addition to SAO and CNES, other subcenters included: the Goddard Space Flight Center, the Soviet Academy of Sciences, and the Ondřejov (Czechoslovakia) Observatory. As the largest single tracking network in the program, SAO contributed significantly to the more than 10,000 laser observations that have yielded range measurements accurate to within a meter or less.

Many of the same US and foreign agencies are now cooperating in an observation program organized and coordinated by SAO for other scientific objectives. This Earth-Physics Satellite Observation Campaign (EPSOC) is using precise laser observations of earth satellites to study irregular motions in the rotation of the earth, especially the phenomenon known as the Chandler Wobble. The 14-month EPSOC program is part of SAO's long-term effort to obtain data perti-

nent to a variety of earth-physics phenomena such as polar motion, continental drift, solid-earth tides, and seasonal variations in the earth's gravitational field.

Another precise means of satellite tracking—especially for synchronous orbit objects—is promised by SAO experiments with a technique normally used in radio astronomy. Very Long-Baseline Interferometry (VLBI) makes use of the minute discrepancies in the times that a radio signal from a satellite will be received at two or more widely separated ground stations. This slight time lag can provide a very accurate indication of the satellite's position in space. Obviously, the greater the distance between the stations, the more precisely the satellite's position can be determined. SAO's adaption of VLBI uses independent and highly stable atomic time standards that can be located anywhere, indeed, even on opposite sides of the earth.

**Lunar Investigations.**—Returned lunar samples from the Apollo 12, 14, and 15 missions, as well as samples from the Soviet automated probe Luna 16, were analyzed by one SAO group using optical microscope, X-ray diffraction, and electron microprobe techniques. Another SAO group used mass spectrometer techniques and low-level counting methods to determine the isotopic abundances in this lunar material.

By concentrating on the randomly mixed samples of the lunar soil rather than larger and more specific specimens, SAO scientists have had an opportunity to examine and classify literally thousands of tiny "lunar rock" specimens in the form of individual soil particles. These primordial moon rocks have been identified as (1) anorthosite, a light-colored rock of low specific gravity consisting primarily of the mineral plagioclase; (2) several types of gabbroic rock probably related to the anorthosite; and (3) dark, volcanic basalts that erupted in the lunar surface a billion years after the formation of the moon and filled the giant impact craters, or maria.

Another approach to studying the structure and composition of the moon is to probe the lunar interior with radio waves. During the Apollo 15 flight, SAO scientists recorded the first reception of radio signals broadcast from a spacecraft behind the moon. The experiment confirmed in part a suggestion made in 1966 that the moon's dry, pumice-like upper layers might act as a medium for conducting radio waves in a manner similar to the weak surface propagation of radio waves on earth. Future adaptations of the experiment could produce radio profiles of the lunar interior by beaming signals of various frequencies through the moon from satellites to ground receivers.

The radio transmissions were observed with a 150-foot radio telescope 115 seconds after the Apollo 15 command module, Endeavor, passed behind the moon and out of sight of earth on the evening of August 3, 1971.

**The OAO Telescope Experiment.**—The Telescope experiment prepared by SAO for flight aboard the Orbiting Astronomical Observatory was designed to survey the sky in ultraviolet light and to produce a catalog allowing the study of the basic statistical properties of as many stars as possible. During its 16 months of operation, the Telescope gathered some 8,000 pictures of 1,700 star fields, covering approximately 10 percent of the entire sky and about 20 percent of the region near the Milky Way where the majority of ultraviolet stars are found. A preliminary analysis already has identified a group of stars in the constellation Orion that are anomalously bright in ultraviolet light. Ground-based observations of the same stars from SAO's observatory in Arizona reveal that the stars also exhibit subtle peculiarities in other parts of their spectra.

The Telescope data are also being used by SAO as a guide in the computer modeling of theoretical stellar atmospheres. Because most of the radiation from hot stars is emitted as ultraviolet light, the Telescope results should prove invaluable in the mathematical construction of this type model star.

At the end of 1971, the magnetic tape catalog of all high-priority Telescope data was delivered to the National Space Science Data Center at the Goddard Space Flight Center where the information is available to the scientific community.

**Gamma-Ray Astronomy.**—A major advance in the sensitivity of gamma-ray detectors was achieved this year with the development by SAO and Cornell University of a large-area gas-Cerenkov telescope suitable for use in high-altitude balloons and satellites. The massive instrument—9 feet in diameter and 20 feet long—combines extreme sensitivity, high efficiency, and good angular resolution with simple design. Most important, the detector offers excellent rejection of the charged-particle background, normally a significant factor interfering with the observation of gamma rays—also charged particles—emitted by point sources in the heavens.

The new detector was flown successfully twice this year aboard high-altitude balloons. The experiment made extended observations of such suspected gamma-ray sources as the Crab Nebula, the Pulsar NP 0532, the Quasar 3C273, and the Radio Galaxy M87. Although the analysis of data is still in progress, preliminary results indicate the new telescope functioned perfectly and should make significant contributions to gamma-ray research.

### **National Museum of Natural History**

During the past year the National Museum of Natural History (NMNH) continued its research on extraterrestrial materials, including both recovered meteorites, and lunar materials returned by the Apollo missions.

By correlating data on the chemical and mineralogical composition of the lunar specimens with similar data on terrestrial rocks and meteorites, NMNH scientists have thus been able to compare and contrast the processes involved in the genesis of rocks on the earth and on extraterrestrial bodies. Particular attention has been given to analogies between the lunar rocks and a specific group of meteorites, the pyroxenepagioclase achondrites. These meteorites are comparatively rare—comprising about 5% of all meteorites seen to fall—and present striking similarities to some lunar rocks. However, the present data indicate that the meteorites probably originated from a fragmented asteroid with a similar but not identical history to that of the Moon.

Meteorite research has continued in parallel with work on the lunar rocks. Two specimens (Allende, Mexico and Murchison, Australia) have been of special interest, for both belong to the rare class of carbonaceous chondrites.

### **Center for Short-Lived Phenomena**

The Smithsonian Center for Short-Lived Phenomena (SCSLP) serves as an international early-alert system for the rapid receipt and dissemination of information concerning unpredictable and short-lived geophysical, biological, and astrophysical events of major scientific importance.

During 1971, the Center participated in 15 astrophysical events, including the report of 9 major fireball observations from India, Mozambique, Sweden, Germany, Austria, and the United States, and the recovery of 6 meteorites in Ethiopia, the Sudan, Swaziland, Venezuela, Mauritania, and the United States.

All investigations included contact with event areas by telephone and cable to obtain eyewitness reports of magnitude, direction, duration, color and sound phenomena associated with the fireballs, and the probable impact location of any resultant meteorites. The reports were relayed, in turn, to interested scientists.

Specimens of all six meteorites were quickly recovered and distributed to appropriate laboratories for radioisotope analysis. In some cases, the time between the meteorite's fall and its analysis in a laboratory was no more than a few days. After two major fireball events, ablation products were sampled in the atmosphere by high-altitude aircraft.

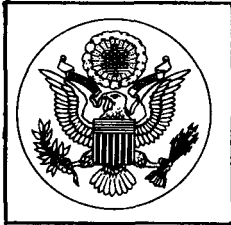
### **National Air and Space Museum**

One of the highlights attracting an estimated five million visitors to Smithsonian museums during 1971 was a special Apollo 11 display organized by the National Air and Space Museum (NASM) to commemorate the first manned landing on the lunar surface. The exhibit included the Apollo 11 Command Module, the space suits worn by astronauts Armstrong, Aldrin and

Collins, and other significant artifacts from that historic mission. The central element in the this exhibit, however, was an actual moon rock returned by the astronauts.

The \$1.9 appropriated in 1971 for the redesign of the new National Air and Space Museum building was committed to an architect. The redesign of the building is in process.

XVI



## Office of Telecommunications Policy

### Introduction

Under Reorganization Plan No. 1 of 1970, which was approved by Congress on April 20, 1970, the Office of Telecommunications Policy was established. Executive Order No. 11556, signed on September 4, 1970 delegated certain responsibilities assigned to the President by the Communications Satellite Act of 1962 to the Director of the Office of Telecommunications Policy. The dynamic nature of satellite communications technology and the ever-increasing requirements for domestic and international communications services require constant review of our communications policies and institutions. As such, the Office of Telecommunications Policy focuses primarily on the application of space technology rather than research and development.

*Intelsat.*—In the spring of 1971 the negotiations for the Definitive Arrangements of INTELSAT were completed. 54 nations signed the agreements on August 20, 1971. After final ratification by the participating nations, these agreements will come into force; thus, establishing a permanent INTELSAT institution.

INTELSAT has now grown to a community of more than 81 nations working toward a common goal of a viable, global, commercial satellite communication system. The reliability of the global satellite network continues to increase.

The initial INTELSAT IV satellite was placed in orbit in 1971 and is now in continued service over the Atlantic ocean.

*Domestic Satellites.*—Domestic satellite communication advanced toward reality in 1971. Following the recommendation of the White House in January 1970 that all financially and technically qualified firms be authorized to participate in domestic satellite communication, the FCC called for applications in March 1970. By April 1971, the commercial response from potential satellite communication firms was complete.

Eight complete satellite communication systems were proposed to serve the domestic market, as well as additional earth terminals to be owned and operated independently of the satellite operators. Among the current applications are the major domestic communications common carriers, prominent aerospace firms, and the Communications Satellite Corporation.

The systems which are planned for domestic service are innovative in technical design and in proposed marketing arrangements. The proposed satellites are large relative to INTELSAT IV, ranging from 12–120 transponders in communications capacity and from 600–4,400 pounds in weight. Most of the satellites are based on current state-of-the-art technology. However, there is considerable diversity in the designs, some of which propose advanced stabilization techniques, advanced antenna configuration, use of frequencies above 10 GHz, and other advanced features.

The applicants expect to use their satellite facilities to serve many long-distance communications requirements within the United States that presently are served by terrestrial technology. These include the trunk requirements of the telephone and record communication systems and the distribution of television programs from the network studios to the affiliated broadcast television stations. In addition, the applicants envision that their systems will generate new communications requirements, such as national interconnection of CATV systems and expanded Picturephone and data communication service.

After reviewing the current applications, the Office of Telecommunications Policy reaffirmed the desirability of an open entry policy toward domestic satellite communication, concluding that the potential benefits of satellite technology would be realized most fully under such a policy. The first generation of domestic communication satellites systems could be in operation in 1973 if authorizations are granted in late 1971 or early 1972. Swift implementation of the domestic satellite communication proposals will bring to the Ameri-

can public real returns from the Federal government's investment in space research.

**Aerosat.**—The Office of Telecommunications Policy set forth policy guidelines for satellite communications to serve the international aeronautical community in January of 1971. The Department of Transportation and the Federal Aviation Agency have formulated programs for the establishment of Atlantic and Pacific Basin aeronautical satellite services.

### **World Administrative Radio Conference on Space Telecommunications (WARC)**

During the period June 7–July 17, 1971, over 100 countries, involving some 700 representatives, met in Geneva, Switzerland, under the auspices of the Inter-

national Telecommunication Union to review and revise as necessary the International Radio Regulations as they pertain to space telecommunications. The results of this Conference contain carefully developed engineering criteria to facilitate increased sharing between space and terrestrial communications systems, modify the international table of frequency allocations so as to provide considerably expanded spectrum resources for space communications, and reflect procedures to assure the necessary coordination among nations in planning for and implementing terrestrial and space systems. The results of this Conference, which upon ratification by the respective Administrations will become effective on January 1, 1973, provide a sound foundation for the application of space communications for the next decade.

XVII



## Federal Communications Commission

### **Introduction**

Significant progress took place in satellite communications. Climaxing two and one-half years of negotiations, international agreement was reached on Definitive Arrangements for the International Telecommunications Satellite Consortium (INTELSAT).

Membership in INTELSAT increased to 82 countries, and the first of a new larger series of satellites (INTELSAT IV) was put into service over the Atlantic. Important new frequency allocations and regulations for space communications and radio astronomy services were adopted at the World Administrative Radio Conference (WARC) of the International Telecommunications Union (ITU).

### **Communications Satellites**

On August 20, 1971, the Definitive Arrangements for INTELSAT were opened for signature at Washington, D.C., marking the end of two-and-one-half years of international negotiations. The Intergovernmental Agreement was signed on behalf of the United States by Secretary of State William P. Rogers, and the Operating Agreement was signed by Dr. Joseph V. Charyk in his capacity of President of the Communications Satellite Corporation (Comsat), which is the designated communications entity of the United States. The Definitive Arrangements are expected to come

into force in 1972, when signed and ratified by at least two-thirds of the members of INTELSAT who hold two-thirds of the investment in the organization.

Membership in INTELSAT has grown to a total of 82 countries as of December 31, 1971. The first launch of the latest generation of INTELSAT satellites, the high capacity INTELSAT IV series, took place on January 25, 1971 and began providing commercial telecommunication services in the Atlantic region on March 26, 1971. The second launch of an INTELSAT IV satellite on December 19, 1971 provides for a two satellite operation configuration in the Atlantic region. At the end of 1971, 52 earth stations with 63 antennas operating in 39 countries were providing satellite communications in the INTELSAT System. The configuration of the space portion of the Global System now consists of two INTELSAT IV satellites serving the Atlantic region; one INTELSAT III Satellite serving the Pacific Ocean region; one INTELSAT III satellite serving the Indian Ocean region, and one INTELSAT III satellite serving as an in-orbit spare.

The eight U.S. earth stations are located at Andover, Maine; Etam, West Virginia; Cayey, Puerto Rico; Brewster Flat, Washington; Jamesburg, California; Paumalu, Hawaii; Talkeetna, Alaska; and Guam. Construction has been completed on a new replacement antenna at the Andover, Maine earth station.

At the end of 1971, the U.S. international communications common carriers were leasing from Comsat 850 voice-grade half circuits to provide their portion of satellite communication service between United States and Europe, Africa and the Near East, and 663 half circuits for service between the United States mainland and Puerto Rico and other points in Latin America. There were 1014 voice-grade half circuits operated between the United States and countries in the Pacific Ocean region and between continental United States and Hawaii, Alaska and Guam.

Some 866 hours of television were transmitted from or received in the United States by means of the Global Satellite System during 1971.

**International Telecommunications Union.**—The International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR) are permanent organs of the International Telecommunications Union (ITU), established under Article 14 of the International Telecommunication Convention (Montreux, 1965) to study technical and operating questions on telegraphy and telephony, and radio, respectively, and to issue recommendations on such questions. Many of these questions deal directly or indirectly with space communications.

The World Plan Committee is a joint CCITT/CCIR study group administered by the CCITT and is the parent body of the four Regional Plan Committees for Africa, Asia and Oceania, Europe and the Mediterranean Basin, and Latin America.

The work of the Plan Committees involves the development of telecommunications traffic and circuit forecasts, the compilation of data on major antenna and routing, and the preparation of questions on technical assistance matters. This work involves all media of telecommunications including satellite communications. One FCC member attended the meeting of the Regional Plan Committee for Africa held in Lagos, Nigeria in January, 1971, and two FCC members attended the meeting of the World Plan Committee held in Venice, Italy in October, 1971.

Commission representatives attended meetings in Geneva of the CCITT study group on general tariff principles and lease of telecommunications circuits in June, and of the study group on telegraph operations and tariffs in September.

Five engineers were sent by the Commission to the Special Joint Meeting of the CCIR held in Geneva during February, 1971. This meeting assimilated all of the available technical data and adopted it for WARC utilization. The output of the SJM was published by the ITU as a two volume report.

During 1971, a reorganization of the study groups of the CCIR became effective. Four Commission employees provide leadership in these groups, three as

U.S. Chairmen and one as International Chairman.

Preparations are under way for an interim CCIR meeting for all study groups to be held in Geneva during April, 1972.

### **Radio Astronomy and Space Services**

Of major importance was the ITU World Administrative Radio Conference on Space Telecommunications (WARC-ST) which had as its primary objective the updating of the international Table of Frequency Allocations to accommodate new space services and to meet the expanding needs of existing space radiocommunication services, as well as radio astronomy. Prior to the conference, the Commission was very active in the extensive preparatory work required. This included the issuance of a series of Notices of Inquiry (Docket 18294) to the public to assist in the development of Draft Proposals of the U.S. in coordination with other Federal offices involved. The conference was completed on schedule and the new international Radio Regulations adopted constitute a treaty which must be signed by the President and ratified with the advice and consent of the Senate before the U.S. is bound by its provisions. The new Regulations are scheduled to enter into force on January 1, 1973. (New international Regulations are implemented by the FCC for non-Government services through established rule making procedures.)

### **Aeronautical Services**

Representatives of the Commission participated in the preparation of guidance material for the use of U.S. representatives to international conferences including those of the ITU, the CCIR, and the ICAO. At the WARC changes to the ITU rules which would, inter alia, provide more suitable frequencies for allocation to the Aeronautical Services. The very limited number of frequencies available for the use of satellite systems to serve the aeronautical requirements was expanded and supplemented with the aim of satisfying the near term needs through the decade of the 1970s. Basically, and to a great degree, the results of the WARC are in accordance with the needs of the U.S. aeronautical community as well as the worldwide aeronautical system and, if ratified by the Congress, will result in necessary changes to the Commission's Rules. Such changes will make it possible to proceed with system development at the allocated frequencies.

New or renewed authorizations for various test programs utilizing existing satellites were authorized. The staff has continued to work with FAA and OTP in the current program development for a preoperational aeronautical satellite system. Further programs, particularly regarding the use of frequencies in the 1535-1660 MHz band, joint usage between aeronautical and

marine users and the suballocation of the band by ATC and operational control function are being studied.

Other aerospace problems, which may be solved by means other than the use of satellites, continue to require concerted effort. The staff is presently involved in studying the merits and drawbacks of particular systems, now in the developmental stage, which are intended to provide a measure of safety concerning aircraft midair collision and terrain avoidance. RFI problems with such equipment in the airborne environment are a factor in determinations. Low cost indicators to warn pilots of general aviation aircraft when a collision is imminent are, as yet, only in preliminary stages of development. The Commission has outstanding authorizations to licensees pursuing these problems but has not yet made a regular operational frequency authorization pending resolution of several technical problems.

Channel splitting of the band used primarily for air carrier operational control purposes was provided in the rules in 1971. Similar rule changes for the ATC portion of the VHF Aeronautical Mobile (R) Service band are being considered at the request of the FAA.

### **Maritime Mobile Service**

The staff continues working with both national and international organizations concerned with the use of satellite techniques by the maritime community. Staff members served in the preparatory groups preparing for the CCIR SJM, the ITU WARC, and the IMCO international conferences dealing with the utilization of space communication techniques in the maritime mobile service. At those conferences the Commission provided spokesmen.

The ITU WARC Space Conference provided, for the first time, for frequencies within the ITU Rules allocated to the maritime services specifically for satellite use. When the ITU provisions are ratified by the Senate the use of those frequencies for such purposes in the Commission's rules will be the subject of normal rulemaking procedures.

Working primarily with the OTP and the government and non-government representatives in the RTCM, staff members are developing programs for the evaluation and development of equipment and systems to supplement the maritime communications and navigation system by space techniques. Additionally, preparation for the forthcoming ITU Maritime Conference has been initiated. Several problems specifically relating to the utilization of maritime frequencies were referred to the ITU Maritime WARC by the Space WARC. The staff is placing particular emphasis on the aspects of search and rescue, safety of life and property and economics in the preparation for the Maritime WARC, as well as in the system program development studies.

### **Amateur Radio Service**

The ITU World Administrative Radio Conference for Space Telecommunications (WARC-ST) which convened in Geneva, Switzerland, on June 7, 1971, established the "Amateur Satellite Service" and amended the International Radio Regulations to provide frequency allocations for amateur satellite operation. The adopted allocations permit operation of amateur satellites in the worldwide exclusive portions of the amateur HF bands from 7 MHz to 29.7 MHz, as well as in the bands 144-146 MHz, 435-438 MHz, and 24-24.05 GHz.

Interest in the development of amateur satellites continues to grow with the approval of NASA of the Radio Amateur Satellite Corporation (AMSAT) plans to launch a sixth amateur satellite, AMSAT-OSCAR B (AO-B), as a secondary payload early in 1972. The amateur satellite will have operating capabilities in the 29 MHz, 144 MHz, and 435 MHz portions of the amateur bands and will provide an experimental multiple access communications program involving small, low powered ground terminals operated by stations in the amateur service. Long range plans for amateur involvement in the area of moon technology are also being explored, including the possibility of the development and placement of an amateur repeater on the moon surface.

# Appendixes

## APPENDIX A-1

### U.S. Spacecraft Record

Year	Earth orbit		Earth escape		Year	Earth orbit		Earth escape	
	Success	Failure	Success	Failure		Success	Failure	Success	Failure
1957.....	0	1	0	0	1965.....	94	8	3	0
1958.....	5	8	0	4	1966.....	95	12	5	1
1959.....	9	9	1	2	1967.....	77	4	10	0
1960.....	16	12	1	2	1968.....	61	15	3	0
1961.....	35	12	0	0	1969.....	58	1	8	1
1962.....	54	12	4	1	1970.....	36	1	3	0
1963.....	60	11	0	0	1971.....	45	2	8	1
1964.....	69	8	4	0	Total.....	714	116	50	12

<sup>1</sup> This earth escape failure did attain earth orbit and therefore is included in the earth-orbit success totals.

Notes: The criterion of success or failure used is the attain-

ment 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.

## APPENDIX A-2

### World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond

Year	United States	U.S.S.R.	France	Italy	Japan	Chinese Peoples Republic	Australia	United Kingdom
1957.....		2						
1958.....	5	1						
1959.....	10	3						
1960.....	16	3						
1961.....	29	6						
1962.....	52	20						
1963.....	38	17						
1964.....	57	30						
1965.....	63	48	1					
1966.....	73	44	1					
1967.....	57	66	2	1			1	
1968.....	45	74						
1969.....	40	70						
1970.....	28	81	2	1	1	1		
1971.....	30	83	1	2	2	1		1
Total.....	543	548	7	4	3	2	1	1

<sup>1</sup> Includes foreign launchings of U.S. spacecraft.

Note: This tabulation enumerates launchings rather than

spacecraft. Some launches did successfully orbit multiple spacecraft.



## Successful U.S. Launches—1971

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Jan. 25 Defense 5A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	244 81 89. 2 110. 8	Decayed Feb. 9, 1971.
Jan. 26 Intelsat IV(F-2) 6A Atlas-Centaur	Objective: To provide equivalent of 3,000 to 9,000 telephone circuits simultaneously or 12 color TV channels or a combination of telephone, TV, and other forms of communications traffic between North America, South America, and Western Europe. Spacecraft: Cylindrical 93.5-in. diameter and 17.6-ft. high; spin stabilized; 12 communications repeaters (transponders); 6 antennas; 42,240 solar cells; weight after apogee motor fire: 1,584 lbs.	22, 608 22, 209 1, 450. 2 0. 6	Launched by NASA for Comsat Corp., manager of Intelsat. First satellite in improved Intelsat IV series and first launched by Atlas-Centaur. Largest commercial communications satellite ever launched, both in weight and communications capacity. Stationed at 24.5° west longitude. Spacecraft operating normally.
Jan. 31 Apollo 14 (CSM 110) 8A Saturn V	Objective: To perform selenological inspection, survey, and sampling of materials in a preselected region of the Fra Mauro Formation; to deploy and activate an Apollo Lunar Surface Experiments Package (ALSEP); to develop man's capability to work in the lunar environment; to obtain photographs of candidate exploration sites. Spacecraft: Carried full lunar landing configuration, including command module, service module, and lunar module. Total weight at initial Earth orbit insertion: 302,626 lbs.; at translunar injection: 102,177 lbs.; 64,438 lbs. CSM: 34-ft. long, 12.8-ft. diameter.	N.A.	Crew consisted of Alan B. Shepard, Jr., commander; Stuart A. Roosa, command module pilot; Edgar A. Mitchell, lunar module pilot. All primary mission objectives were successfully accomplished. Lunar module landed at 09:17:00 (G.m.t.) on Feb. 5 and lifted off again at 18:48:00 (G.m.t.) on Feb. 6. Total lunar stay time 33 hours, 31 minutes. Total flight time 216 hours, 1 minute, 57 seconds.
Jan. 31 Saturn IVB (SA 509) 8B Saturn V	Objective: To bring payload to lunar transfer injection; then to fly independently to impact the moon in further seismic tests to be detected by Apollo 12 ALSEP instruments. Spacecraft: A cylinder about 61.3-ft. long by 21.7 ft. in diameter. Total weight at impact, about 30,842 lbs.	N.A.	Lunar strike.
Jan. 31 Lunar Excursion Module (LM 8) 8C Saturn V	Objective: To support lunar landing and takeoff for return to lunar orbit in support of tasks named above. Spacecraft: Combined descent and ascent stages about 13.5-ft. high, 12.3-ft. wide, and 10.3-ft. deep. Total weight about 33,680 lbs.	N.A.	
Feb. 3 NATOSAT-2 (NATO 2) 9A Thorad-Delta	Objective: The NATOSAT-2 is a military communications satellite placed in geostationary orbit over the mid-Atlantic Ocean. It will be used for command and control of NATO military forces. Spacecraft: Cylindrical 54-in. diameter and 32-in. high spacecraft constructed of two concentric cylinders with the apogee motor within the inner cylinder. A despun antenna system, partially mounted within the inner cylinder, is located on the spacecraft bottom. High pressure hydrazine system used for stabilization and positioning. Weight: 535 lbs.	22, 283 21, 394 1403. 4 2. 8	Launched by NASA for USAF which acted as the agent of NATO. Spacecraft successfully placed into synchronous transfer orbit and apogee motor fired Feb. 5.

## Successful U.S. Launches—1971—Continued

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Feb. 17 Defense 12A	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	517 477 100.8 98.8	Still in orbit.
Feb. 17 Calsphere 3, 4, 5 12B, 12C, 12D Thor-Burner 2	Objective: To provide targets for radar calibration and to evaluate surface material erosion and drag effects vis-a-vis the inert gold or aluminum surface. Spacecraft: three 10-inch spheres, two gold surface, one aluminum surface, each with a weight of approximately 2 lbs.	518 474-480 100.8 98.8	Still in orbit.
March 13 Explorer 43 (IMP-I) 19A Thorad-Delta	Objective: To investigate, during a period of decreasing solar activity, through several solar rotations, the nature of the interplanetary medium and the interplanetary-magnetospheric interaction including characteristic features of the solar wind; the interplanetary fields and sector structure; and modulation effects on cosmic rays. Spacecraft: 16-sided 71-in. high drum-shaped structure, consisting of aluminum honeycomb RF shield panels and three bands of solar panels (16 panels per band) mounted on honeycomb aluminum platform. The experiment and instrument modules are mounted in the instrument compartment in the topside of the honeycomb shelf. Two diametrically opposed experiment booms (each 11½-ft. long) and two attitude control system booms (each 5 ft. long), spaced 90° from the experiment booms, are appended to the spacecraft exterior and deployed after launch. The spacecraft is fitted with eight equally spaced, RF antennas (turnstile type) which extend from spacecraft top. Spacecraft is spin stabilized, and contains 12 scientific experiments, an onboard experimental computer, and a silver cadmium battery. Weight: 635 lbs.	127, 124 219 5, 656.1 28.8	First of a series of second-generation Explorer spacecraft; largest and most advanced in series. Exceeded its mission objectives, with 11 of 12 scientific experiments operating successfully.
Mar. 21 Defense 21A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	24, 399 204 701.8 63.2	Still in orbit.
Mar. 24 Defense 22A Thorad-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	146 107 88.5 81.5	Delayed Apr. 12, 1971.

## Successful U.S. Launches—1971—Continued

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
April 1 ISIS 2 24A Thorad-Delta	Objective: To inject the spacecraft into a near circular earth orbit which will permit the study of the topside of the ionosphere above the electron peak of the F region; to continue and extend the cooperative Canadian/U.S. program of ionospheric studies initiated by <i>Alouette 1</i> by combining sounder data with correlative direct measurements for a time sufficient to cover latitudinal and diurnal variations during a period of declining solar activity. Spacecraft: Eight-sided oblate spheroid with 50-in. diameter and 48-in. high. Spacecraft frame consists of a central 16-in. diameter thrust tube which supports eight radial ribs. Sixteen solar cell panels and eight equatorial panels are mounted on the ribs. In addition to twelve ionospheric experiments, the spacecraft contains telemetry and tracking transmitters, command receiver and decoder, PCM equipment, tape recorder, housekeeping and power electronics, and attitude and spin control systems. Appendages include eight telemetry antennas, two 15-in. probes, and a beacon antenna 14 in. in diameter. When in orbit, four sounding antennas are extended to form orthogonal dipoles 240 ft. and 61½ ft. tip-to-tip. Weight: 582 lbs.	887 844 113.6 88.1	Still in orbit.
Apr. 22 Defense 33A Titan IIIB-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	249 81 89.8 110.9	Decayed, May 13, 1971.
May 5 Defense 39C Titan IIIC	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	22,271 22,154 1,434.0 0.9	Still in orbit.
May 30 Mariner 9 51A Atlas-Centaur	Objective: To select an orbit which will permit, during the primary orbital operational lifetime of 90 days, the viewing of about 70 percent of the planet's surface with the wide angle imaging camera at a resolution of about 1 km. per TV line; to study the dynamic characteristics and time variable features of Mars from a Martian orbit selected to permit the viewing of selected areas periodically during the primary operational lifetime of 90 days. Spacecraft: Basic octagonal structure 54½-in. high with four solar panels attached, each 84½-in. long and 35½-in. wide. Spacecraft measures 8 ft. from the separation plane to the top of the low-gain antenna and its span is 22 ft., 7½ in. with the solar panels extended. Two sets of attitude control jets, consisting of six jets each, are mounted on the ends of the solar panels. High-gain antenna 40-in. diameter; low-gain antenna 4-in. diameter extends 57 in. from the top of the octagonal structure; medium-gain antenna is mounted on a solar panel outrigger. Canopus star tracker located on the upper ring structure of the octagon. Six scientific experiments include a TV, an ultraviolet spectrometer, an infrared radiometer, and an infrared interferometer spectrometer. Large propulsion subsystem for orbital insertion; attitude control subsystem; nickel-cadmium battery with 600-w.-hr. capacity. Weight at launch: 2,200 lbs.	In Martian orbit	Mission still in progress.

## Successful U.S. Launches—1971—Continued

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
June 8 SESP 54A Thor-Burner 2	Objective: To test an infrared celestial mapping sensor system. Spacecraft: Not announced.	360 338 95.8 90.2	Still in orbit, but experiment completed.
June 15 Defense 56A Titan IIID	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	180 111 89.1 96.3	Decayed, Aug. 6, 1971.
July 8 Explorer 44 (Solrad 10) 58A Scout	Objective: To place the satellite into an orbit that will enable it to monitor the sun's X-ray and ultraviolet emissions in order to better understand the solar physical processes, and to improve the prediction techniques of solar activity and ionospheric disturbances. Spacecraft: Twelve-sided cylinder, 23-in. high and 30-in. diameter. Four symmetrically placed 7-in. by 21-in. solar cell panels deployed after third-stage burnout. Spin-stabilized; carries 15 scientific experiments; two redundant telemetry transmitters. Weight: 253½ lbs.	392 269 95.3 51.0	Third of a series of cooperative NRL/NASA missions. All spacecraft operations are functioning normally and all 15 scientific instruments are operating satisfactorily and returning data.
July 16 Defense 60A Thorad-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	315 303 94.5 75.0	Still in orbit:
July 26 Apollo 15 (CSM 112) 63A Saturn V	Objective: To perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Hadley-Apennine region; to emplace and activate surface experiments; to evaluate the capability of the Apollo equipment to provide extended lunar surface stay time, increased EVA operations, and surface mobility; to conduct in-flight experiments and photographic tasks from lunar orbit. Spacecraft: Carried full lunar landing configuration, including command module, service module, and lunar module; also lunar roving vehicle, added lunar module consumables, and Scientific Instrument Module (subsattellite) for extensive lunar orbital scientific investigations. Total weight at initial Earth orbit insertion: 309,330-lbs; at translunar injection: 116,314-lbs.; 69,445 CSM: 34-ft. long, 12.8-ft. diameter.	N.A.	Crew consisted of David R. Scott, commander; Alfred M. Worden, command module pilot; James B. Irwin, lunar module pilot. Fourth successful lunar landing mission. Extensive geology traverses with first lunar roving vehicle. Lunar module landed at 22:16:000 (G.m.t.) on July 30 and lifted off again at 17:11:000 (G.m.t.) on Aug. 2. Total lunar stay time 66 hours, 55 minutes. Three dual EVA's totaling 18 hours, 36 minutes. Total flight time 295 hours, 11 minutes, 53 seconds.
July 26 Saturn IVB (AS 510) 63B Saturn V	Objective: To bring payload to lunar transfer injection; then to fly independently to impact the moon in further seismic tests to be detected by Apollo 12 and 14 ALSEP instruments. Spacecraft: A cylinder about 61.3-ft. long by 21.7-ft. in diameter. Total weight at impact, about 30,203 lbs.	Lunar strike.	
July 26 Lunar Excursion Module (LM II) 63C Saturn V	Objective: To support lunar landing and takeoff for return to lunar orbit in support of tasks named above. Spacecraft: Combined descent and ascent stages about 13.5-ft. high, 12.3-ft. wide, and 10.3-ft. deep. Total weight about 36,155 lbs.	N.A.	

## Successful U.S. Launches—1971—Continued

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
July 26 Subsatellite 63D Saturn V	Objective: To pursue extensive, continuing lunar scientific studies from lunar orbit. Spacecraft: Hexagonal 31-in. long and 14-in. diameter with three 5-ft. booms extended; carried magnetometer and charged particle sensors. Weight: 80 lbs.	Lunar orbit: 88 63 119.8 151.3	Still in orbit.
Aug. 7 OV 1-20 67A Atlas	Objective: Energetic proton analyzer to study the intensities and energy distribution of protons trapped in the earth's magnetic field, particle energy and flux thermal detector to study the effects of space plasmas on experimental antennas, and UV solar radiation intensity variations in wavelength and time. Spacecraft: Not announced.	1,201 85 105.9 92.0	Decayed, Aug. 28, 1971.
Aug. 7 OV 1-21 67B Atlas	Objective: Velocity mass spectrometer; atmospheric composition sensor to measure ion densities, composition and temperature; ELF/VLF antenna effects transceiver, operating on 7 frequencies and at 7 voltages, in 14 narrow bands and 1 broad band. Spacecraft: Includes 2-60 feet arms dipole antennas.	570 490 101.9 87.6	Still in orbit.
Aug. 7 Cannonball 2 (OAR 901) 67C Atlas	Objective: Accelerometers to model atmospheric densities. Spacecraft: Low altitude density sphere, ejected from OV-1-20.	1,115 81 104.2 92.0	Still in orbit.
Aug. 7 Musketball (OAR 907) 67D Atlas	Objective: Electric field measurement, ion density and composition sensors to measure variations in density during increased geomagnetic activity. Spacecraft: Sphere also carrying C-band transponder, ejected from OV 1-21.	406 81 92.3 87.6	Decayed Sept. 19, 1971.
Aug. 7 AVL 802 67E Atlas	Objective: To gather aerodynamic data for use in design and development of orbiting vehicles. Spacecraft: 2-ft rigid-aluminum sphere, ejected from OV 1-21.	570 492 101.9 87.6	Still in orbit.
Aug. 7 AVL 802 67F Atlas	Objective: To gather aerodynamic data for use in design and development of orbiting vehicles. Spacecraft: 7 ft inflatable sphere of aluminum foil and mylar, ejected from OV 1-21.	570 474 101.6 87.5	Still in orbit.
Aug. 7 AVL 802 67G Atlas	Objective: To gather aerodynamic data for use in design and development of orbiting vehicles. Spacecraft: 7 ft inflatable grid sphere 1, of wire mesh and subliming plastic skin, ejected from OV 1-21.	570 483 101.8 87.8	Still in orbit.
Aug. 7 AVL 802 67H Atlas	Objective: To gather aerodynamic data for use in design and development of orbiting vehicles. Spacecraft: 7-ft inflatable grid sphere 2, of wire mesh and subliming plastic skin, ejected from OV 1-21.	570 483 101.8 87.6	Still in orbit.
Aug. 7 RTD 701 67J Atlas	Objective: Radar calibration target of one meter cross section. Spacecraft: 44-in. rigid sphere of aluminum, ejected from OV 1-21.	569 481 101.7 87.6	Still in orbit.

## Successful U.S. Launches—1971—Continued

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Aug. 12 Defense 70A Titan IIIB-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	250 83 89.8 110.9	Decayed Sept. 3, 1971.
Aug. 16 Eole (CAS-1) 71A Scout	Objective: To place the spacecraft into an appropriate earth orbit to analyze the meteorological data acquired from constant density surface balloons for the study of the characteristics and movements of air masses. Spacecraft: Octagonal-shaped prism 23-in. long by 28-in. diameter. Eight 24-in. long by 11-in. wide rectangular polar panels extend from satellite body. Stabilization system consists of 33-ft. long gravity gradient boom. A 400 MHz antenna resembling a truncated cone is used to communicate with and receive data from the spacecraft. Silver cadmium battery. Weight: 187 lbs.	562 421 100.6 50.1	Second cooperative France/United States project. French-built Cooperative Applications Satellite launched successfully by NASA. All spacecraft operations are functioning normally and monitoring air temperature and pressure from balloons released daily from three sites in Argentina.
Sep. 10 Defense 76A Thorad-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	137 105 88.3 74.9	Decayed. Oct. 5, 1971.
Sep. 10 Defense 76B Thorad-Agena	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	315 303 94.5 75.0	Still in orbit.
Sept. 29 OSO 7 83A Thorad-Delta	Objective: To obtain high resolution data from the solar corona in particular spectral bands in the XUV and in the visible regions during one solar rotation. Spacecraft: Revolving 9-sided polyhedron 56-in. diameter made of aluminum honeycomb material. Rectangular-shaped sail, mounted on top of the wheel, carries the solar cell array and pointed experiments. Spin stabilized; carries six scientific experiments. Overall height is 80 in. Weight: 1,400 lbs.	355 202 93.5 33.1	Although placed into non-circular orbit by second-stage launch vehicle anomaly, pitch angle was corrected by ground controllers and all spacecraft operations are functioning normally. Spacecraft located and observed for the first time a large (class 2) solar flare; also obtained the first observations of the corona in white light and extreme ultraviolet.
Sept. 29 TETR 3 83B Thorad-Delta	Objective: To test NASA's Manned Space Flight Network and to train MSFN personnel. Spacecraft: 45-lb. satellite carrying an S-Band transponder mounted in rear section of Delta 2d stage; magnetically stabilized.	354 250 94.3 33.0	Test and Training Satellite ejected successfully from Delta 2d stage; satellite receives and transmits signals simulating those of the Apollo spacecraft.
Oct. 14 Defense 87A Thor-Burner 2	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	546 494 101.6 98.9	Still in orbit.

## Successful U.S. Launches—1971—Continued

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Oct. 17 SESP 1971-2 89A Thorad-Agena	Objective: To test advanced development payloads: celestial mapping infrared scanner to test the closed loop radiator/pump cooler and to gather celestial background radiation pointed toward tracking ballistic missiles during midcourse of flight; 1,500 watt flexible roll-up solar cell array, with multiple deploy-retract cycles, to verify both mechanics and long term power generation characteristics; test of a secure command and control system; and study of energetic particles interaction with the ionosphere. Spacecraft: Basic Agena craft carries 5.5-ft. wide solar cell panels rolled up like window-shades which roll out on parallel extension arms stored in ribbon form which extend as stiff tubes to a length of 32 ft. To sustain the principal experiments, conventional arrays supply 500 watts of power.	498 481 100.5 92.7	Still in orbit.
Oct. 21 Debris of ITOS B 91A Thorad-Delta	Objective: To place in orbit an improved TIROS operational weather satellite of the NOAA series. Spacecraft: The base of the main body was about 40 in. by 40 in. height was about 40 in. Three solar panels were to extend outward from the structure. Total weight, about 675 lbs.	922 182 102.7 102.5	Payload placed in preliminary orbit, but failed upon attempt to circularize orbit.
Oct. 23 Defense 92A Titan IIIB-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	244 83 89.7 110.9	Decayed Nov. 17, 1971.
Nov. 3 DSCS 2-1 95A Titan IIIC	Objective: To provide communications channels for the automatic voice, automatic digital, and secure voice communications networks of the Defense Department. Spacecraft: Carries single frequency conversion X-band repeaters, with a bandwidth of 410 MHz to carry up to 1,300 duplex voice channels, or a million data bits per second. Spacecraft is cylindrical with 8 solar array curved panels generating 520 watts. Dimensions: 9-ft. diameter, 13-ft. tall. Final orbital weight: 1,200 lbs.	22, 255 22, 250 1, 436.1 2.6	Still in orbit.
Nov. 3 DSCS 2-2 95B Titan IIIC	Objective: Same as above. Spacecraft: Same as above.	22, 255 22, 250 1, 436.1 2.6	Still in orbit.

## Successful U.S. Launches—1971—Continued

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Nov. 15 Explorer 45 (SSS) Scout	Objective: To measure the characteristics and formation of the Earth's ring current and development of main-phase magnetic storms; the relation between magnetic storms, aurora, and the acceleration of particles within the inner magnetosphere and relative importance of various diffusion mechanisms in populating the radiation zones at a 4-5 Earth radii elliptical equatorial orbit. Spacecraft: 26-sided polyhedral shaped satellite 25-in. diameter. 30-in. boom along the spin axis supports a three-axis fluxgate magnetometer. Search coil magnetometers are packaged on two of the 2-ft. long radial booms and electric field spheres are in the two 9-ft. long booms. Total length with booms deployed 19 ft. Spacecraft body covered with solar cells; spin stabilized; silver cadmium battery; four antennas six experiments. Weight: 110 lbs.	16, 799 137 469. 0 3. 6	Fourth spacecraft in a joint Italian/United State cooperative space program. Launched successfully from an Italian platform in the Indian Ocean off the coast of Kenya, Africa by an Italian crew. All spacecraft systems operating normally. Five of six experiments turned on and operating satisfactorily.
Dec. 11 Ariel 4 (UK-4) 108A Scout	Objective: To investigate interactions among the plasma, charged particle streams and electromagnetic waves in the upper ionosphere. Spacecraft: A cylindrical body with booms. The main body is 30 in. in diameter and 36in. long. After launch, the four booms are deployed increasing the diameter to 11 ft., and the antennas are deployed to 45 ft. Weight: 218 lbs.	365 293 95. 2 83. 0	U.K./U.S. Cooperative program All experiments which have been turned on are operating satisfactorily.
Dec. 14 Defense 110A, 110C, 110D, 110E Thor-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	621 611 104. 9 70. 0	Still in orbit.
Dec. 18 Intelsat IV (F-3) 115A Atlas-Centaur	Objective: To provide equivalent of 3,000 to 9,000 telephone circuits simultaneously or 12 color TV channels, or a combination of telephone, TV, and other forms of communications traffic. Spacecraft: Cylindrical 93.5-in. diameter and 17.6 ft. high; spin stabilized; 12 communications repeaters (transponders); 6 antennas; 42,240 solar cells; weight after apogee motor fire; 1,548 lbs.	22, 387 22, 196 1, 458 0. 47	Launched by NASA for Comsat Corp., manager of INTELSAT. Second satellite in improved INTELSAT IV series. Will be stationed over Atlantic Ocean at 19.5° West longitude.



APPENDIX A-4

**Aeronautics Events of 1971**

Jan. 1 . . . . .	The S-67 Blackhawk helicopter set a world's speed record of 216.7 mph over a 3 Km. closed course.
Jan. 7 . . . . .	A statement of U.S. Government policy to promote satellite telecommunications for International Civil Aviation operations was released.
Jan. 15 . . . . .	The new V/STOL Wind Tunnel at the Langley Research Center became operational providing greatly improved testing capability for scaled models.
Mar. 9 . . . . .	A modified F-8 jet aircraft flew supersonic for the first time with the NASA high-speed supercritical wing.
Mar. 29 . . . . .	The X-24 lifting body research vehicle flew to its maximum speed of 1,048 mph.
Mar. 30 . . . . .	The joint DOT-NASA Civil Aviation Research and Development Policy Study (CARD) was completed. The Study defined the direction of aeronautical technology in the mid-70's and beyond.
Apr. 30 . . . . .	Pacific Southwest Airlines became the first airline to equip its entire fleet with new jet engine combustors reducing visible smoke.
May 21 . . . . .	Congress voted to terminate the United States SST program.
June 15 . . . . .	A new Terminal Area Control concept was initiated which separates air traffic around major terminals.
July 15 . . . . .	The McDonnell Douglas DC-10 became the first commercial airplane certified under the new Federal Noise regulation, Part 36.
Aug. 5 . . . . .	The McDonnell Douglas DC-10 "airbus" made its first commercial flight, which lasted 3 hours 18 minutes between Los Angeles and Chicago.
Aug. 25 . . . . .	The M2-F3 lifting body research vehicle made its first supersonic flight.
Sept. 2 . . . . .	The F-14 fighter aircraft successfully demonstrated the first automatically programable variable wing sweep.
Sept. 6 . . . . .	The Anglo-French Concorde 001 supersonic transport made its first trans-Atlantic test flight.
Sept. 9 . . . . .	The Cessna Citation, a small twin-engine jet airplane, was certified for commercial operations.
Oct. 15 . . . . .	The FAA established a rule requiring emergency locator transmitters on all aircraft (except turbojets, scheduled air carriers, and agricultural aircraft).
Oct. 26 . . . . .	The U.S. Army CH54B helicopter set a new world altitude record of 16,798 ft. while carrying a payload of 10,000 kilograms.
Nov. 16 . . . . .	The General Electric Quiet Experimental Engine successfully completed initial tests in a NASA program to reduce jet engine noise.
Dec. 3 . . . . .	The NASA let contracts on Phase I, competitive design, of a program to develop a quiet experimental short take-off and landing (STOL) transport research aircraft.

APPENDIX B

**U.S. Applications Satellites 1958-1971**

Date	Name	Launch vehicle	Remarks
GEODESY			
Oct. 31, 1962	Anna 1B	Thor-Able Star	Used 3 independent measuring techniques: Doppler frequency shift, flashing lights, and radio triangulation. Uses radio triangulation and trilateration. Conducted reflecting-light geodetic measurements.
Jan. 11, 1964	Secor I	Thor-Agena D	
Oct. 10, 1964	Beacon-Explorer XXII	Scout	Spacecraft is a 100-foot-diameter balloon used as a photographic target to make 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	
Aug. 19, 1966	Secor VII	Atlas-Agena D	
Oct. 5, 1966	Secor VIII	Atlas-Agena D	
June 29, 1967	Secor IX	Thor-Burner II	
Jan. 11, 1968	GEOS II	Thor-Delta	
Apr. 14, 1969	Secor XIII	Thor-Agena D	
Apr. 8, 1970	Topo I	Thor-Agena D	

## U.S. Applications Satellites 1958-1971—Continued

Date	Name	Launch vehicle	Remarks
COMMUNICATIONS			
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.
Mar. 30, 1961	Lofti I	Thor-Able Star	Low-frequency experiment; failed to separate from rest of payload.
Oct. 21, 1961	Westford I	Atlas-Agena B	First attempt to establish filament belt around earth; failed to disperse as planned.
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	
May 9, 1963	Westford II	Atlas-Agena B	Filaments formed reflective belt around earth as planned for emergency communications experiment.
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 United States and U.S.S.R.
Aug. 19, 1964	Syncom III	Thor-Delta	Synchronous-orbit Comsat; after experimental phase, used operationally by DOD.
Feb. 11, 1965	LES I	Titan IIIA	Experimental payload did not reach intended apogee.
Mar. 9, 1965	Oscar III	Thor-Agena D	
Apr. 6, 1965	Intelsat I (Early Bird)	Thor-Delta	First Intelsat (Comsat Corporation) spacecraft, 240 2-way voice circuits; commercial transatlantic communication service initiated June 28, 1965.
May 6, 1965	LES II	Titan IIIA	All solid state advanced experiment.
Dec. 21, 1965	LES III	Titan IIIC	All solid state, UHF signal generator.
	LES IV		All solid state SHF or X band experiment.
	Oscar IV		
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(TAT)	First in Intelsat II series spacecraft; 240 2-way voice circuits or 1 color TV channel. Orbit achieved not adequate for commercial operation.
Nov. 3, 1966	OV 4-1T	Titan IIIC	Transmitter and receiver for low-power satellite-to-satellite F layer experiments.
Dec. 7, 1966	OV 4-IR		
Jan. 11, 1967	ATS I	Atlas-Agena D	Multipurpose, including VHF exchange of signals with aircraft.
	Intelsat II-F2	Thor-Delta(TAT)	Transpacific commercial communication service initiated Jan. 11, 1967.
Jan. 18, 1967	IDCSP 8-15	Titan IIIC	
Mar. 22, 1967	Intelsat II-F3	Thor-Delta(TAT)	Positioned to carry transatlantic commercial communication traffic.
Apr. 6, 1967	ATS II	Atlas-Agena D	Multipurpose, but did not attain planned orbit.
July 1, 1967	IDCSP 16-18	Titan IIIC	
	LES V		Tactical military communications tests with aircraft, ships, and mobile land stations from near synchronous orbit.
	DATS		Electronically despun antenna experiment.
	DODGE		Multipurpose, gravity stabilized.
Sept. 27, 1967	Intelsat II-F4	Thor-Delta(TAT)	Positioned to carry commercial transpacific communication traffic.
Nov. 5, 1967	ATS III	Atlas-Agena D	Multipurpose including communications.
June 13, 1968	IDCSP 19-26	Titan IIIC	
Aug. 10, 1968	ATS IV	Atlas-Centaur	Multipurpose; failed to separate from Centaur, did not reach planned orbit.
Sept. 26, 1968	LES 6	Titan IIIC	Continued military tactical communications experiments.
Dec. 18, 1968	Intelsat III (F-2)	Thor-Delta(TAT)	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.
b. 6, 1969	Intelsat III(F-3)	Thor-Delta (TAT)	Stationed over Pacific to carry commercial traffic between the United States, Far East, and Australia.
. 9, 1969	Tacsat I	Titan IIIC	Demonstrated feasibility of using a spaceborne repeater to satisfy selected communications needs of DOD mobile forces.

## U.S. Applications Satellites 1958-1971—Continued

Date	Name	Launch vehicle	Remarks
COMMUNICATIONS—Continued			
May 22, 1969	Intelstat 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.
August 12, 1969	ATS V	Atlas Centaur	Multipurpose; for millimeter and L band communications; entered flat spin.
Nov. 22, 1969	Skynet I (IDCSP-A)	Thor-Delta(TAT)	Launched for the United Kingdom in response to an agreement to augment the IDCSP program.
Jan. 15, 1970	Intelsat III(F-6)	Thor-Delta(TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, Latin America, and the Middle East.
Jan. 23, 1970	Oscar V (Australis)	Thor-Delta(TAT)	Ham radio satellite built by amateur radio operators at Melbourne University, Melbourne, Australia.
Mar. 20, 1970	NATOSAT-I (NATO-A)	Thor-Delta (TAT)	First NATO satellite, stationed over Atlantic to carry military traffic between the United States and other NATO countries.
Apr. 23, 1970	Intelsat III (F-7)	Thor-Delta (TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, North Africa, and the Middle East.
Jul. 23, 1970	Intelsat III (F-8)	Thor-Delta (TAT)	Spacecraft failed to achieve the proper orbit. Not usable. Last launch of Intelsat III series.
Aug. 22, 1970	Skynet II (IDCSP-B)	Thor-Delta (TAT)	Launched for the United Kingdom in response to an agreement to augment the IDCSP program. Spacecraft failed to achieve the proper orbit.
Jan. 26, 1971	Intelsat IV (F-2)	Atlas-Centaur	First in Intelsat IV series of spacecraft; 3-9,000 2-way voice circuits or 12 color TV channels. Positioned over the Atlantic.
Feb. 3, 1971	NATOSAT-II (NATO-B)	Thor-Delta (TAT)	Second NATO satellite, stationed over the Atlantic to carry military traffic.
Nov. 3, 1971	DSCS 2-1, 2	Titan IIIC	Operational defense communications satellites launched as a pair to 24-hour synchronous orbits to provide high capacity voice, digital, and secure voice communications for military networks.
Dec. 19, 1971	Intelsat IV (F-3)	Atlas Centaur	Second in new high-capacity series.
NAVIGATION			
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	
Mar. 11, 1965	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	
Aug. 27, 1970	NavSat	Scout	

## U.S. Applications Satellites 1958-1971—Continued

Date	Name	Launch vehicle	Remarks
WEATHER OBSERVATION			
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	
Aug. 28, 1964	Nimbus I	Thor-Agena B	First weather satellite designed to transmit continuously local cloud conditions to ground stations equipped with APT receivers.
Jan. 22, 1965	Tiros IX	Thor-Delta	Carried advanced videcon camera system, APT, and a high resolution infrared radiometer for night pictures.
July 2, 1965	Tiros X	Thor-Delta	
Feb. 3, 1966	ESSA 1	Thor-Delta	First weather satellite in a sun-synchronous orbit.
Feb. 28, 1966	ESSA 2	Thor-Delta	First operational weather satellite; carried 2 wide-angle TV camera systems.
May 15, 1966	Nimbus II	Thor-Agena B	
Oct. 2, 1966	ESSA 3	Thor-Delta	
Dec. 6, 1966	ATS-1	Atlas-Agena D	Complemented ESSA I with 2 wide-angle APT cameras.
Jan. 26, 1967	ESSA 4	Thor-Delta	Odd-number ESSA spacecraft carry 2 advanced videcon camera systems. Even-numbered spacecraft carry 2 automatic picture transmission camera systems.
Apr. 20, 1967	ESSA 5	Thor-Delta	
Nov. 5, 1967	ATS-3	Atlas-Agena	Provided continuous black-and-white cloud-cover pictures from a synchronous orbit, using a Suomi camera system.
Nov. 10, 1967	ESSA 6	Thor-Delta	Provided continuous color cloud-cover pictures from a synchronous orbit, using 3 Suomi camera systems.
Aug. 16, 1968	ESSA 7	Thor-Delta	
Dec. 15, 1968	ESSA 8	Thor-Delta	
Feb. 26, 1969	ESSA 9	Thor-Delta	
Apr. 14, 1969	Nimbus III	Thor-Agena	
Jan. 23, 1970	ITOS I (Tiros M)	Thor-Delta	Provided first vertical temperature profile on a global basis of the atmosphere from the spacecraft to the Earth's surface.
Apr. 8, 1970	Nimbus IV	Thor-Agena	Second generation operational meteorological satellite.
Dec. 11, 1970	NOAA-1 (ITOS-A)	Thor-Delta	Fifth in a series of 7 advanced research and development weather satellites.
Aug. 16, 1971	Eole (CAS-1)	Scout	Second generation operational meteorological satellite.
			French satellite to gather data from constant density surface balloons relaying meteorological data for the study of the characteristics and movements of air masses. New balloons are released daily from three sites in Argentina, for this cooperative French/U.S. project.

## APPENDIX C

## 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 4 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 3 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 mins.).
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. 35 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 space craft (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. 37 mins.	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	260 hrs. 9 mins.	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgi Beregovoy	94 hrs. 51 mins.	Maneuvered near unmanned Soyuz 2.

## History of U.S. and Soviet Manned Space Flights—Continued

Spacecraft	Launch date	Crew	Flight time	Highlights
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	147 hrs. 1 min.	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. 23 mins.	Soyuz 4 and 5 docked and transferred 2 Cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris Volynov Aleksey Yeliseyev Yevgeniv Khrunov	72 hrs. 56 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.
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy Kubasov	118 hrs. 42 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 Filipchenko Vladislav Volkov Viktor Gorbatko	118 hrs. 41 mins.	
Soyuz 8	Oct. 13, 1969	Vladimir Shatalov Aleksey Yeliseyev	118 hrs. 50 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.
Apollo 13	Apr. 11, 1970	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	142 hrs. 55 mins.	Mission aborted due to explosion in the service module. Ship circled moon, with crew using LEM as "lifeboat" until just prior to reentry.
Soyuz 9	June 1, 1970	Andrian G. Nikolayev Vitaliy I. Sevastianov	424 hrs. 59 mins.	Longest manned space flight lasting 17 days 16 hrs. 59 mins.
Apollo 14	Jan. 31, 1971	Alan B. Shepard Stuart A. Roosa Edgar D. Mitchell	216 hrs. 42 mins.	Third manned lunar landing. Mission demonstrated pin-point landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir Shatalov Aleksey Yeliseyev Nikolai Rukavishnikov	47 hrs. 46 mins.	Docked with Salyut 1, but crew did not board space station launched April 19. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Georgiy Timofeyevich Dobrovolskiy Vladislav Nikolayevich Volkov Viktor Ivanovich Patsayev	570 hrs. 22 mins.	Docked with Salyut 1 and Soyuz 11 crew occupied space station for 22 days. Crew perished during final phase of Soyuz 11 capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	David R. Scott Alfred M. Worden James Bensen Irwin	295 hrs. 11 mins. 53 secs.	Fourth manned lunar landing and first Apollo "J" series mission which carry the Lunar Roving Vehicle. Worden's in-flight EVA of 38 min. 12 secs. was performed during return trip.

APPENDIX D-1

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant <sup>4</sup>	Thrust (in thou- sands of pounds)	Max. dia. (feet)	Height <sup>3</sup> (feet)	Payload (pounds)		
						100 NM orbit	Escape	First launch
Scout . . . . .	1. Algol (IIB) . . . . .	Solid . . . . .	100.9	3.3	64.4	410	50	1965(60)
	2. Castor II . . . . .	Solid . . . . .	60.7					
	3. Antares II . . . . .	Solid . . . . .	20.9					
	4. Altair III or FW4 . . . . .	Solid . . . . .	5.9					
Thrust-augmented Thor-Delta . . . . .	1. Thor (SLV-2J) plus nine TX 354-5 . . . . .	LOX/RP Solid . . . . .	205 <sup>2</sup> 57.3	11	109	4,300	1,050	1972(60)
	2. Delta (DSV-3) . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	9.2					
	3. TE 364 . . . . .	Solid . . . . .	15					
Thrust-augmented Thor-Agena . . . . .	1. Thor (SLV-2H) plus three TX 354-5 . . . . .	LOX/RP Solid . . . . .	170 <sup>2</sup> 52	11	110	2,900		1966(60)
	2. Agena . . . . .	IRFNA/UDMH	16					
Atlas-Burner II . . . . .	1. Atlas booster and sustainer (SLV-3A) . . . . .	LOX/RP	400	10	84	6,000	700	1968
	2. Burner II . . . . .	Solid . . . . .	10					
Atlas-Agena . . . . .	1. Atlas booster and sustainer (SLV-3A) . . . . .	LOX/RP	400	10	100	8,000	1,430	1968(60)
	2. Agena . . . . .	IRFNA/UDMH . . . . .	16					
Titan IIB-Agena . . . . .	1. LR-87 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	464	10	113	9,200	1,700	1966
	2. LR-91 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	102					
	3. Agena . . . . .	IRFN/UDMH . . . . .	16					
Titan IIC . . . . .	1. Two 5-segment 120" diameter . . . . .	Solid . . . . .	2,400	10x30	108	28,000	6,000	1965
	2. LR-87 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	523					
	3. LR-91 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	102					
	4. Transtage . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	16					
Titan IID . . . . .	1. Two 5-segment 120" diameter . . . . .	Solid . . . . .	2,400	10x30	95	20,000		1971
	2. LR-87 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	523					
	3. LR-91 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	102					
Titan IID-Centaur . . . . .	1. Two 5-segment 120" diameter . . . . .	Solid . . . . .	2,400	10x30	128		11,000	1974(est.)
	2. LR-87 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	523					
	3. LR-91 . . . . .	N <sub>2</sub> O <sub>4</sub> /Aerozine . . . . .	102					
	4. Centaur (Two RL-10) . . . . .	LOX/LH . . . . .	30					
Atlas-Centaur . . . . .	1. Atlas booster and sustainer . . . . .	LOX/RP . . . . .	400	10	103	11,300	2,700	1967(62)
	2. Centaur (Two RL-10) . . . . .	LOX/LH . . . . .	30					
Saturn IB . . . . .	1. S-IB (Eight H-1) . . . . .	LOX/RP . . . . .	1,640	21.6	142	40,000		1966
	2. S-IVB (One J-2) . . . . .	LOX/LH . . . . .	230					
Saturn V . . . . .	1. S-IC (Five F-1) . . . . .	LOX/RP . . . . .	7,570	33	281	285,000	103,000	1967
	2. S-II (Five J-2) . . . . .	LOX/LH . . . . .	1,150					
	3. S-IVB (One J-2) . . . . .	LOX/LH . . . . .	230					

<sup>1</sup> The date of first launch applies to this latest modification with a date in parentheses for the initial version.  
<sup>2</sup> Each motor.  
<sup>3</sup> Height to spacecraft interface.  
<sup>4</sup> 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—IRFN/UDMH; Nitrogen Tetroxide and 50% UDMH and 50% Hydrazine (N<sub>2</sub>H<sub>4</sub>)—N<sub>2</sub>O<sub>4</sub>/Aerozine; Liquid Oxygen and Liquid Hydrogen—LOX/LH.

APPENDIX D-2

**U.S. Successful Launches to Earth Orbit or Beyond  
By Launch Vehicle, 1958-71**

Launch vehicle	Subtotals	Launch vehicle	Subtotals
Thor-Able.....	3	Titan IIIB Agena.....	34
Thor-Able Star.....	14	Titan IIIC.....	16
Thor-Delta.....	81	Titan IIID.....	1
Thor-Agena.....	160		
Thor-Altair.....	5	TITAN total.....	65
Thor-Burner II.....	13	SCOUT total.....	46
<b>THOR total.....</b>	<b>276</b>	Saturn I.....	6
		Saturn IB.....	3
Atlas.....	17		
Atlas-Agena.....	90	SATURN I total.....	9
Atlas-Centaur.....	20	SATURN V total.....	10
		REDSTONE total.....	3
<b>ATLAS total.....</b>	<b>127</b>	JUPITER total.....	4
		VANGUARD total.....	3
Titan II.....	11		
Titan IIIA.....	3	Grand total.....	543

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 ALSEPS of Apollo 14 & 15.
SNAP-10A	Unmanned missions	Tested in orbit in 1965.
Transit <sup>1</sup>	Navigation satellites (DOD)	Development program underway.
Pioneer <sup>1</sup>	Jupiter flyby mission (NASA)	Modified SNAP-19 generator system will be used.
Viking <sup>1</sup>	Mars unmanned lander mission (NASA)	Modified SNAP-19 generator system will be used.
Multi-Hundred Watt <sup>1</sup>	Outer planet missions (NASA)	Development program underway.

<sup>1</sup> Planned missions.



### Space Activities of the U.S. Government

13-YEAR SUMMARY AND 1973 BUDGET RECOMMENDATIONS, JANUARY 1972—NEW OBLIGATIONAL AUTHORITY

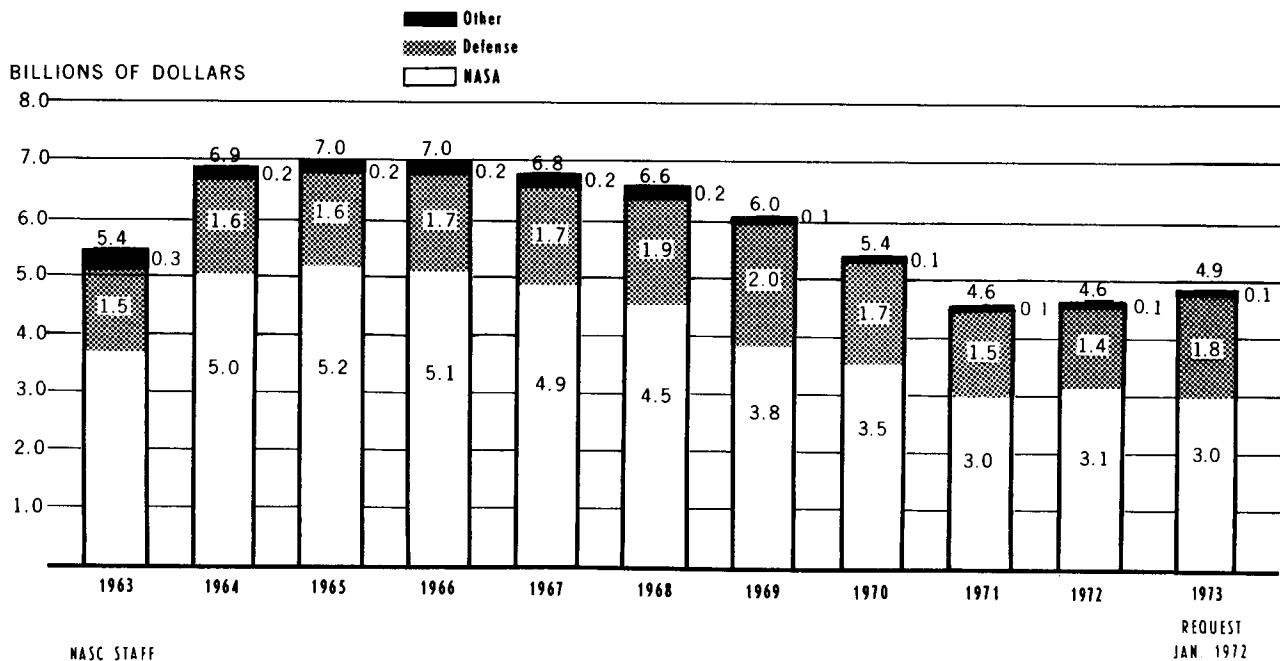
[In millions of dollars (may not add due to rounding)]

	NASA		Department of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total space
	Total	Space <sup>1</sup>							
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
1970.....	3,745.8	3,547.0	1,678.4	102.8	8.0	2.0	0.8	2.4	5,341.4
1971.....	3,311.2	3,001.3	1,512.3	94.3	27.4	5.2	0.8	2.4	4,643.7
Budget:									
1972.....	3,294.6	3,058.7	1,424.9	57.7	31.4	9.8	3.5	2.8	4,588.8
1973.....	3,377.6	3,082.3	1,782.8	66.4	44.6	9.8	3.5	2.8	4,992.2

<sup>1</sup> Excludes amounts for aviation technology.

Source: Office of Management and Budget.

### U. S. SPACE BUDGET - NEW OBLIGATIONAL AUTHORITY



## Space Activities Budget, January 1972

[In millions of dollars]

	New obligational authority			Expenditures		
	1971 actual	1972 estimate	1973 estimate	1971 actual	1972 estimate	1973 estimate
<b>Federal space programs:</b>						
NASA <sup>1</sup> .....	3,001.3	3,058.7	3,082.3	3,171.0	2,953.7	2,940.3
Defense.....	1,512.3	1,424.9	1,782.8	1,693.0	1,487.0	1,647.0
AEC.....	94.3	57.7	66.4	97.3	62.5	56.0
Commerce.....	27.4	31.4	44.6	29.8	25.1	35.6
Interior.....	5.2	9.8	9.8	4.5	8.6	8.6
NSF.....	2.4	2.8	2.8	2.4	2.8	2.8
Agriculture.....	0.8	3.5	3.5	1.0	3.0	3.2
<b>Total.....</b>	<b>4,643.7</b>	<b>4,588.8</b>	<b>4,992.2</b>	<b>4,999.0</b>	<b>4,542.7</b>	<b>4,693.5</b>
<b>NASA:</b>						
Manned space flight.....	1,781.8	1,633.7	1,572.9	1,884.8	1,636.6	1,571.1
Space science and applications.....	704.2	893.1	1,013.1	660.6	765.7	853.3
Space technology.....	264.0	214.6	171.4	272.0	220.0	187.9
Aviation technology.....	209.9	235.9	295.3	209.6	226.0	250.7
Supporting activities.....	362.7	330.3	336.1	365.0	344.4	339.2
Less receipts.....	-11.4	-13.0	-11.2	-11.4	-13.0	-11.2
<b>Total NASA.....</b>	<b>3,211.2</b>	<b>3,294.6</b>	<b>3,377.6</b>	<b>3,380.6</b>	<b>3,179.7</b>	<b>3,191.0</b>

<sup>1</sup> Excludes amounts for aviation technology.

Source: Office of Management and Budget.

## Aeronautics Budget

[In millions of dollars]

	New obligational authority		
	1971	1972 estimate	1973 estimate
<b>Federal aeronautics programs:</b>			
NASA <sup>1</sup> .....	209.9	235.9	295.3
Department of Defense <sup>2</sup> .....	1,707.5	1,984.3	1,947.5
Department of Transportation.....	72.8	98.3	102.2
<b>Total.....</b>	<b>1,990.2</b>	<b>2,318.5</b>	<b>2,345.0</b>

<sup>1</sup> R. & D., R. & P.M., C. of F.<sup>2</sup> R.D.T. & E. aircraft and related equipment.<sup>3</sup> Office of Sec. of Trans. and FAA

Source: Office of Management and Budget.

Note: Some of the estimates shown in the above table are as of December 31, 1971, and may not agree with final budget figures.