

WILLIAM D. CONNOR



Aeronautics and Space Report of the President

1970

TRANSMITTED TO THE
CONGRESS
JANUARY 1971

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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:

In this first year of the new decade, we have been working to establish a firm basis for a balanced national aeronautics and space program which is compatible with our national priorities, goals and resources and which insures continuing progress throughout the decade. 1970 has been a year of transition from past successes to new challenges.

The activities of our space program during the year are consistent with the recommendations I made in March for a balanced space program. Our goals are continued exploration, scientific knowledge and practical applications. The technology acquired through our space programs has many practical applications on earth ranging from communications, meteorology and navigation to agriculture, education and transportation.

Specific objectives guide our space endeavors. We should continue to explore the moon and increase the scientific return on the investment in the Apollo program. We should also continue to explore the planets of our solar system and the universe. We must strive to reduce the cost of space operations. We should try to expand our knowledge of man's ability to perform productively in the hostile environment of space and to relate this knowledge to uses here on earth. We must apply space-related technology to the critical assessment of our environment and to the effective use of our resources. We should also promote international cooperation in our space program by pursuing joint space ventures, exchanging scientific and technical knowledge, and assisting in the practical application of this knowledge. We are greatly encouraged by European interest in joining us in cooperative post-Apollo planning.

From our aeronautics activities have come substantial contributions to continued U.S. pre-eminence in civil aviation, major improvements in aeronautical services, and impressive developments in a sound SST program. This year has seen the initiation of new military aeronautics programs that will enhance our national security. We must consider other new means to insure that our national aeronautics program is given the opportunity and encouragement to contribute to our national well-being.

I am pleased to transmit to Congress this report of our national aeronautics and space activities during 1970. I take this opportunity to express my admiration for the men and women whose devotion, courage and creativity have made our aeronautics and space progress a source of national pride.



THE WHITE HOUSE,
January 1971.

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I



Progress Toward U.S. Aeronautics and Space Goals in 1970

Introduction

The decade of the Sixties was an exciting period of growth and development of the nation's aeronautics and space endeavors. The primary goal around which the space activities centered was to land a man on the moon and to return him safely to earth. The year 1969 saw the fulfillment of man's age-old dream to travel beyond the confines of his terrestrial home to another celestial body. This great achievement of technical skill and human determination marked the successful accomplishment of a national goal and added to the distinction of this first chapter of U.S. space history. The attainment of the primary goal of the Sixties signaled that the time was appropriate to examine the successes of the past and to propose a follow-on space program for the new decade and the future. An extensive effort was undertaken to evaluate the alternatives open to the nation in selecting future space programs which would be clearly defined and feasible, and simultaneously compatible with other national priorities.

The result of the evaluation became the basis for a bold and energetic yet well balanced space program for the Seventies. In March of 1970, new goals and objectives for continuing the progress of space achievements were announced based on three general purposes: space exploration, scientific knowledge and practical applications. Six specific objectives were outlined: continued exploration of the moon; bold exploration of the planets and the universe; substantial reduction in the cost of space operations; extension of man's capability to live and work in space; expansion of the practical applications of space technology and the encouragement of greater international cooperation in space.

The year saw substantial progress in U.S. aeronautics activities which served to maintain the U.S. pre-eminence in the field. Advancements in the design of the supersonic transport and an aggressive research and development program highlighted this year of aeronautical progress. The year also saw considerable activity dedicated to the initiation of new military aeronautics programs that will enhance our national security.

The scientific knowledge gained through space exploration opens a new door to greater scientific and intellectual comprehension of man himself, the planet on which he lives, the solar system, and the universe.

With the information gleaned from each space venture, man increases his ability to devote his scientific and technical skills toward the benefit of life and improvement of its conditions throughout the entire world.

Continued Exploration of the Moon

Four Americans have explored the lunar surface, set out scientific equipment around their landing sites, made geologic observations of the surrounding area and collected 123 pounds of selected samples of rock and lunar material for further analysis on earth. Returned lunar rocks have been displayed throughout the world where they have attracted great interest and admiration for our country. The study and analysis of the material during 1970 has been the basis for estimating that the moon was formed about four and a half billion years ago, approximately the same time as the earth and meteorites. Scientists and investigators from 16 countries are continuing analyses to glean whatever facts the material has yet to yield. These achievements have greatly improved our knowledge of the moon and have given the world a new capability to understand the solar system and its origin. The remaining Apollo flights will yield progressively increased scientific returns as exploration radius and time on the moon are expanded. New experiments, new equipments, and, further analysis of the information and material received will continue to improve knowledge.

Scientific equipment and instruments which were placed on the moon by astronauts continue to transmit new and valuable information about its structure, physical state, magnetic fields, solar winds, and atmosphere. The SNAP 27 nuclear power unit provides power for these experiments and it has operated continuously, above its mission requirements, since emplacement. By laser ranging on the reflector deployed by the Apollo 11 crew, the distance between the moon and the earth can be measured to an accuracy of less than one foot. These measurements are made several times a week, giving an accurate ephemeris of the moon, and helping to discern lunar motions and tidal effects.

Two lunar flights, Apollo 13 and 14, were scheduled to be made in 1970. As the world knows, the attempt to put the third crew of Americans on the moon was cut short when an oxygen tank failure occurred on Apollo 13. The courageous astronauts were returned safely to

earth with the help of skillful ground controllers and aided by the dedicated support and prayers of people throughout the world. Subsequent analysis of the entire Apollo system and the modifications necessary to prevent recurrence of similar problems resulted in the decision to reschedule the launch of Apollo 14 for early 1971.

More scientific equipment will be set out by the crew of Apollo 14 when they arrive on the moon. The Mobile Equipment Transporter, a two wheel rickshaw-like device, has been developed to help the astronauts carry equipment and instruments in their lunar travel. Apollo 15, scheduled to be launched later in 1971, will be the first to carry a Lunar Roving Vehicle (LRV) to the moon. This vehicle is four wheeled and self-propelled; it will carry the two astronauts and their equipment, thereby providing a much greater range of exploration during their visit. Improvements planned in life support systems will permit greater stay times, and expanded use of the LRV will increase substantially the crew's capability to deploy scientific instruments and devices, collect lunar materials, and make scientific observations.

In September after much deliberation and consideration of all factors, the difficult decision was made to eliminate two of the future Apollo missions, and to apply the resources to other elements of the space program. Apollo 16 and 17 will be the final missions and are presently scheduled to be flown in 1972.

Exploration of the Planets and the Universe

The United States continued the pace of its scientific exploration of the planets and the universe and made plans for a bold program in the decade of the '70's dedicated to the greater understanding of the space environment.

The Orbiting Astronomical Observatory (OAO) -2, launched in 1968, continues to provide important data uniquely available from this spacecraft. A series of observations of an exploding star (a nova) in the constellation Serpens was made which could not be seen from ground-based telescopes due to the filtering effect of the earth's atmosphere. With the completion of the celestial telescope experiment aboard OAO-2, the beginning of the analysis of ultraviolet spectral data on some 25,000 stars was undertaken. A third Orbiting Astronomical Observatory was launched late in 1970 but failed to achieve orbit. The Orbiting Geophysical Observatories 3, 4, 5, and 6 (launched between 1967 and 1969) made sky-surveys and provided much valuable data that could be correlated with data from other satellites, sounding rockets, and ground-based instruments.

Through the Smithsonian Astronomical Observatory's automatic photographic patrol, a bright fireball was optically tracked and three meteorite fragments

were recovered near Lost City, Oklahoma. This was the first time that recovered fragments could be correlated with a specific meteoroid coming from a known orbit.

The discovery of the existence of a large number of interstellar molecules by radio astronomers in the past two years has led to the identification of more complex and unexpected molecules in space. Spectral measurements indicate that complex chemical reactions take place during the evolution of interstellar clouds into stars and planets. In fact, these molecules have been identified as some of the building blocks necessary to produce simple lifelike forms. More recently, analysis of a meteorite which landed in Australia provided the first positive identification of amino acids of extraterrestrial origin. This is probably the first conclusive proof of extraterrestrial chemical evolution, the chemical processes which precede the origin of life.

The first of the Small Astronomy Satellite series (named Uhuru, the Swahili word for freedom) was launched in December by the Italians for the United States from the San Marco range to investigate several spectral regions of the electromagnetic spectrum. The satellite, now in orbit, is designed to develop a catalog of celestial X-ray sources. It should transmit more data in a single day than was transmitted through the total observation time of the X-ray instruments on all earlier satellites and rockets. Satellites of the Explorer series as well as some of the international satellites continue to provide useful environmental information that will lead to a better understanding of the physical properties and mechanisms of interactions in space.

Planning and development of other spacecraft intended for exploration of the planets continued throughout 1970. The Mariner class spacecraft which returned such outstanding photographs of Mars in 1964 and again in 1969 were being improved for missions to Mars, Venus, and Mercury. Spacecraft design was completed for Pioneer spacecraft to go to Jupiter. Experiment definition, instrument concepts, and mission plans were advanced for the Viking spacecraft which will orbit and land on Mars. Planning continued for "Grand Tour" missions later in the decade to Jupiter, Saturn, Uranus, Neptune, Pluto, and their satellites. A prime contractor was selected for the Helios spacecraft, a cooperative US-West Germany project which will fly close to the sun.

Substantial Reduction in the Cost of Space Operations

During 1970 the feasibility of reusable space shuttles as a means of reducing the cost of space operations was examined in greater detail. In-depth studies were initiated to define better not only the vehicle hardware but also payloads, system economics, and civilian and

military mission traffic requirements for a Space Transportation System (STS). Mission objectives are being considered by a NASA/DOD interagency STS Committee with observers from the National Aeronautics and Space Council staff. A major effort has been devoted to the development of international cooperation in our post Apollo program; several European countries are presently considering the nature and degree of participation (including financial), which they may wish to propose with the space shuttle program as a primary focus of effort.

In another area for reducing costs in space program operations, DOD and NASA conducted a joint study of common support services at the Eastern Test Range and the Kennedy Space Center. The study led to recommendations for the consolidation of support services which is expected to save over one million dollars per year in the operation of these two facilities.

Extension of Man's Capability To Live and Work in Space

Much has been learned from the Mercury, Gemini and Apollo missions about man's capability to live and perform productively in the environment of outer space. The next step in our manned space flight program will explore extended duration missions using Apollo hardware as an experimental space station. This program, called Skylab, was known previously as the Orbital Workshop.

During the past year program development has progressed quite well. The Skylab program objectives are: (1) to determine and evaluate man's adaptation to the space environment and his readaptation to terrestrial conditions through a series of progressively longer missions; (2) to develop and evaluate techniques for utilizing man's sensory, decision-making, discriminatory, and mechanical capabilities in space operations; (3) to develop techniques for increasing systems and subsystems life for long duration habitability and mission control; (4) to conduct science, technology, and applications experiments in which man's contribution is expected to improve the quality and/or yield of the results. Major experiments to be included are the large solar telescope and the multi-spectral earth resources survey equipment. Present planning calls for a late 1972 launch of the Skylab followed the next day by a launch of an Apollo Command and Service Module carrying three astronauts who will activate the station and use it as a laboratory for up to 28 days. The station will be revisited by two additional crews. Based on the experience of the first crew, it is planned to extend the time of stay for the second and third visits up to 56 days each.

On the basis of experience with Skylab, it will be possible to make sound decisions on how to proceed

with longer duration space stations or platforms in the future. Initial conceptual studies and program definition activity are being continued in this area in order to establish alternative program options for future multi-purpose space platforms.

Practical Applications of Space Technology

The most visible benefits deriving from activities in space are evident in the applications of space technology. These applications are manifested in areas such as communications, meteorology, navigation and traffic control, geodesy, surveying the earth's resources from space, and national defense. Such activities offer the greatest immediate prospect for helping man improve the quality of life on earth.

Communications.—The country continued with an aggressive space oriented communications program to provide for both our civil and military requirements. An experiment was initiated using the Applications Technology Satellite (ATS)-1 for educational and public radio transmissions by Alaska. ATS-3 was used for educational telecasts between South Carolina and California. Signal acquisition and tracking tests for digital communications and ranging were performed by the L-band transponder of ATS-5.

The first phase of the Defense Satellite Communications System (DSCS) designed to provide long distance communications capability by satellite, presently uses 23 operational spacecraft and 29 earth terminals. The system continued to satisfy unique and vital military communications requirements. As an adjunct to satisfying these needs, the military satellite communications system also provided services in civilian areas. Procurement of the satellites for the second phase of DSCS is well underway and launch of the spacecraft into synchronous orbit to initiate the improved system is scheduled for mid-1971. The Phase II DSCS satellites will have significantly higher power and bandwidth capability permitting many additional communications channels. These satellites coupled with scheduled improved terminal performance will provide significant improvement in satellite communications reliability, capability and service.

The research and development phase of the Tactical Satellite Communications Program (TACSAT) was completed in 1970. The objective of this phase was to investigate the use of space borne communications repeaters to satisfy selected communications needs of our mobile forces. Tests were performed using aircraft, jeeps, trucks, ships, and submarines and included the use of the Lincoln Experiment Satellite (LES)-6, the TACSAT-1 satellite and 65 mobile terminals. The data obtained is being analyzed to determine the design of future operational systems.

This year the United States launched three satellites for Intelsat, the partnership of telecommunications entities in 77 nations. One of these failed to achieve synchronous orbit. Five commercial communications satellites are in operation to provide worldwide coverage. Two are over the Atlantic, two over the Pacific, and one over the Indian Ocean. An advanced design satellite Intelsat IV having almost eight times the circuit capacity of the current-Intelsat III series is being readied for launch early in 1971.

Meteorology.—The nation added significantly to its meteorology capability with the successful launch of the first Improved TIROS Operational Satellite (ITOS)-1. This became the prototype for the second generation of operational environmental satellites. The second of the ITOS satellites, designated NOAA-1, and the first operational satellite of the system was launched at the end of 1970. This addition to our operational capability further enhances the contributions that this country is in a position to make toward the understanding of meteorological phenomena and the improving of worldwide forecasting ability. Nimbus IV, another in a series of advanced research and development weather satellites was launched in April.

ITOS supports the National Operational Meteorological Satellite System and is an improved type satellite which is to replace two types of TIROS operational satellites. Nimbus made the first satellite measurements of vertical temperature soundings in the lower stratosphere; these measurements provide significant new data for long range weather forecasting. Nimbus also carries a SNAP 19 nuclear power generator. In addition, Nimbus has achieved extremely precise and stable spacecraft attitude control. The proof of this system's performance is extremely important to the Earth's Resources Technology Satellite which requires such stability for taking high resolution images.

As a secondary payload with ITOS-1, the fifth of the Orbiting Satellites Carrying Amateur Radio (OSCAR) was launched. This spacecraft was designed and built by students at Melbourne University, Australia and was prepared and qualified for launch by a United States organization of amateur radio operators.

The National Weather Service furnished support, under the World Meteorological Organization Voluntary Assistance Program, for the installation in foreign countries of ten ground stations. These are now receiving data directly from U.S. environmental satellites.

Aeronautical and Maritime Services.—With the advent of larger transport aircraft and supersonic transports, and increases in traffic volume over land and sea areas, the need for better systems for communi-

cations, surveillance, navigation, and traffic control becomes increasingly significant. Safety, economy, and convenience are but some of the considerations that contribute to the need for improved systems. The Office of Telecommunications Policy has been working with others to develop policy guidance in this area of space applications.

The Department of Transportation (DOT), the Department of Defense (DOD), and NASA are investigating means for providing navigation and traffic control assistance by use of space borne equipment. Using the ATS-1 and ATS-3 spacecraft, the Federal Aviation Administration (FAA) and the U.S. Coast Guard joined NASA in conducting experiments which demonstrated the feasibility of using satellites in geostationary orbit for aircraft-to-land communication and for position determination.

DOT and NASA have collaborated in assessing satellite capabilities, through the ATS-5, for transoceanic aeronautical traffic control and communication. The satellite provided signals useful in ranging measurements at ultra-high frequencies.

NASA and the European Space Research Organization (ESRO) conducted joint studies in which it was determined that a satellite system could meet the technical aviation needs of the late 70's for communication and independent surveillance of aircraft in the Atlantic region.

Geodesy.—The U.S. geodetic satellite program is designed to provide information, in cooperation with international agencies, that will lead to a more precise description of the earth's size, shape and gravity field. An additional goal of the program is to improve the position accuracy of points on the earth's surface. Final plans were made for the initiation of the International Satellite Geodesy Experiment (ISAGEX) in anticipation of a formal start in 1971. This program is cooperatively supported by the United States, France, Bulgaria, Hungary, Rumania, Czechoslovakia, USSR, West Germany, Italy, Japan, Australia, Switzerland, Latvian SSR, Mongolia, and others. The program is dependent on GEOS II, which was launched and is being operated by the United States.

A joint Army and Marine test program is underway to investigate the potential application of geodetic satellite systems to tactical positioning requirements of the Services.

Data acquisition for the National Geodetic Satellite Program (NGSP) was completed in 1970. A total of 43 stations in 23 countries participated in this program to provide a unified three-dimensional framework including the earth and connecting all major land masses of the world within an accuracy of 33 feet in all three positional components.

A program was initiated this year to apply geodetic satellite technology and associated precision tracking

laser techniques to studies that should provide new data for geoscientists to use in preparing models for predicting major earthquakes, volcanic eruptions, changes in major ocean circulation patterns, and long term changes in the earth's climate.

Earth Resources Survey.—In 1970, the Earth Resources Survey program made significant progress, both technically and organizationally. The program is an experimental effort to investigate the usefulness of remote sensing of the earth from aircraft and spacecraft. Information gathered from these platforms holds great promise as an aid to productive and rational management of the earth's resources and environment. Because the benefits are potentially broad—agriculture, forestry, oceanography, cartography, urban planning, etc.—the program involves many agencies of the Federal Government and should also eventually serve state and local agencies, businesses, educational institutions as well as private citizens. The potential benefits of a viable earth resources survey program has also aroused substantial international interest.

During this year, earth resources aircraft flew missions to survey test sites in the United States and to investigate the application of remote sensing techniques. These aircraft missions provided valuable data on storm damaged areas, corn blight, oil spills, and ecological problems and have resulted in a new understanding of how earth survey information can be used for environmental management and solutions to special problems.

Earth resources surveys from space represent a companion and complementary activity to aircraft surveys. The year brought new applications of space photography taken in earlier Apollo and Gemini flights and progress in the art of analyzing and extracting useful information from remotely sensed data. An important milestone for the space portion of the program was the selection of the prime contractor for the Earth Resources Technology Satellites (ERTS) A and B and completion of their design. Progress was also made on an Earth Resources Experiments Package (EREP) to be flown on the Skylab space station. In addition to the technical aspects of the program, progress was also made in the development of understanding of the complex intergovernment organization which will bring the program's benefits to ultimate users. Inter-agency committees under the guidance of the National Aeronautics and Space Council began work on the definition of the data handling network, data standards and format, and management of a national program.

Defense Support.—In addition to activities in the other disciplinary areas of space applications such as communications, navigation, and geodesy, a sixth pair of Vela nuclear detection satellites was successfully

placed in orbit. These spacecraft provide an extended capability to view surface and low altitude detonations while, at the same time, maintaining a constant monitoring of deep space.

International Cooperation

It has been the policy of the United States to encourage greater cooperation in space activities among nations; to this end, several new bilateral agreements have been achieved.

Included elsewhere in this chapter are the following specific cooperative efforts:

- Lunar sample investigation by scientists working on U.S. samples in 16 foreign countries.
- Lunar sample public displays all over the world.
- An astronomy satellite launched for the U.S. by the Italians at the San Marco Range.
- Communication satellite launches by the U.S. for the international Intelsat system and plans for satellites for over-ocean international aviation and maritime services.
- Meteorological satellites which supply constant and regular weather service directly to many countries and also through the World Meteorological Organization.
- Geodetic satellites which supply earth measurements in cooperation with international agencies.
- Earth Resources Survey satellites planned for use when available to all interested countries.

In other chapters of this report, all of the cooperative efforts of the past year have been described by each agency which participated. The programs which involve the United Nations Organizations and international agreements are covered in Chapter VI. Other bilateral and multi-lateral programs carried out under statutory responsibility are fully reported in the responsible agency's chapter.

A significant new development in our cooperative efforts with the USSR took place in Moscow in October when US and USSR representatives discussed arrangements for compatible docking systems in future United States and Soviet manned spacecraft. Since then the USSR has suggested possible other new areas of US and Soviet space cooperation. These possibilities are being pursued.

Following several discussions in Europe and in Washington, the European Space Conference is considering active participation in the post-Apollo program. Substantial contributions to such plans might be possible over the next ten years if a formal agreement is reached.

Plans are being developed for an International Workshop on Earth Resources Survey Systems to be held in May at the University of Michigan. It will be cosponsored by the Department of State and NASA with the help of other agencies. Invitations were extended to all UN Member States by the US delegation in December.

Aeronautics

Activities and accomplishments in aeronautics continued at a steady pace throughout the year. Excellent progress was achieved in the design and development of the Supersonic Transport (SST). Contracts were awarded to the major subcontractors in mid-year and fabrication of the prototype hardware was immediately initiated. Intense Congressional interest in the SST centers around national priorities, economics and environmental questions. Additional research programs were initiated to provide a better basis for resolving the environmental issues before decisions on a production go-ahead are made.

It is a national policy that commercial supersonic transports will be prohibited from supersonic flight over all land areas of the United States. On April 16, 1970, the Federal Aviation Administration issued a Notice of Proposed Rule Making which will prohibit commercial supersonic flight over the United States and its territories at any speed that would produce a sonic boom that would reach the ground.

The jet transport age fostered by the technology developed in the past by the Federal Government, opened a new phase of air transportation with the introduction of the first commercial airline operation of the 747 wide-body jet. Two new "airbus" aircraft, the DC-10 and the L-1011, were flown on their maiden flights, initiating the flight test certification programs. These airbus aircraft have large capacities like the jumbo jets, yet are designed especially for medium to long range flights. New quiet engines and smoke-free exhausts on all these new airliners demonstrated positive results of aviation's attention to environmental issues.

Aeronautics research and development supported by the Federal Government continues to add to the information base vital for military and civilian system advancements by an important national industry. The Whitcomb "super critical" wing, designed to provide more efficient flight up to the speed of sound, was flown in a full-scale configuration on a modified jet trainer aircraft. The X-24 "lifting body" research vehicle made its first flight early in the year and achieved supersonic flight in October. This vehicle along with the NASA M2-F3 and HL-10 is being used to study a "wingless" configuration for space shuttle applications. Much progress was made on the quiet engine programs oriented towards application

to existing civil transports. A contract was let on a short take-off and landing (STOL) experimental vehicle as part of a cooperative U.S.-Canadian research effort. Hypersonic engine technology was advanced with successful wind tunnel testing at a speed of Mach 7.4 and at temperatures approaching 2000° F. Other major milestones were achieved in R&D during 1970 on all-weather landing systems, collision avoidance equipment, area navigation equipment, flight control system improvements, turbine engine development, nozzle inlet and engine-airframe integration, helicopter component design and testing, and other similarly important areas.

Significant developments in military aircraft were also achieved in 1970. The Navy F-14 carrier based tactical fighter flew for the first time in December, less than two years after the award of the engineering development contract and ahead of the planned schedule. The Air Force F-15 air superiority fighter successfully completed its Preliminary Design Review in September. The B-1 Advanced Manned Bomber went into airframe and engine engineering development after a contract was awarded in June. The Air Force bomber is intended to replace the aging B-52 which so well fulfilled its strategic role since the mid-1950s. Engineering development of the carrier based S-3A antisubmarine warfare aircraft was highlighted by a full system mockup review in March. The U.S. Marines contracted with an English contractor for delivery of 12 A-8A Harrier V/STOL aircraft. This program was supported by NASA test of a P-1127 research aircraft. The need for a new close-air support fighter was recognized in April when development was initiated on the new Air Force attack aircraft, the A-X. Proposals to build the A-X have been evaluated, and two contractors have been chosen to build prototype aircraft for a flyoff competition. The radar development for the Airborne Warning and Control System (AWACS) aircraft was completed and the aircraft program contractor was chosen. A joint Navy-Air Force development program resulted in operational deployment of the A-7 light attack aircraft. Navy A7E's have already demonstrated their flexibility and capability in combat; the Air Force A7D has been delivered to the first operational squadron. Operational deployment of C-5A Heavy Logistic Transports was initiated and regular missions are now being flown to the Pacific and European theaters.

With the passage of the Airways and Airports Development Act of 1970 in May, funds for airways and airport development were placed in a trust fund financed by air transport and general aviation user taxes. The initial radar traffic control system, ARTS III, was installed at Chicago's O'Hare International Airport to provide automated assistance for high density traffic control. Plans are to have sixty-two airports similarly equipped during the next three years. In

addition, FAA has installed 15 computers at traffic control centers as an initial step in automating enroute traffic control.

After airliner hijacking reached unprecedented heights during the year, the President initiated a five-point program to deal with the problem. Strong measures were implemented: included were the assignment of armed U.S. Government personnel to certain commercial passenger flights, the establishment of effective pre-boarding procedures and the installation of weapons detection equipment. Development of other devices to curb hijacking and sabotage has been initiated.

The extent of Federal involvement in Civil Aeronautics Research and Development (CARD) has been studied vigorously in 1970 by a NASA-DOT group. The CARD Policy Study is designed to explore and define the significance of civil aviation to the nation, to forecast the research effort needed to maintain the United States as a leader in aviation, and to develop

alternatives for government and industry financing of those efforts. The CARD study group is expected to complete their work in early 1971.

Summary

1970 saw a transition in the national space program which bridges the spectacular successes of the Sixties with the plans and expectations of the Seventies and beyond. Our space program is a continuing national asset devoted to improving life and knowledge for all people on earth. Aeronautics will continue its impact on our mobility and productivity as a nation, and must provide a base for the military security which is so necessary to insure our freedom and democracy. 1970 did indeed usher in a decade of promise wherein balanced aeronautics and space activities will stand at the forefront of progress and will continue to be a source of great national pride.

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 Secretary of Transportation was added to the Council on September 23, 1970, with the enactment of an amendment to the National Aeronautics and Space Act of 1958.

Formal meetings of the Council are held to review and assess policies, plans, programs, and accomplishments of aeronautics and space activities, and to decide issues or to make recommendations to the President. Council members frequently meet to consider important issues which do not require the involvement of

the Chairman or all members. Much of the Council's business is conducted through the Council staff.

The Executive Secretary is a member of two National Security Council subcommittees which review and recommend programs and projects involving U.S. international space cooperation. Staff activity throughout the year has supported his contributions to these committees.

Specific Activities

During 1970, the Council was concerned with and involved in many important aeronautics and space activities. Among these were:

Supersonic Transport (SST).—The Council members and staff strongly supported the SST program because it can contribute materially to the maintenance of U.S. world leadership in civil aviation. The advanced technology being applied in the design and construction of this aircraft will provide higher speed, greater capacity, and resulting higher productivity to compete effectively with the Anglo-French Concorde and Russian TU-144 aircraft which are flying today. The

current SST program is to build and test two prototype aircraft. Data from the flight test program are essential for decisions regarding production. Properly instrumented flights of the prototype SST and other aircraft will also provide important data which can be used to help resolve the environmental issues. The Council staff has been actively reviewing the progress of government and industry sponsored programs to reduce jet aircraft noise and smoke. In particular, considerable activity has been focused on planning for comprehensive research programs to reduce sideline noise.

Short Haul Air Transportation.—The Council approved a study by the staff to examine short haul air transportation to determine its potential role in the national transportation system. In aviation, short haul concerns flights of 500 miles or less. New short take-off and landing (STOL) aircraft promise more economical operations, less noise, and less congestion on and around airports. The Council staff has served as a focus working with federal agencies, airlines, and aerospace manufacturers and a continuing dialogue on STOL technology has been established. In addition, joint coordination meetings have been held among airlines, federal agencies, and the Council staff to address common requirements for STOL vehicles. Interagency cooperation on environmental issues is excellent and has led to additional research and development on quieter jet engines. Coordination is also excellent in other vital aspects of the program, such as STOL ports and air traffic control. In addition, there are indications that new regional developments can be accomplished through an improved short haul air transportation system.

Civil Aviation Research and Development (CARD) Policy Study.—The CARD Policy Study was undertaken jointly by NASA and DOT, as recommended by Senate Report 957, to determine the criteria for federal involvement in civil aviation research and development. The specific objectives of the CARD Policy Study are to identify significant policy issues, to recommend courses of action relative to these issues, to identify CARD areas of emphasis and the criteria for setting levels of effort in these areas, and to assess the benefits which will accrue to the nation from this research and development.

Aeronautical and Marine Services Satellites.—The Council reviewed the policy implications of aeronautical and marine services satellites for civil, military, and international users. To assist, the Council staff undertook to identify the principal national and international organizations, both public and private, which have responsibilities for or an interest in surveillance, navigation position fixing, air traffic control, aeronautical and maritime communications, emergency

location and rescue operations, and similar functions which could be facilitated by aeronautical and marine services satellites. The most pressing near-term need which aeronautical services satellites can satisfy appears to be reliable communications with aircraft operating in oceanic areas. The Council staff participated in an Executive Office working group chaired by the Office of Telecommunications Policy (OTP) to examine the communications segment of the aeronautical services satellite.

Earth Resources Survey Program.—Another issue addressed by the Council was the national earth resources survey program which employs devices located on the earth's surface, in aircraft, and in spacecraft to sense remotely and record data relating to earth resources and the condition of the environment. The Executive Secretary convened an ad hoc interagency group to identify relationships between the existing experimental Earth Resources Survey Program and a future operational program as well as the roles and responsibilities of government agencies in both phases. In addition, the group was requested to determine alternatives for interagency coordination and for management of the program.

An in-depth examination of the program was made in management, data acquisition, data handling, and user requirements. The study was based on past and current activities both from an experimental and operational viewpoint, and was aimed at determining the direction and schedule for future activity. A preliminary summary report was furnished to the Office of Management and Budget to support the fiscal year 1972 budget deliberations and the full report will be completed in early 1971.

Communications Satellites.—Assistance was given in defining the government's role in developing commercial domestic satellite systems, and also in establishing guidance on the use of satellites for broadcast purposes for the U.S. delegation to the United Nations Committee on the Peaceful Uses of Outer Space.

Geodetic Data Policies.—Because of increased scientific interest, both national and international, in advanced theories of continental drift coupled with the high precision measurement made possible by the use of lasers and orbiting satellites, the Council called for a review of the U.S. policies on the release of geodetic data. New policies were established which will permit NASA to assume the U.S. leadership in an international cooperative program which is intended to make precise geodetic measurements under the auspices of COSPAR.

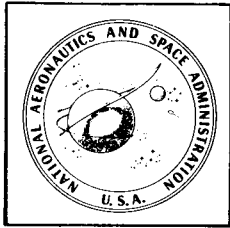
Review and Approval Procedures for Use of Radioisotopes in Space.—A guide for the use of small radioisotope sources in space was approved by the Council

members in July. It had been prepared by the Council staff with the guidance and assistance of the principal agencies involved.

International Cooperation in the Post-Apollo Program.—The Council members and the staff have been active in the area of international cooperation to insure that the benefits of space are shared with all mankind. Cooperation in aeronautical, navigation, communications, and earth resources satellites con-

tinues both bilaterally and multilaterally with other nations. The space shuttle and space station are subjects of serious discussions with the European community; definitive proposals from Europe are anticipated. Based on these discussions, the European countries will decide whether or not to develop an independent large booster capability, or to rely on the purchase of U.S. boosters. If the latter course is followed, European funds will be available for use in post-Apollo cooperative ventures.

III



National Aeronautics and Space Administration

Introduction

NASA's priority assignment for the 1960's—landing a man on the moon and returning him safely to earth—was successfully completed with the Apollo 11 mission. In 1970, only one launch took place in the Apollo program—Apollo 13. That mission was unsuccessful, and as a result, the scheduled Apollo 14 launch was postponed to January 1971, to allow time for spacecraft modifications that would assure the safety of the astronauts.

Consistent with new national goals established for the 1970's, NASA reviewed its priorities and redirected its activities in line with budgetary constraints. Steps were taken to develop a sound aeronautics and space program compatible with national resources and in keeping with the objective of maintaining our position of technological leadership.

In the Manned Space Flight area, in addition to Apollo, NASA was deeply engaged in work on the Skylab program, formerly known as Apollo Applications. Good progress was made in design, development, and testing for Skylab, and fabrication of flight hardware is underway. Space Shuttle and Space Station studies also moved ahead. For the shuttle, system characteristics were established and study contracts were let for both the vehicle and engine. For the space station, program definition studies were in the process of being completed.

NASA unmanned space programs for scientific investigations and space applications were also active. During 1970, previously launched orbiting observatories continued to make scientific discoveries, observations, surveys, and coordinated investigations. OAO-3, which carried a large telescope and other

instruments, was launched November 30, but failed to go into orbit.

NASA also launched three Intelsat III commercial communications satellites for Comsat, and was preparing the first of the Intelsat IV series for launch. Applications Technology Satellites already in orbit were used experimentally for educational broadcasts, and for studies of the use of satellites for navigation and air traffic control.

This year, the 10th anniversary of the meteorological satellite flight program, the agency launched Nimbus 4 and Tiros-M, both highly sophisticated spacecraft. Tiros-M became operational as ITOS-1, the first of a new generation of Tiros spacecraft, and began support of the National Operational Meteorological Satellite System. In the earth resources survey program, aircraft were used in tests of remote sensing devices which are planned for use aboard spacecraft to obtain earth resources data from space. In addition, the Earth Resources Technology Satellite spacecraft design was completed and some parts were being fabricated.

The NASA advanced research and technology effort continued to investigate a very wide range of aeronautical and space problems. In one area of study, a theory was developed for predicting clear air turbulence under certain conditions; in another, progress was made in developing methods of improving control of general aviation aircraft; and in V/STOL research, the augmentor-wing concept looked promising as a means of developing jet transport aircraft with a good short-takeoff-and-landing capability.

Other research activities collected data on the behavior of groups in confined habitats (Tektite), on the ability of the balance control mechanism of the

inner ear to adapt to sustained weightlessness; and on the feasibility of using optical techniques to give general aviation pilots warning of impending collisions.

Manned Space Flight

Apollo Program.—Two lunar landing missions were initially planned for 1970; however, after the unsuccessful Apollo 13 mission in April, the scheduled launch of Apollo 14 was changed from October 1970 to January 1971 in order to incorporate changes in the spacecraft to eliminate the problems encountered by Apollo 13.

In September, NASA reduced the number of remaining lunar missions from six to four. The elimination of two flights will permit their funding to be applied to future programs. This decision will give the space program some additional flexibility, providing Apollo hardware for possible use in future programs where manned operations or a heavy boost capability is required. It is now planned to complete the Apollo program in 1972.

Apollo 13.—The third intended lunar landing mission was successfully launched on schedule from Kennedy Space Center on April 11. Its major objective was to explore the Fra Mauro formation.

Launch, earth orbital insertion, and translunar trajectory insertion (TLI) all were satisfactory. Separation of the command and service modules (CSM), docking with the lunar module (LM), and extraction of the LM from the third propulsion stage (S-IVB), were also performed without difficulty. The S-IVB stage was then placed on a trajectory to impact the lunar surface near a seismometer left by the Apollo 12 crew nearly 5 months earlier. The recorded seismic impulse is contributing to an improved understanding of the subsurface lunar composition.

During the mission's third day while the spacecraft was still enroute to the moon, a failure in the service module oxygen system caused it to lose the ability to supply oxygen to the command module and to generate CSM electrical power and water with the fuel cells. It was decided to cancel the lunar landing. The command module, while still capable of supporting the crew for a short period, no longer contained enough consumables for the long journey around the moon and back to earth. It was therefore decided to retain the LM and use it as a "lifeboat," thereby conserving the command module and its limited consumables for reentry and splashdown. This required both flight and ground crews to modify the LM, intended only for two-man support, to a configuration that enabled it to support three men during more than 3 days of space flight.

Emergency systems were designed on earth and constructed by the astronauts from onboard materials; these systems supported them with no ill effects except discomfort caused by the cold and cramped quarters in the LM. These cold conditions were due to the necessity to power down equipment and heaters to conserve power. The astronauts returned to the command module shortly before reentry and jettisoned the LM. The command module then made nominal reentry and splashdown. Landing was within sight (about 4 miles) of the recovery ship U.S.S. *Iwo Jima*, and the astronauts were aboard the carrier within 45 minutes.

The actions taken to bring the spacecraft home safely under extremely adverse conditions demonstrated the inherent flexibility designed into the Apollo systems and operations. The spacecraft systems provided many different options from which a series of configurations were chosen to meet the varying requirements on the trip home. At the same time, the flight and ground crews demonstrated outstanding competence and the value of many hours of training in meeting a set of unusual circumstances.

A review board appointed by the NASA Administrator conducted an exhaustive investigation of the Apollo 13 mission. Its findings were conclusive: the anomaly was determined beyond a reasonable doubt to have been caused by the ignition of Teflon-coated wires inside the oxygen tank resulting in internal pressure which caused the tank to rupture. These wires were inadvertently damaged during prelaunch checkout at Cape Kennedy, although no evidence of the damaged wires was detected during the testing before the launch.

The recommendations of the Review Board are being carried out through changes in hardware and procedures for Apollo 14 and subsequent missions. A third oxygen tank will be installed in the service module. It will provide an adequate supply of oxygen for life support even if the other two oxygen tanks fail. Other modifications include removal of electric motors and fans from exposure to the high pressure oxygen atmosphere. Modifications have also been made to provide improved CSM return capability. These include adding a 400-ampere-hour battery for electrical power and additional stowage capability for potable water.

Lunar Exploration.—The Apollo 11 and Apollo 12 missions have made it possible to collect more data about our nearest neighbor in space than has been recorded since history began. The two missions returned a total of 123 pounds of lunar material. The scientific analysis of this material and of information obtained from experiments and observations is being carried out by experts in the United States and 16 foreign countries.

The data collected has been the basis for important conclusions about the moon. Lunar materials have been classified into four general categories: fine-grained and medium-grained igneous rocks, breccia (an accumulation of local material consolidated by temperature and pressure), and fines (small fragmented material, glass, and similar items). A very vigorous examination of near surface material has revealed no evidence of any viable organisms or fossil evidence of them on the moon. On remaining missions, deeper samples will be obtained for the same close examination.

Most lunar rocks are similar to the earth's volcanic rocks. A prime characteristic in the classification of such rocks is the silica content. An indication of the diversity of lunar rocks is the fact that rocks from the Apollo 12 site alone have a greater range of variation in silica content than is known for the rocks of the Hawaiian Islands. The average content of titanium, a refractory element in Apollo 12 rocks, is less than half that of Apollo 11 rocks. This element rarely exceeds 3 percent in terrestrial volcanic rocks but on the moon the range is primarily between 4 and 14 percent. Even larger differences are anticipated from samples to be brought back from the lunar highlands. It is expected that titanium will become a key parameter in the classification of lunar rocks. The moon's composition is heterogeneous, even at individual landing sites.

The present evidence indicates that the moon was formed around 4.5 billion years ago, approximately the same time as the earth and meteorites. The isotopic composition of lead in the samples is, however, distinct from that of the earth and meteorites indicating that three separate closed systems might have been formed. The moon must have been at least partially molten 500 million years to 1,000 million years after it was formed. Although there is no way of determining the percentage of melting or whether the melting was caused by meteorite impact or internal heat, it had to be on a large scale to accomplish the degree of differentiation found in the rocks. One obvious conclusion drawn from the studies is that events on the moon occurred over a long period of time and the moon can serve as a Rosetta Stone in unraveling the early history of the earth. Since no direct evidence older than 3.5 billion years is available for the earth, the possibility exists that the study of lunar rocks may yield information on the missing first billion years of history.

Passive Seismometer Experiments (PSE) were emplaced to detect vibrations of the lunar surface to determine its internal structure, physical state, and tectonic activity. The lunar seismic signals are different from those on earth and very complex. The PSE records an average of one moonquake a day. Although the source of these events could be shallow internal moonquakes, they are thought to be caused by meteor-

ite impacts. The Apollo 13 spent S-IVB stage was impacted on the lunar surface 85 miles from the Apollo 12 site with an approximate force of 11.5 tons of TNT. The data from this well-calibrated signal indicate that the lunar material is fractured to depths of approximately 12 miles and shows no evidence of the major discontinuities which are a striking characteristic of the solid earth. More than 200 events of natural origin have been recorded by the seismometer during the first 8 months of operation. Fifty-eight of these events have been identified as moonquakes.

The moonquakes have been divided into nine different categories, i.e., nine zones producing seismic activity within a 200-mile radius of the passive seismometer. At least 26 are shallow moonquakes occurring within 3 days of the time when the moon comes closest to the earth (perigee) during its monthly orbit cycle. The source of these events is considered to be in the vicinity of Fra Mauro, to be visited on the Apollo 14 mission, about 125 miles from the PSE. This last group stands out as the most positive evidence of internal lunar activity. Otherwise the moon's outer shell appears very stable and cold in comparison with the earth's seismic activity.

A magnetometer was emplaced by the Apollo 12 crew to measure the magnetic field of the moon. Analysis of the data from this device showed the presence of a small magnetic field that measures approximately 38 gammas. The data indicates that this field is the result of a localized magnetic source near the Apollo 12 landing site rather than a uniform dipole associated with the whole moon. The origin of this field is considered highly significant by scientists.

It is also known, because of the remnant magnetism in some of the Apollo samples, that the moon's magnetic field was probably higher when the rocks solidified than it is now. Analyses of all the lunar magnetic data indicate that the moon may have a small central core of temperature near 800° to 1,000° C. This much heat in the lunar interior is still not sufficient to make the moon into a heat-engine resembling the earth, for no deep interior quakes have as yet been detected and there is no evidence of the kind of crustal movement and mountain building that is so important to earth's topography.

The Solar Wind Spectrometer measures the direct impact of the solar wind undeviated in any way in its path from the sun to the moon. The suprathreshold ion detector records ionized particles near the lunar surface particularly at lunar sunrise. Large signals were also recorded at time of the S-IVB impact and at lunar perigee. These ionized particles do not occur in sufficiently large numbers or at low enough velocities to be chemically identified.

Efforts were made to measure the ambient lunar atmosphere with a Cold Cathode Gauge. Initial measurements made while the lunar module was still on the

surface were inconclusive. The instrument stopped transmitting science data 14 hours after deployment. Through ground tests with similar equipment the failure has been identified, and an improved instrument will measure the lunar atmosphere on future missions.

The Solar Wind Composition Experiment exposes a strip of aluminum foil to the lunar environment to determine the elemental and isotopic composition of gases in the solar wind. Variations in isotopic ratios were found between Apollo 11 and Apollo 12. When compared with results obtained from lunar sample analyses, variations in the solar wind composition may be observed dating from antiquity.

The Laser Ranging Retroreflector (LR3) deployed at Tranquility Base by the Apollo 11 astronauts continues to perform as designed. It is serving as a target for point-to-point distance measurements from earth performed by recording the round trip travel time of short pulses of ruby laser radiation transmitted from a telescope, reflected from the LR3, and received approximately $2\frac{1}{2}$ seconds later by the same telescope. Several measurements per week, with a precision of about 1 foot or less in the earth-moon distance, are being made on a routine basis by the McDonald Observatory staff. A continuing lunar ranging program has also been started by the Air Force Cambridge Research Laboratory. Additional Laser Ranging Retroreflectors will be deployed on the Apollo 14 and Apollo 15 missions to provide a network of instruments which will allow scientists to determine the dynamics of the earth-moon system. Measurements to date have been incorporated into the best numerical ephemeris of the moon to produce improvements in knowledge of lunar motion. The LR3 is available to any scientific observatory throughout the world which wishes to reflect signals from it.

The Apollo 12 astronauts visited the Surveyor III automated spacecraft during their second EVA on November 19, 1969. They returned to earth portions of the spacecraft which had been on the lunar surface and exposed to solar and cosmic radiation for 31 months. Engineers and scientists in the United States and Switzerland are evaluating the effects of space environment on the Surveyor parts. Most of the components, materials, optics, and other devices encountered had satisfactorily survived extremes of vacuum, radiation, and temperature well beyond design requirements. The detailed results can be used to reduce the uncertainties associated with the effects of operation and long storage in lunar and space environment, and to improve design and testing techniques for future missions.

Forthcoming Launches.—Two Apollo lunar landing missions are scheduled for 1971; Apollo 14 in January and Apollo 15 in July.

The landing site for Apollo 14 will be Fra Mauro, the intended site for Apollo 13. The Apollo 14 crew will deploy an Apollo Lunar Surface Experiments Package (ALSEP) similar to the one placed at the Ocean of Storms site by Apollo 12, and the Apollo 14 ALSEP will include several experiments which have been deployed on previous missions: the Passive Seismic Experiment, the Suprathermal Ion Detector, and the Cold Cathode Ionization Gauge. Two new experiments will be added to the package. One is an Active Seismic Experiment (ASE) to generate and monitor artificially stimulated seismic waves in the 3–250 Hz range in the lunar surface and near subsurface. It will also monitor natural events in the same frequency range. The other is a Low Energy Solar Wind Experiment to ascertain proton and electron flux data for evaluation of solar wind and cosmic rays.

Three other experiments will be independently deployed by the Apollo 14 astronauts on the lunar surface. A Laser Ranging Retroreflector (LR3) for precise earth-to-moon measurements will be the first leg of a planned LR3 network on the moon. A Solar Wind Composition Experiment to determine the isotopic composition of noble gases in the solar wind at the lunar surface will be retrieved at the end of EVA and returned to earth for analysis. And a portable magnetometer to measure the magnetic field of the moon at the Apollo 14 landing site will be deployed at the point of furthest traverse from the Lunar Module.

The magnetometer will be transported aboard the Mobile Equipment Transporter (MET), a lightweight two-wheel vehicle resembling a ricksha to be used on Apollo 14 only. The MET will also carry cameras, hand tools, and sample bags for use by the astronauts.

The Apollo 15 landing is planned at Hadley-Apennine, a site named for the meandering Hadley Rille and the nearby Apennine Mountains. It is hoped that the astronauts will be able to visit and collect samples both at the base of the mountains which rise over 8,000 feet, and at the rille which resembles a dry riverbed. Apollo 15 will be the first mission to carry a Lunar Roving Vehicle (LRV) to increase the range of travel for the astronauts on the lunar surface. The battery powered LRV, which will weigh approximately 500 pounds, will carry the astronauts and up to 170 pounds of equipment and lunar samples.

The last three Apollo missions, Apollo 15, 16 and 17, will have significantly increased capabilities for lunar exploration. The EVA's will be increased from two to three, providing 40 man hours per mission instead of 18; the landed scientific payload will be doubled (500 to 1,000 pounds); the LRV and suit mobility improvements will provide increased range and efficiency of surface operations; and each mission will carry an experiment package in the Service Module for use in lunar orbit to supplement the experiments de-

ployed on the lunar surface. The intent is to maximize the scientific returns from the remaining Apollo missions.

Skylab Program.—The Skylab Program, formerly known as Apollo Applications, is designed to make important contributions to future manned space operations by contributing new knowledge in many fields—earth resources, environmental systems, oceanography, meteorology, solar and stellar astronomy, space physics, bioscience, space technology and engineering, zero “g” materials processing, measurements of the space environment, and the physiology of man in space.

The program objectives are: to determine and evaluate man’s physiological responses and aptitudes in space under zero gravity conditions and his post mission adaptation to the terrestrial environment through a series of progressively longer missions; to develop and evaluate efficient techniques for utilizing man in sensor operation, discrimination, data selection and evaluation, manual control, maintenance and repair, assembly and installation of hardware components, and mobility involved in various operations; to develop techniques for increasing systems life, for long duration habitability and long duration mission control, and to investigate and develop techniques for in-flight test and qualification of advanced subsystems; to conduct astronomy and other science, technology, and applications experiments in which man’s contribution is expected to improve the quality and/or yield of the results.

All program activities made good progress in design, development, and ground testing. Critical design reviews were completed by the third quarter and manufacture of hardware was underway on all flight articles in parallel with the final design phase.

A significant addition to the program was an Earth Resources Experiment Package (EREP). Carefully selected sensors will permit the astronauts to perform geological, geographical, hydrological, agricultural, forestry, oceanographic, and meteorologic studies of selected ground targets. The data acquired will be coordinated with other information obtained from airborne flights and from the Earth Resources Technology Satellite (ERTS) to demonstrate the potential usefulness of this technology in mapping, monitoring, and understanding phenomena which affect the environment.

NASA decided to utilize Launch Complex 39 at the Kennedy Space Center (KSC) for checkout and launching of Saturn IB as well as Saturn V launch vehicles to consolidate activities and economize on Skylab prelaunch test operations. The technical feasibility of launching Saturn IB’s from LC-39 had been established in earlier studies by KSC, but action had been deferred because of schedule conflicts with

Apollo. After the Skylab workshop was reconfigured to the so-called “dry” version, not requiring a mobile service structure, and schedule conflicts were resolved, the change was implemented. The decision will result in significant cost savings and more efficient launch operations at KSC.

Space Shuttle.—In keeping with space program objectives, NASA took steps to reduce the cost of future space operations and provide a capability for a balanced program of space activity by moving ahead with work on the Space Shuttle.

Space Shuttle system characteristics were established early in the year, and definition study contracts of 11 months duration were awarded in June. Each Shuttle is planned for 100 or more flights with payload transportation similar to commercial airline practice. The orbiting stage will contain a large compartment of about 10,000 cubic feet to accommodate a varying payload mix of satellites, passengers, and cargo. The Shuttle will be capable of being launched in any direction and on short notice—within 2 hours if necessary. With its low operating cost, flexibility, internal environment, and large payload capacity, applications such as placement or repositioning of satellites, satellite servicing, rescue operations, and space station support will be practical. Since the shirtsleeve environment within the Shuttle will be very much like that of an airplane, passengers will not require astronaut skills. The moderate acceleration loads will allow average people in good health to fly into space in comfort.

Two sets of study contracts were awarded and work is in progress. One set consists of two studies for the Shuttle vehicle, and the other comprises three studies for the engine. The fully reusable two-stage vehicle approach is being examined in detail. Basic definition objectives are to define the Shuttle system and the engine requirements, accomplish preliminary design, and predict the scope, schedule, and cost of the program. In addition, other contractual studies of alternate vehicle concepts are also being conducted to insure that all approaches are fully explored.

In February, NASA and the Air Force signed an agreement establishing a Space Transportation System Committee which will ensure that objectives of both agencies in the field of space transportation will be fulfilled.

Concurrently with the definition effort, NASA also initiated other studies and analyses in areas such as payloads, economics, and mission traffic requirements. These efforts will provide better understanding of what the Shuttle will mean to payload designers, what its realistic value is as an economic investment, and how the projected missions will fit into a national traffic pattern.

Thermal protection systems were under study to determine the optimum high temperature structures

for the Shuttle configuration. Technical studies proceeded in areas such as aerodynamic configurations, high pressure rocket engines, and integrated electronics systems.

NASA solicited international participation in the Shuttle effort in support of the President's policy of space cooperation. European representatives as well as Japanese officials were briefed on Shuttle opportunities, and talks were conducted with the European Space Research Organization, the European Launcher Development Organization, and with officials from a number of foreign countries.

Space Station.—NASA contractors were in the process of completing comprehensive program definition studies started in 1969 on two versions of a space station which could be launched on a Saturn-V-class vehicle. The designs are of a self-contained, general purpose laboratory whose facilities can be supplemented by attached or free-flying modules. The studies will provide operational, technical, and programmatic information on the station, its facilities, experiments, and modules for comparison with other station designs under consideration.

Program definition contractors were instructed to investigate modular space station designs which could provide the same facility capability but in a shuttle-compatible configuration. This approach would reduce early funding requirements and appears to offer a higher degree of flexibility from both technical and program implementation aspects. Most of the modular designs being considered require a cluster of modules, each of which would be delivered by a shuttle, to be assembled in orbit before commencing operations. While the modular stations generally have less initial capability than monolithic station concepts, similar capabilities can be achieved by the addition of modules in orbit. Also, the ease with which modules can be replaced would enhance program flexibility significantly.

In a parallel effort, equally applicable to either space station concept, potential station users were approached for help in determining facility characteristics, categorizing research activities, developing utilization management procedures, and generally making their requirements known at a very early design stage. Those approached included representatives of industry, government, and universities, both foreign and domestic.

Advanced Manned Missions.—Advanced Manned Missions activities continued the detailed examination of the NASA integrated plan with the goal of affirming that the projects in the plan would best serve national goals. Contracts initiated in 1969, which were directed toward specific requirements of the Space Station and Space Shuttle programs, were completed in 1970, and

the results utilized to support the definition of those programs. Because the Space Station and Space Shuttle had progressed into the definition phase and therefore had independent status, the Advanced Manned Missions program focused its attention on integrated planning beyond these two programs. Conceptual studies were begun of the Space Tug, the Nuclear Shuttle, the Lunar Orbit Station, and the Lunar Base to provide NASA management with information about these projects and their role in the integrated planning concept. Additional studies considered safety and rescue aspects of the missions in the plan.

Space Science and Applications

Orbiting Observatories.—NASA's Orbiting Observatories continued to make major scientific contributions and to demonstrate their versatility and prolonged operating lifetimes. The Orbiting Astronomical Observatory-2 (OAO-2), launched in December 1968, discovered a great hydrogen cloud surrounding the bright comets Tago-Sago-Kosaka and Bennett. The cloud proved to be many times larger than ground observers had theorized. OAO-2 also made a series of observations of a nova (exploding star) in the Constellation Serpens, which could not be seen from ground-based telescopes.

A third Orbiting Astronomical Observatory (OAO-3), carrying a 38-inch telescope and weighing 4,700 pounds, was launched November 30, but failed to achieve orbit. It was designed to measure ultraviolet radiation from selected celestial objects, and to point with an accuracy of one-arc second.

In 1970 the Orbiting Geophysical Observatory-5, orbited in March 1968, made a sky survey of Lyman-alpha radiation and observed the hydrogen cloud around the Comet Bennett. OGO-6, launched in June 1969, performed satisfactorily during the year, and achieved its mission objectives. Orbiting Solar Observatories-3, -4, -5, and -6 (launched between 1967 and 1969) were also utilized for investigations coordinated with other satellites and with observations from sounding rockets and ground-based instruments.

A bright fireball was optically tracked in January and three meteorite fragments from it were recovered near Lost City, Okla. This was the first time that recovered fragments could be correlated with a specific meteoroid coming from a known orbit. In March, scientists carried out an unprecedented study of a total solar eclipse, their observations involving complementary satellite, ground-based, and rocket-borne experiments.

Explorer and International Satellites.—NASA orbited its first Small Astronomy Satellite (SAS-A) in December. The SAS series of satellites (also designated Explorer) will investigate X-ray, gamma ray, ultra-

violet, and infrared spectral regions of the electromagnetic spectrum. SAS-A was designed to develop a catalog of X-ray sources through systematic scanning of the celestial sphere, and in a single day it should transmit more data than through the total observation time of the X-ray instruments on all earlier satellites and rockets. This 320-pound spacecraft was launched into a 342-mile orbit by a Scout vehicle from the San Marco site operated by Italy off the coast of East Africa—the first American satellite to be launched outside the territorial limits of this country.

Explorer satellites still providing useful information included the University of Iowa satellite (Injun 5 launched in 1968) which detected trapped particles with masses greater than helium in the Van Allen radiation belts; Radio Explorer 1 (also orbited 1968) which continued to map the distribution of ionized hydrogen in the Milky Way; and Explorer 35 (IMP-E launched in 1967) which was mapping the magnetic field and providing support for the ALSEP experiments on the moon.

ISIS-1—largest of the international satellites and orbited in 1969—was continuing investigations of the upper ionosphere begun by Canadian-American spacecraft of the Alouette 1 and 2 series of 1962–65. Low energy particle detectors aboard the satellites have monitored a quite unexpected amount of low energy flux ranging from high to low latitudes.

Sounding Rockets and Balloons.—Almost 100 sounding rockets were launched to heights between 100 and 1,000 miles for studies in space physics and astronomy. Sixteen of these were launched from Wallops Island and three from the White Sands Missile Range during the solar eclipse; one of the 19 detected an unexpectedly high amount of neutral hydrogen streaming into the earth's upper atmosphere. Three launches were made from Woomera, Australia to obtain measurements from stars in the southern celestial sphere which cannot be seen from flights in the Northern Hemisphere. In addition, launches were made from Hawaii, Australia, Norway, Sweden, Brazil, Canada, and India.

About 60 high-altitude balloons were launched for outer space observatories at altitudes as high as 150,000 feet, or above about 95 percent of the earth's atmosphere. One of these balloons carried Stratoscope 2, a 6,000-pound diffraction-limited, optical telescope 3 feet in diameter, remotely controlled from the ground.

Space Bioscience.—In research on the effects of altered gravity on living organisms, scientists at the University of California found that by increasing the force of gravity to three times that of the earth an extra amount of a "fat-regulating hormone" was forced from the hypothalamus and the pituitary gland. This hormone mobilizes fat from storage depots in the body, making it available for the production of energy

vital to life processes. It may also find applications in the search for a means of controlling obesity.

In a research project at Emory University to study the possible benefits of depressing body functions during prolonged space flight, a technique—differential hypothermia—was developed. The procedure consists of cooling most of a warm-blooded animal's body to a low temperature of 4° to 10° C. but keeping another part (a tumor) warmed to normal body temperature (37°). Hypothermic animals were able to tolerate very toxic or even lethal amounts of anti-cancer drugs with no ill effects. The reduced or depressed metabolic rate reduces the concentration of the drug in the cold tissues, focusing its effects on the malignant tissue or tumor only. The cooling process seemed to increase the metabolic rate of the warm tissues, making them more susceptible to the anti-cancer drug.

In research to discover ways by which earth's organisms might adapt themselves to the hostile environments of the planets such as Mars, scientists at the State University of New York in Buffalo have synthesized a living cell able to reproduce. In their experiments small, single-celled amoebae were dismembered and components from a number of them were put back together again to achieve the artificial synthesis.

Mariner Mars '71.—The two-Mariner spacecraft to be launched in May 1971 and to reach Mars in November, were fabricated and assembled and proof tests completed. The flight spacecraft were progressing toward final testing. For mission operations, planning was completed, training begun, and computer programs neared completion. Fabrication of the two Atlas/Centaur launch vehicles was finished, and they were being tested.

Mariner Venus-Mercury '73.—Another spacecraft of the Mariner class, to be launched sometime in October–November 1973, will pass Venus early in February 1974, and arrive at Mercury in late March. It is designed to investigate the environment, atmosphere, and body and surface characteristics of Mercury, and to obtain environmental and atmospheric data about Venus.

The Project Office at the Jet Propulsion Laboratory selected these experiments for the flight science payload: A charged particle telescope, dual magnetometers, a scanning electrostatic analyzer, and two TV cameras to provide wide- and narrow-angle pictures.

Viking.—In February, the Viking mission was rescheduled from 1973 to 1975 because of funding limitations. Viking is the program to investigate Mars by means of two spacecraft which will orbit the planet and send instrumented landers to the surface. The orbiters will map the planet and relay data from the landers to earth. Emphasis will be placed on

collecting information relevant to the possibility of life on Mars.

During the year substantial progress was made in this project. Teams of scientists defined the experiments, developed instrument concepts, and helped NASA plan the mission. Baseline designs were prepared for the orbiter and the lander, and most planning and control documents were completed. Subcontractors began development of critical instruments and subsystems, and significant tests of spacecraft subsystems and instruments were conducted under simulated flight conditions. Model landing tests, wind tunnel tests, and laboratory tests were also conducted.

Pioneer.—Pioneer spacecraft F and G were in the planning and development stage. Spacecraft design was completed and engineering models of both spacecraft and scientific instruments were being assembled and tested. A radioisotope-thermal electric generator to supply electrical power for up to 5 years was designed for the AEC and is undergoing tests.

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.

Helios.—The Federal Republic of Germany selected a prime contractor to build two instrumented spacecraft which will fly close to the sun between 1974 and 1975. Scientific experiments for this cooperative NASA-West German project will transmit measurements on solar plasma, cosmic rays, magnetic fields, zodiacal light, and micrometeoroids as the spacecraft orbits the sun. A Titan-Centaur booster will be used for the launches.

Advanced Studies and Technology.—The mission design for a Grand Tour to the outer planets was completed, and a functional approach of the spacecraft for the mission was established. Conceptual design of key elements of the spacecraft was also established, with emphasis placed on the feasibility of an onboard Self-test and Repair (STAR) computer.

A conceptual 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 completed. This system is initially planned for use in exploring Venus.

NASA continued its studies of other possible future planetary missions.

Applications Technology Satellites.—Applications Technology Satellites (ATS) 1 and 3 (orbited in 1966 and 1967) were still being used in experiments in March 1970. The Corporation for Public Broadcasting carried out educational telecasts between Columbia, S.C. and Los Angeles, Calif., via ATS-3, and initial tests were made of an experiment which will employ

the very high frequency transponder aboard ATS-1 for educational and public radio transmissions studies by Alaska.

In addition, signal acquisition and tracking tests for digital communications and ranging were performed by the L-band transponder of ATS-5. NASA selected a contractor for the ATS F and G spacecraft, and construction is scheduled to start in early 1971.

Navigation and Traffic Control Satellites.—ATS-1 and 3 demonstrated the feasibility of using satellites in geostationary orbit to fix the position of ships and aircraft in navigation and traffic control. The Federal Aviation Administration and the Coast Guard participated in the tests by providing the vehicles and by analyzing the data.

Joint technical studies by NASA and the European Space Research Organization of satellites for communications and independent surveillance of aircraft in the Atlantic Ocean region determined that a satellite system could meet technical aviation needs of the late 1970's.

Communication Satellites.—NASA launched three of the Intelsat III series commercial communications satellites for the Communications Satellite Corporation (Comsat) on a reimbursable basis in January, April, and July. The July (Intelsat III F-8) mission was unsuccessful as a result of a spacecraft failure. Five commercial communications satellites were in full operation in 1970—two in the Atlantic area, two in the Pacific area, and one over the Indian Ocean. A sixth satellite is available, on a contingency basis, for service in the Atlantic Ocean area.

The first of the Intelsat IV series was being prepared for a scheduled launch early in 1971. It will provide nominally 6,000 two-way channels compared to the 1,200 channels of Intelsat III. A maximum of 9000 two-way channels can be obtained by exclusively using regional rather than global beams. Intelsat IV will have a design life of 7 years as against 5 years for Intelsat III. An Atlas/Centaur launch vehicle will be used for the Intelsat IV program, and the launches will also be on a reimbursable basis.

NASA provided facilities and consulting services on a reimbursable basis to Comsat and advised the FCC and the OTP on Intelsat launchings and domestic satellites.

Geodetic Satellites.—GEOS-2, launched in January 1968, supported Air Force camera teams in geodetic observations; U.S. and French radar calibrations; Navy Tranet systems tests and calibration of the geociever doppler system; and the preliminary phase of the ISAGEX (International SAtellite Geodesy EXperiment) program. ISAGEX—sponsored by the International Committee of Space Research under

French project management—is supported by the U.S., France, Bulgaria, Hungary, Rumania, Czechoslovakia, U.S.S.R., West Germany, Italy, Japan, Australia, Switzerland, Latvia SSR, and Mongolia among others. The program will probably start in January 1971, and require that GEOS-2 be operated through most of that year.

In addition, GEOS-2 supported an experiment to determine the feasibility of using ground-based laser tracking equipment for more precise measurements of the motion of the earth's pole and for reducing the time for making the measurements from 5 days to less than 1 day.

Meteorological Satellites.—In support of the world weather program, the Nimbus spacecraft continued flight-testing sensors and techniques for quantitative measurements of global atmospheric structure and processes. Nimbus 3—after operating more than 17 months—suffered a failure of its aft scanner, which eventually caused most of the sensor data to be unusable. Nimbus 4, launched in April, carried nine experiments for measuring temperature structure, cloud cover and composition, emitted and reflected radiation from the ultraviolet to the infrared, composition of the atmosphere, solar energy variation, and wind velocities. Nimbus 4 made the first satellite measurement of vertical temperature soundings in the lower stratosphere which provides significant new data for long range weather forecasting. In addition, Nimbus achieved extremely precise stable spacecraft attitude control. The proof of this system has significance to the Earth Resources Technology Satellite which requires such stability for high resolution image taking. Nimbus E and F, with more sophisticated sensors, were being developed for launches in 1972 and 1973.

Tiros M—the operational prototype of the second generation of operational meteorological satellites—was launched in January. Redesignated ITOS-1 upon achieving orbit, it began supporting the National Operational Meteorological Satellite System (NOMSS) as the primary operational satellite for the National Oceanic and Atmospheric Administration (NOAA). The spacecraft, funded and developed by NASA to meet NOAA's requirements, is the first of an improved type to replace the two kinds of Tiros operational satellites operated earlier in the NOMSS.

ITOS-1 carries TV cameras to store global cloud-cover data for remote readout; Automatic Picture Transmission cameras for local readout of cloud-cover data; and newly developed scanning radiometers for global cloud data for remote and local readout, both day and night. The sensors are duplicated for reliability and designed with mutually complementary circuitry to extend their life if individual components fail. Since

it can provide night coverage for the first time, ITOS-1 fully satisfies the primary objectives of NOMSS, that of obtaining global cloud-cover day and night.

As a secondary payload with the ITOS-1, NASA launched the Australis-Oscar (AO-5) radio amateur satellite. The first amateur spacecraft launched by the agency, and the fifth of the OSCAR satellites (*Orbiting Satellites Carrying Amateur Radio*), it was designed and built by students at Melbourne University, Australia. The 39-pound spacecraft carried beacon transmitters and was prepared and qualified for launch by the Radio Amateur Satellite Corporation, a Washington, D.C., organization of amateur radio operators.

The second satellite of the ITOS series (NOAA-1) was launched in December. Its sensors are identical to those of ITOS-1.

ESSA-8, after almost 2 years in orbit, continued to transmit local readout cloud-cover data and to support NOMSS by providing morning Automatic Picture Transmission (APT) coverage. ESSA-2, orbited in 1966, was converted to standby status in March and deactivated in October. ESSA-5 was deactivated in February; ESSA-7 in March; and ESSA-9 passed the 1-year-in-orbit mark in February.

Meteorological Sounding Rockets.—NASA launched 46 rockets of the Nike-Cajun class to obtain data on the structure and characteristics of the atmosphere at heights of between 20 and 60 miles. Techniques used for providing the vertical atmosphere profiles of wind, temperature, density, and ozone were acoustic grenades, pitot-static tubes, light reflecting vapor trails, luminous vapor trails, optical ozonesondes, and chemiluminescent ozone sensors. New instruments flown for the first time included a 31 grenade-payload, a second generation ozonesonde, and a transponder falling sphere. A series of ozone measurements was made using rocketborne optical techniques coincident with measurements from the backscatter ultraviolet ozone measuring instrument on Nimbus 4.

Wallops Station fired 204 boosted-Dart and Arcas-type meteorological sounding rockets in support of range operations, the sounding rocket development program, and national and international cooperative sounding programs. These soundings provided research and development data in conjunction with those cooperatively launched from other U.S. locations, and from Argentina, Brazil, and Spain. An experiment using nine research rockets (grenade, pitot-static tube, ozone, and falling sphere) and 11 Arcas and boosted-Dart rockets was also conducted from this site before, during, and after the March 7 solar eclipse. New information was obtained about diurnal variations of ozone to an altitude of 40 miles, as was other meteorological data up to 75 miles altitude at the time of the eclipse.

The program of developing a cost-effective meteorological sounding rocket system continued—including a joint NASA–Army project to develop an efficient low cost meteorological rocket motor for routine probings up to 45 miles.

Earth Resources Survey Program.—In support of the program to develop the technology for remote sensing of earth resources data from space, three aircraft of the Earth Resources Survey Program, an aircraft of the University of Michigan, and support aircraft of other agencies completed over 50 missions.

Significant agricultural data were developed by aircraft flights as followups of the Apollo 9 multispectral photography experiment of 1969, and by surveys of blight made over the Corn Belt this year in cooperation with Purdue University. Surveys were also made of selected “census cities” to compare population and land use. A byproduct of this aircraft survey program was their use in various disaster surveys, such as hurricanes Camille and Celia and the Lubbock, Tex., tornado. International cooperation was marked by surveys following the Peruvian earthquake in August, and surveys of the Lake Ontario region in cooperation with the Canadian government.

The aircraft also carried out various sensing experiments for user agencies, such as the Department of Agriculture, Interior, Navy, and NOAA. Spectral coverages in the visible, infrared, near infrared, and microwave frequencies were providing data for the development of resources management methods in a wide range of user disciplines, such as agriculture, oceanography, fisheries, hydrology, geography, geology, and forestry.

During 1970 the prime contractor for the Earth Resources Technology Satellite (ERTS) was selected. Final design of the ERTS–A and –B spacecraft was completed, and certain components were in the fabrication stage. The first complete camera of the high resolution TV system underwent satisfactory tests, as did the mirror for the multispectral scanner. Several components of the wide band video tape recorder were also tested successfully.

Launch of ERTS–A is scheduled for March 1972 and ERTS–B a year later. An invitation was sent to all interested natural resources scientists here and abroad to participate in analyzing and interpreting the data from these two missions.

Earth Physics and Physical Oceanography.—A program was begun this year to apply geodetic satellite technology and associated precision tracking methods to studies of the motion of the earth’s pole, variations in the rate of rotation of the earth, continental drift, and the general circulation of the world’s oceans. These investigations should provide new data for geoscientists to use in preparing models for predicting major earth-

quakes, volcanic eruptions, changes in major ocean circulation patterns, and long term changes in earth’s climate.

Significant progress was made in demonstrating the feasibility of using remote sensor techniques on aircraft and satellites to observe, monitor, or measure ocean surface and shallow water bottom features, sea surface temperature, ocean color, sea state conditions, sea ice, and pollutants. For example, aircraft flew over the ocean carrying a number of optical, microwave, and infrared remote sensor instruments to collect information; and data obtained by infrared sensors on Nimbus 4 and ITOS–1 were used in preparing ocean surface temperature maps.

Skylab Earth Resources Experiments Package (EREP).—The Skylab earth resources experiment sensors will include six bore-sighted cameras, an infrared spectrometer, a multispectral scanner, a 13.9 GHz radiometer/scatterometer, and 1.4 GHz radiometer. Several of the photographic bands and multispectral scanner bands correspond to the bands selected for the ERTS return beam vidicon and scanner. This correspondence will permit correlation of Skylab photographic and scanner data with the ERTS data.

The EREP sensors—along with associated tracking, control, and recording equipment—will be mounted in the Multiple Docking Adapter of Skylab and launched as part of the cluster. Skylab will be placed into a 50° inclination circular orbit at an altitude of 270 miles. Investigators will be given the opportunity to propose special observations or studies using EREP data.

Global Atmospheric Research Program.—NASA was also cooperating with other Government agencies and the scientific community in planning for U.S. participation in the Global Atmospheric Research Program (GARP). The program was set up as the result of a growing recognition by meteorologists of the possibility of long range weather predictions, and is expected to rely heavily on space technology in acquiring meteorological data on a global scale. In support of GARP, NASA will concentrate on improving data acquisition methods and planning for a Data Acquisition Test and the first GARP Global Experiment.

Launch Vehicle and Propulsion Programs.—The Scout launch vehicle successfully launched the RAM C–C and OFO–A missions, a Defense Department navigation satellite, and the SAS–A spacecraft from the San Marco Range in Africa.

At the Western Test Range, the Air Force launch team was replaced by a contractor team under a NASA Scout system management contract. The development of an improved Scout first stage-motor continued with two successful motor firings.

Thor-Delta vehicles orbited the Intelsat III F-6, F-7, and F-8, ITOS-1, NATOSAT, SKYNET 2, and NOAA-1 satellites. The ITOS-1 launch was the first using more than three solid motors for thrust augmentation—six motors were used for the Thor booster. Also, the first Universal Boat Tail booster was delivered to NASA. It will be able to utilize three, six, or nine motors for thrust augmentation, as required by the mission. Other progress was made in adapting the Delta Inertial Guidance System.

Agreements were signed with the European Space Research Organization for the launching of the HEOS A-2 and TD-1 satellites on a Delta vehicle. In addition, preliminary discussions were held with Telesat Canada and the Italian Government concerning other missions using the vehicle.

Negotiations were completed with the Air Force for exclusive NASA use of Air Force Complex 41 at Cape Kennedy for launching the Titan-Centaur vehicle and for joint use of other Air Force support buildings and facilities associated with the assembly and checkout of the Titan boosters. Interface and launch complex details were defined and contract negotiations were initiated.

Advanced Research and Technology

High Strength Glass.—Research on glass resulted in the development of a stiff, high strength glass fiber 86 percent stiffer and over 60 percent stronger than that currently available. Composite materials containing the new fibers are expected to exhibit significant weight savings in advanced aerospace vehicles.

Improved Graphite.—A study of the behavior of graphite at high temperatures led to the invention of a boron-doped graphite having an electrical resistance nearly constant from room temperature to 5,000° F. Because the resistance of industrial graphite electrodes and resistors decreases as the temperature rises, such devices require costly controls to prevent burn out. The use of the boronated graphite should eliminate the need for special control devices and result in considerable savings.

Electrically Charged Polymers.—A new class of electrically charged polymers, called ionenes, synthesized for aerospace uses may have application in biomedical engineering. Heparin, a blood anticoagulant, can be bonded to these charged polymers, and they thus might have potential in the development of non-clotting tubing for blood transport in artificial kidney machines and in heart-lung assist devices. The ionenes are also bactericidal and may be useful in surgical sutures and similar applications where the growth of bacteria must be prevented.

High Temperature Polymers.—A new polyimide polymer with greatly improved high temperature mechanical properties was synthesized. It has a rigidity at room temperature twice that of commercially available polyimides, and even at 600° F. its stiffness exceeds that of the commercial materials at room temperature. Further research must be conducted to determine if these polyimides can be used in such aerospace applications as high temperature adhesives and foams.

Improved Electron Microscopy.—In surface physics research, investigators at the Ames Research Center discovered a new method of improving the resolution of the electron microscope. Use of the new technique made it possible to resolve discrete planes of atoms in extremely thin gold films and to make quantitative determination of the orientation of the films. The new method should enhance NASA capabilities in thin-film technology for electronic devices and in the control of surface behavior of materials for structural applications.

Structures.—The NASA sponsored comprehensive computer program for structural analysis—NASTRAN—was released in November for public use. The program tapes and documentation are available from the Computer Software Management and Information Center (COSMIC). Since its delivery to NASA last year, NASTRAN has been thoroughly evaluated and its capabilities confirmed.

Intensive research has shown that significant weight savings in spacecraft, space shuttle, and aircraft structures can be achieved with extensive applications of such composite materials as boron-aluminum, boron-epoxy, graphite-epoxy, and others. Test results are confirming the enhanced strength and stiffness properties of such structures. Work continued to define the design limits for these materials when subjected to the extreme environments associated with space vehicle and aircraft applications.

Space Shuttle Oscillation.—In studies of critical dynamic problems areas for the space shuttle, important progress was made in understanding the unusual dynamic conditions associated with shuttle-type configurations. Research determined the potentially critical nature of wind-induced oscillations on the launch pad and bi-wing interference flutter at transonic speeds during boost. Techniques for minimizing these problems are under development.

Fluid Dynamics.—Recent hypersonic research revealed what may be a fundamental aspect of high Mach number turbulent flow. Measurements made in a Mach 20 helium tunnel indicated that the pressure at the surface of a body may be two or more times greater than the pressure at the outer edge of the

boundary layer. This finding puts in question a previously held assumption that pressure is nearly constant through the boundary layer. The increased pressure level experienced at the body surface could have an important effect on the loading of hypersonic vehicles and a strong influence on vehicle design.

A theory was developed for the prediction of clear air turbulence under certain conditions. Local gradients in temperature and velocity are related to a parameter called the Richardson number. When the Richardson number decreases to a certain level, turbulence can be expected. The newly obtained theory relates changes in Richardson number to topographical features such as mountains. Several instances of pilot-reported clear air turbulence have been successfully correlated with the theory.

A simple model was developed for predicting nitrogen oxide formation in turbojet combustors. This pollutant is a major ingredient in the photochemical process that results in the formation of smog. Nitrogen oxide is present in all hydrocarbon-air combustion processes and currently is much more significant for automobiles than for aircraft. However, the aircraft contribution is not negligible, and a model such as this one will contribute to the better understanding needed to reduce the nitrogen oxide emission to a minimum.

General Aviation Aircraft.—In research on improved control and display for general aviation aircraft, the Ames Research Center studied the use of aerodynamic spoilers on powered light aircraft. A spoiler system, similar to that used on gliders, was installed on a typical four-place single-engine general aviation airplane. Preliminary results indicate marked improvements in the precision of flight path control and a reduction in touchdown point dispersion. The range of variation in the ratio of lift to drag (L/D) available through the use of spoilers, in addition to providing an effective “speed brake” for terminal area maneuvering, permits a threefold increase in usable approach angles. Further studies will be conducted on control techniques and the effectiveness of this system when used differentially as a lateral control device.

V/STOL Aircraft.—Early in 1970, NASA decided to use a research aircraft to verify promising analytical results obtained on the augmentor-wing concept. In this concept, originated by a Canadian corporation, engine exhaust air is ejected into a channel formed by the upper and lower portions of a specially-designed flap system. Large-scale wind tunnel model tests conducted for several years indicated that significant increases in lift are attainable, compared with other concepts studied making possible the design of jet transport aircraft with attractive short-take-off-and-landing (STOL) capability. A contractor was selected to modify the NASA C-8A transport research aircraft

to incorporate an augmentor wing. NASA flight research with the modified aircraft is scheduled to begin in the spring of 1972. The vehicle will have the capability of landing and taking off at speeds of about 75 m.p.h. and an associated capability of operating from fields of 1,500-foot length.

Tests, initiated in 1969, were completed this year to determine the effects of aeroelasticity, Mach number, and scale on the performance of tilt rotors. The concept appears promising for several military and civil applications requiring a helicopter-like hover capability but higher cruise performance than that of a helicopter. In this joint program, use was made of the NASA 40- by 80-foot low-speed tunnel, the U.S. Army 7- by 10-foot low-speed tunnel, and the French ONERA 26-foot transonic tunnel. Both rigid and dynamically-scaled rotor models were tested, and reports comparing the experimentally-determined results with predicated values are in preparation.

To conduct studies of the many stability, control, and other problems associated with improvement of instrument flight at very low airspeeds, NASA continued its V/STOL terminal-area flight-research program, which uses fundamentally different VTOL aircraft concepts and advanced VTOL cockpit-display concepts. This year, NASA flight tests were completed on the Air Force XC-142 transport, which utilizes the tilt-wing, deflected-slipstream concept. The investigation identified major factors influencing the precision low-speed, instrument-approach task—as related to the tilt-wing concept specifically and to VTOL handling-quality and cockpit-display requirements in general. A similar, though more limited flight investigation was completed on the DO-31 transport which utilizes direct-lift jet engines to provide VTOL capability; the program was carried out by NASA pilots in the Federal Republic of Germany under an agreement with the builder of the aircraft. Related studies were continued using the NASA XV-5B fan-in-wing research aircraft; a variable stability helicopter having in-flight simulation capability; and ground-based simulators. A joint Navy-Air Force-NASA program was initiated to extend such studies through use of the Navy X-22 tilt ducted-fan variable stability research airplane.

Subsonic Aircraft.—The supercritical wing concept intended to permit efficient near-sonic cruise was successfully tested on wind tunnel models representing advanced transport configurations. A wing was constructed for flight test on an F-8 airplane to provide initial validation of wind tunnel results. An alternate application, intended to permit structural weight savings on moderate speed subsonic aircraft by use of a thickened supercritical wing section, was tested successfully in flight.

Supersonic Aircraft.—NASA participated in the development of the Navy F-14 and the Air Force F-15 aircraft by providing technical consultations and over 5,200 hours of test time in various NASA wind tunnels. Design information was obtained in areas such as inlet system improvement, high-lift systems, nozzle-airframe interactions, spin and recovery characteristics, stability, control, and performance.

NASA-USAF YF-12 Flight Research Program.—Two YF-12 aircraft made 60 flights during 1970. The USAF aircraft carried out 40 flights at speeds up to the cruise mach number to obtain information pertinent to air defense studies. Before the mid-year grounding of the NASA aircraft for instrumentation overhaul and updating, 20 flights were completed and preliminary information was obtained on structural deformation, stability and control, and handling qualities criteria. The NASA phase of the program will continue to provide advanced design information for supersonic aircraft in such areas as aerothermoelastic effects on aircraft structures and on stability and control, inlet dynamics, airframe-propulsion systems interaction, and aerodynamic properties such as skin friction and heat transfer.

Hypersonic Research Engine.—The Langley Research Center began testing the first of two Hypersonic Research Engine models designed, developed, and fabricated to explore air-breathing propulsion systems capable of Mach 8 sustained flight. This model has a flight-weight, hydrogen regeneratively-cooled construction, and is being tested to demonstrate the integrity of a practical hypersonic structural design concept. The engine structure has been subjected to test conditions of 1,500 p.s.i.a. and 2,300° F. Another model being assembled has similar internal flow lines and will be used to study engine operation with hydrogen fuel and subsonic combustion at Mach numbers below 6, and supersonic combustion above Mach 6. Supersonic combustion is necessary at the higher Mach numbers to avoid excessively high internal temperatures and pressures. This aerothermodynamic model is water-cooled and is scheduled to be tested in mid-1971.

Runway Slipperiness.—The Langley Research Center developed a technique to provide pilots with knowledge of the slipperiness of wet runways in a practical and accurate manner. The technique uses an automobile, modified so the operator can apply brakes to one set of diagonal wheels with bald treads, while the opposite diagonal wheels with conventional treads continue rolling for directional control during the tests. The operator performs a locked-wheel skid from 60 m.p.h. The ratio of the distance it takes the car to stop on a wet pavement to the distance it takes to stop

on a dry pavement measures the slipperiness. This ratio was found to be directly applicable to aircraft stopping ratios on the same pavement, thus giving the pilot and airport operators accurate knowledge of runway slipperiness and length required to stop under adverse conditions.

V/STOL Avionics.—NASA and the FAA have undertaken a joint program to implement and flight test terminal area avionics equipment and procedures which will allow efficient operation of V/STOL aircraft at crowded hub airports. The Ames Research Center is responsible for the airborne equipment and flight tests; Langley Research Center and FAA's National Aviation Facilities Experimental Center (NAFEC) will cooperate on system simulation of ATC situations; DOT's Transportation Systems Center will develop area navigation technology for Ames' use; and FAA will furnish microwave instrument landing systems and other ATC components for the flight tests. Results will guide design of V/STOL airport runways, traffic patterns at hub airports, navigation aids, and V/STOL navigation, guidance and flight control equipment. Equipment development is underway and flight tests are scheduled to commence in 1972.

Aircraft Noise.—Nacelle modifications intended to reduce fan compressor noise from a four-engine jet aircraft were fabricated and flight tested. Subjective reaction to the flyover noise following the nacelle modifications was assessed by asking a group to judge the acceptability of the sound of modified and unmodified aircraft as reproduced in an anechoic chamber, using the method of constant stimulus differences to assess pairs of stimuli. Each pair consisted of one recording from each aircraft, and sounds recorded outdoors and indoors were included. Operational conditions in the tests represented takeoff, reduced climb gradient, and landing approach thrusts at heights ranging from 500 to 2,500 feet. The installation of the modified nacelles produced improvements for all heights and thrusts investigated; improvements from 11 to 14 decibels of effective-perceived-noise level (EPNdB) for the landing-approach thrust condition; and a finding that the EPNdB noise-rating scale adequately assessed the improvement in acceptability.

Behavioral Research.—Tektite II, a marine sciences, biomedical, and behavioral studies project jointly conducted by the Navy, NASA, and the Department of the Interior, was carried out in an underwater habitat near the U.S. Virgin Islands. Teams of scientists, including one team of five females and one team of mixed nationals, lived and carried out research projects in this stressful environment for periods as long as 60 days. Their activities and responses to their confined

habitat and close living conditions, typical of those likely to be obtained in future space stations, provided information on crew behavior and habitability as well as data on microbiology and hematology. NASA is presently analyzing the data.

Life Support Systems Testing.—A four-man 90-day closed-door test of a space vehicle cabin simulator was conducted for the Langley Research Center. This was the longest test in the United States utilizing a regenerative life support system. A space station type of system provided purified water and oxygen reclaimed from the crew's body wastes. The chamber was operated at 10 p.s.i.a. total pressure, with a partial pressure of oxygen equal to that at sea level. Potable water was reclaimed from urine and perspiration by a vacuum distillation-vapor filtration subsystem which used a radioisotope heat source. Separate equipment, containing filters, activated charcoal, and ion-exchange resins, recovered and purified the water used by the crew for washing. Oxygen was recovered from the carbon dioxide exhaled by the crew by the atmosphere purification and control subsystem, consisting of thermal control, carbon dioxide removal, and toxin control units, and by the atmosphere supply and pressurization subsystem containing a Sabatier reactor, water electrolysis unit and atmosphere supply control unit.

The 90-day run and earlier shorter runs indicated that successful long missions using regenerative life support systems will require the capability for onboard maintenance and repair. This will necessitate improved design for maintainability, ready access to operational and performance data, and appropriate crew training.

Orbiting Frog Otolith Experiment.—A 7-day space flight experiment using two bullfrogs as subjects provided information on the adaptability of the vestibule in the inner ear (which controls balance) to sustained weightlessness as well as its response to acceleration. The experiment was launched on a single Scout vehicle on November 9 from NASA Wallops Station, Wallops Island, Va. Excellent data were obtained on the electrical impulses from the otolith sensors and on the frogs' heart rates. Microelectrodes implanted in the vestibular nerves of the two bullfrogs furnished the first direct measures of the otolith sensor response during alternating periods of weightlessness and partial gravity.

Preliminary analysis of the data obtained suggests that adaptation occurred and that it extended to the sensor organ itself. If this preliminary finding is confirmed, it may mean that man can function in weightlessness for long periods without being incapacitated by vestibular influences on his balance, vision, digestive function, circulation, heart rate, and muscular coordination.

Lifting-Body Flight Research Program.—In the joint NASA-Air Force Lifting-Body Program, the NASA M2-F3 and HL-10, and the Air Force X-24A lifting-body research vehicles were flown 22 times during 1970, for a total of 77 flights to date. With its scheduled flight program essentially completed, the HL-10 made its most recent flights to evaluate powered approaches and landing. Both the X-24A and the M2-F3 were gradually flown at higher speeds and altitudes to study the problems and handling qualities associated with these vehicles. The pilots indicated that the handling qualities for the HL-10 were as good as, or better than, most current fighter aircraft.

Space Shuttle.—Approximately 10,000 hours of wind tunnel testing at Ames and Langley Research Centers were used in an aerothermodynamic study of space shuttle concepts.

Planetary Program.—The 5-year program of flight and wind tunnel testing to develop large parachutes capable of landing unmanned spacecraft on Mars was successfully concluded this year. In the flight test program, dummy payloads with various type parachutes up to 84 feet in diameter were propelled to test altitudes considerably over 100,000 feet. Following 18 test flights, the so-called disc-gap-band parachute was selected as the most suitable for the very low density and pressure conditions believed to exist near the surface of Mars. The unmanned Viking Mars lander scheduled for launch in 1975 will use a disc-gap-band parachute to help land a payload on Mars.

Significant improvements in the ability to predict spacecraft temperature during planetary entry resulted from the availability of a computing program to determine heating rates. As a consequence, the extremely high heating rates previously calculated for entry into the atmosphere of Jupiter have been reduced and will affect the future design of probes for a Jupiter exploration.

Planetary Approach Guidance.—From results of the Planetary Approach Guidance experiment which was on the Mariner VI spacecraft, it appears that this new technique is as good as presently used navigation systems at Mars distances and probably better at outer planetary distances. Earth-based navigation systems get progressively worse as the distance from earth increases while the planetary approach technique improves in accuracy as the target planet is approached. In this technique, a calibrated imaging tube on the spacecraft looks at the planet being approached and determines the spacecraft position by star sights on the limb of the planet itself or on its moons. The closer the spacecraft approaches, the more accurate the sightings become because all measurements are based on the position of the planet itself rather than radio signals from earth.

Planetary approach guidance is particularly important when gravity assisted flybys are used to change direction as is proposed for the longer outer planetary missions. In such cases, the distance from the planet at flyby is extremely critical in obtaining the proper trajectory to the next planet, and it is possible that only the planetary approach guidance technique can achieve the required accuracy.

Landing Radar.—Langley Research Center developed and flight tested an improved landing radar which is suitable for use by V/STOL aircraft or by planetary landers. The improvements were achieved by using a new modulation technique consisting of on-off continuous waves at higher altitudes and frequency modulation with carefully controlled modulation sidebands at lower altitudes. The control of these sidebands gives the radar especially good capability for measuring range and range rate at the lower altitudes including touchdown.

Magnetic Bearings.—Goddard Space Flight Center developed a magnetic bearing which eliminates essentially all the mechanical friction in an electric motor. The bearing with its electronic controls floats the rotating shaft within the bearing without mechanical or liquid support and thus permits the design of much more accurate control systems, aircraft instruments, and navigation devices.

Deep Space Unfurlable Antennas.—The Jet Propulsion Laboratory demonstrated the feasibility of constructing large, dish-type, deep-space communication antennas which can be folded for launch stowage. The antenna reflecting surface is a conic section of single curvature that makes it possible to maintain surface distortions within tolerable limits without extensive bracing. Use of the single curved surface was made possible by design of a special Gregorian-type subreflector which corrects beam distortion induced by the flat main reflecting surface. Further development of this technique will make it possible to design stowable antennas 50 feet or more in diameter to provide the communications capacity required for outer planet exploration missions.

Communications Channel Coding.—Research at Goddard Space Flight Center (GSFC) and Ames Research Center has produced telemetry coding techniques which significantly improve both information transmission rate and error reduction for space communication channels. Error correcting codes commonly operate by adding strategically located redundant bits to the data stream. Decoding of these redundant bits allows the correct identification of a limited number of data bits which may have been masked by channel noise. Since the added bits are

themselves subject to noise induced error, current coding techniques require a compromise between the number of data bits and the number of redundant bits transmitted. GSFC developed a mathematical coding technique which avoids this compromise and approaches the theoretical maximum error correcting capability by suppressing all data bits and transmitting only properly coded error correcting bits from which the data bit stream is reconstructed. Error correcting codes are particularly applicable to such missions as Pioneer, Mariner, and outer planet exploration, as well as to earth survey or space station missions.

The complexity of hardware and computer operations required to implement error correcting codes has limited the rate at which information in coded form may be transmitted. The ARC research, which complements the GSFC effort, led to the development of a laboratory prototype coding device which provides a 15-fold increase in channel information rate.

High Volume Data Processing.—Research at GSFC in optical methods for data processing continued in an effort to apply lasers and coherent optics to the problem of handling and analysis of extremely large volumes of experimental data from spacecraft. A major impediment to their early employment has been the lack of an effective device for real time conversion of electrical signals to an optical form which can be handled by lenses. GSFC demonstrated that such a device is feasible and a test unit is being built.

Microprocessor Spacecraft Computer.—In research at GSFC, microcircuit techniques were developed which are applicable to the design of ultra low power, high performance, miniaturized spacecraft computing systems for both routine and complex data processing aboard aerospace vehicles. The microprocessor computers will relieve the burden on ground data processing facilities and increase performance in applications ranging from small scientific satellites to highly complex earth resources and space station missions.

Work by NASA and DOD on microcircuits has reduced circuit fabrication costs of complementary metal oxide semiconductor devices to the point where these devices are competitive in the commercial market for application in commercial and industrial systems.

Pilot Warning Indicator.—Flight tests were conducted to determine the feasibility of using optical techniques for providing general aviation pilots with early warning of impending mid-air collisions. All the equipment tested used a flashing xenon lamp on one aircraft to provide the warning signal which was then detected by an optical sensor on a second aircraft. Xenon lights are already installed on many aircraft for enhanced visibility and would require very little development to make them operational. The detectors would require

further research to make them suitable for aircraft use. Two different sets of equipment were tested. Each detected other aircraft at ranges of 2–3 miles and warned the pilot of the approximate direction in which to look for further evaluation of the collision risk. Each device had an unacceptably high false alarm rate caused principally by the direct or reflected energy from the sun. Filter techniques may reduce this rate to an acceptable level, and other problems which were encountered, such as radiated electrical interference, can be easily solved. Both units are being redesigned and further flight tests will be conducted.

Optical Communication.—GSFC developed the equipment for and conducted the first experiment to measure the effect of the atmosphere on laser beams projected vertically to a near-stationary measuring platform. The measurements were made by a detector package carried to an altitude of about 18 miles by a large balloon. Two lasers on the ground operating at wavelengths of 10.6 and 0.5 microns were continuously pointed at the balloon package where the intensity of the beam was measured as a function of height, position in the beam, and weather conditions. Additional flights will be conducted in the summer of 1971 when weather conditions again permit balloon flights to add statistical credence to the first results and to conduct tests under a wider variety of weather conditions.

Electrophysics.—In research at Massachusetts Institute of Technology, ionized gas cells were placed in the path of a laser beam to control the wavelength of the laser. By varying the voltage applied across the cell, a point is reached where some of the excited gas molecules produce strong absorption characteristics over a very narrow bandwidth and at the laser frequency. If the laser radiation tends to deviate from its nominal frequency, it is pulled by this absorption line, called the “Lamb Dip,” back to its original value. By this process the frequency of the laser oscillator can be precisely controlled, making it suitable for use as a frequency standard or for spectrographic analysis.

Digital Blast Gage.—A maintenance-free, standby digital blast gage that is totally self-contained and capable of operating from -40° to $+150^{\circ}$ F. was developed by Marshall Space Flight Center to detect and record the magnitude of shock and blast fronts in the vicinity of test stands and launch pads. Explosion history is sensed, timed, digitized, and recorded on magnetic tape. Overpressures ranging from 0.1 to 1000 p.s.i. are detected by means of a quartz pressure transducer which initiates the recording of the impact and its storage in a memory bank. The system has the capability of initiating safety countermeasures.

Integrated Circuit Inspection Criteria.—NASA worked closely with the DOD to develop a standard

for microcircuit inspection criteria. The criteria include drawings and photographs delineating defects and establishing reject criteria. The jointly developed military standard is now an accepted standard which microcircuit manufacturers are required to use on all DOD and NASA procurements of high reliability integrated circuits.

Nondestructive Weld Inspection.—A system developed by Ames Research Center for making and testing welded interconnections monitors such critical variables as temperature, pressure, and voltage waveform and maintains these variables within prescribed limits during the fabrication process. If any two of the three variables exceeds the prescribed limits, the device is rejected. Evaluation of the system on the production lines of two microcircuit manufacturers, including varying the process parameters to produce both good and bad welds, indicated that the system could successfully detect all bad welds.

Electronically Tuned Optical Filter.—A liquid-crystal-dye system was discovered in which the orientation of the molecular structure can be altered by applying an electric field, producing changes in the optical density of the material and consequently changing the color of light transmitted through the medium. The technique is being used to develop a series of filters which can produce a wide variety of colors. They may be used as color filters for aerial photography calling for films of various sensitivities and for information displays in which color can increase the efficiency with which information can be stored and/or read out by an observer.

Electrochemical Power.—Extended tests on rechargeable nickel cadmium cells and batteries showed that long cycle life can be attained by keeping the temperatures between 30° and 50° F. and by avoiding excessive overcharging. New battery-making procedures were developed and cell specifications written to assure greater uniformity and reliability of nickel-cadmium batteries. A novel inorganic separator appears to be of value for extending the usefulness of silver-zinc cells in space. Wet stand life was extended from a few weeks to well over 1 year, and active life of several hundred cycles was attained by putting each electrode in its own bag made of this separator material.

Solar Power.—A lightweight, 30 watts-per-pound solar array was ready for the technology stage. Lithium-doped cells with the same efficiency as conventional cells became available; preliminary data indicated about three times the radiation resistance under electron bombardment compared with normal cells. Exploratory work showed the feasibility of simultaneous

multiple-cell connections and of the sandwiching of modules between Teflon covers. If these procedures prove to be practical, they will lower manufacturing costs and make safe and convenient storage of modules possible. The problems of high voltage solar arrays were being studied.

Electric Power Processing and Distribution.—In-house and contracted studies were concurrently examining the electric power processing and distribution needs of the space station, the space shuttle, and advanced aircraft in order to establish as high a degree of commonality among these vehicles as is practical. Maximum commonality will make it possible to conserve R. & D. resources, reduce logistics costs, and may improve performance significantly by concentrating R. & D. efforts on common problems.

Research and development activities related to advanced power systems for outer planet spacecraft demonstrated weight and volume reductions of 50–70 percent and reduction of piece parts and discrete interconnections by about 75 percent. The improvement was obtained through adaptation of hybrid thick film electronic circuit techniques on an alumina substrate, a combination with the essential characteristics of both high electrical insulation and high thermal conductivity.

Electric Propulsion.—The research aimed at providing the technological base required to realize the advantages of electric propulsion continued to progress. Interest in these devices is based on the fact that electric thrusters have the highest performance of all practical rocket engines known and may be able to sharply reduce the system mass and cost of high energy space missions.

The SERT II orbital test sought to demonstrate 4,383 hours operation in space of a 1-kilowatt mercury bombardment ion engine. Premature failure caused by erosion limited the test, and only 3,782 hours were accumulated on one engine and 2,011 hours on a second. Initial ground tests verified the design changes necessary to eliminate the erosion. The ground system technology program intended to demonstrate all the propulsion functions required on a solar-array-powered electrically propelled mission continued to progress toward an integrated system test planned for 1971. Data from the ground program and the SERT II flight results served as the basis for significant planning on a solar electric multimission space vehicle, considered the next logical step in the introduction of electric propulsion into mission use.

Thermoelectric Conversion.—The two SNAP-19 radioisotope thermoelectric generators (RTG's) aboard the Nimbus-3 satellite continued to deliver useful power to the spacecraft. The SNAP-27 RTG

placed on the moon by the Apollo 12 crew also continued to supply power and heat to the Apollo Lunar Surface Experiments Package.

Work on prototype fueled RTG's for the Pioneer F Jupiter mission proceeded on schedule, and RTG development work for the Viking Mars Lander mission was underway. An advanced RTG for long duration outer planet missions was undergoing design and technology development.

Chemical Propulsion.—In the space shuttle propulsion area, main engine technology efforts were directed toward improving turbomachinery and developing the ability to calculate accurately combined chamber and nozzle performance. Turbomachinery work concentrated on propellant conditioning requirements at the pump inlet, amelioration of the effects of two-phase flow, feed system stability and dynamic interactions, and improved impeller fabrication. Combustion chamber work was investigating devices to observe local variations in mixture ratio in situ, combustion oscillation damping devices, improved injector configurations, and analytical procedures to define internal combustion and flow processes.

In the shuttle auxiliary propulsion technology area, studies were concerned with defining optimum systems and generating a technology base for the components of the systems. Experimental and analytical efforts were in progress to define thruster capabilities by exploring several alternate schemes for ignition, chamber cooling, injection of propellants, valves, and other items.

In work on spacecraft and upper stage propulsion, a hydrazine monopropellant attitude control system for long life outer planet spacecraft was designed. The design is based on thrusters of 50 to 100 millipound thrust, and initial tests of these thrusters indicated good performance for such very small devices.

The FLOX-Methane propellant combination is intended for large planetary orbiters and landers where higher thrust requirements suggest the need for pump-fed engine designs. A program to demonstrate the operational capability of a FLOX-Methane spacecraft propulsion system progressed towards testing a complete system in a simulated space environment. All parts for the propellant storage, pressurization, and feed subsystems were ordered, and a contract for the design, fabrication, test, and delivery of two 5,000-pound thrust pump-fed engines was awarded.

The technology program for the OF₂-Diborane propellant combination moved toward the demonstration of integrated system performance capability and operational readiness. Propellant storage, pressurization, and feed subsystem designs for a representative spacecraft propulsion system were frozen, and some parts were ordered. Several thrust chamber cooling techniques were being evaluated at the nominal 1,000-

pound thrust level and at a subscale 200-pound thrust level. They included regenerative cooling, cooling by means of the heat pipe concept, ablative cooling using carbon phenolic materials, and boundary-layer-assisted radiation cooling.

A solid rocket motor containing 2,800 pounds of high energy propellant was successfully ignited, burned for 34 seconds, then extinguished by injection of a small quantity of water. Only 13 pounds of water were required to drop the 9,000 pounds of thrust to essentially zero in 1 second. This is especially impressive since the propellant was a particularly "hot" composition, developing 10 percent more thrust per pound than those propellants currently in use. Later versions of this motor will be designed to allow reignition for a second burn, then a second quench. This stop-start motor is essentially two stages in one, giving the mission planner the ability to determine the duration of each pulse.

Solid rocket motors developing relatively low thrust for long durations were tested. They were designed to slow spacecraft gradually as they approach a planet, allowing a planetary orbit to be obtained. All 11 tests in this program were successful. In one test—the first that included a very large nozzle cone—a motor weighing 800 pounds (90 percent propellant by weight) was fired under simulated vacuum conditions. The burning time was over 2 minutes, roughly three times that normally attained in this motor shape. In three tests of a similar but smaller motor, "all carbon" nozzles performed successfully. The nozzles are made by a new process of wrapping carbon cloth and sequentially impregnating and charring the binder, and they operate at white heat without degradation. Since they can be very thin, there is considerable weight savings.

In sounding rocket research, the first dual thrust level, advanced state-of-the-art motor was fired, and performance was as predicted. This 2,700-pound unit is a full size prototype of a motor that could meet future NASA requirements in solar physics and astronomy experiments and is a potential replacement for the aging Aerobee systems. The design included low cost construction, a new and very flexible propellant binder, and a one-piece molded nozzle.

In chemical propulsion technology, an igniter for gaseous hydrogen-gaseous oxygen thrusters based on heating of the gas by resonant phenomena was tested. Reliable ignition was obtained in 0.030 to 0.040 seconds after the flow was initiated. The advantage of this system is that it can be integrated with the propellant valves, and it requires no separate electrical system as does a spark igniter.

The regime of low density flows in small altitude control engines was investigated analytically and experimentally. Results from both the mathematical analyses and the sophisticated laboratory tests verified that for an optimum engine design, the low density flow

conditions (random loose molecular flow) must be accounted for. These results have also been of value in wind tunnel design.

Advances were made in the basic understanding of the nature of solid propellant polymer binders as part of an effort to develop the ability to make propellants with specific physical properties and predictable behavior. A binder which is essentially a pure compound was manufactured. It was used in propellant mixes, and the physical properties compared against various theories to check their validity.

New methods of measuring the exact burning rate of a solid propellant at any instant were found to be feasible. The new techniques involved microwave and ultrasonic devices which look through the motor case and propellant to the burning surface. Data collected by using these techniques will ultimately be used to select the best burning theories and to make possible more precise design of motors.

Nuclear Rocket Program.—The major objective of the joint NASA-AEC nuclear rocket program is to develop a 75,000-pound-thrust engine, NERVA, for space flight missions. Long range plans call for an engine which can be employed in a reusable nuclear stage as well as in a single-use application. The nuclear rocket program also includes a variety of supporting and advanced research and technology projects designed to extend the capability of solid-core nuclear rockets, to conduct research on advanced forms of nuclear propulsion, and to provide the base of information for the development of a nuclear stage.

Progress in NERVA Development.—The emphasis in NERVA development during 1970 was on the definition and preliminary design of the NERVA flight engine. Engine system and nonreactor development activities included the analysis of systems engineering results, the preparation of engine system and critical component specifications, and engine design. The systems engineering analyses sought to verify that the performance and reliability criteria established for the NERVA engine could be met through the materials and component design selections which evolved from the systems engineering NERVA trade studies. The analyses culminated in the preparation of engine system and component specifications for proceeding with the engine detailed design and the fabrication of hardware for development and qualification tests. In October, the preliminary design review of the engine was initiated to examine all engine design documentation, effect the review for adequacy to meet design compatibility requirements and correct design deficiencies, and to officially approve the baseline engine configuration for proceeding with the next phase of engine development. These activities are expected to continue into the second quarter of 1971.

In addition to the NERVA design activities, important progress was achieved in other program areas. Procurement was initiated for certain engine critical components parts such as the turbopump and various valve parts. A turbopump bearing test program was started to examine the performance of high-speed, cryogenically-cooled bearing components under varying load conditions. Tests of materials for various high-stress cryogenic applications were continued in support of critical component detailed design activities. Work also was begun to procure, modify, and checkout the host of laboratory jigs, fixtures, and test equipment that will be required to test and evaluate engine components.

Facilities.—Preliminary planning and analyses aimed at the definition of Engine Test Stand No. 1 facility requirements for testing the NERVA engine were completed, and the preliminary design was initiated on the test stand modifications necessary to meet these requirements. Attention was focused on the hot-hydrogen exhaust and altitude simulation system, propellant storage system, and instrumentation and control system. Modification of the stand is scheduled to be completed by the latter half of 1974. A preliminary Engineering Report of Engine/Stage Test Stand No. 2 was completed, and performance and design requirements to support the test objectives for NERVA engine and stage development were established.

Nuclear Flight Stage Definition Studies.—The nuclear-powered stage definition studies were continued with primary emphasis on reusable stages. Potential uses treated in the studies included manned or unmanned transportation between earth orbit, lunar orbit, and geosynchronous orbit in a fully reusable mode, and the propulsion of payloads into deep space, employing the vehicle in either a reusable or expendable mode, depending on the mission objectives and vehicle size. The results of preliminary studies on stage concepts and program definition were published in May, and the study contracts were extended to May 1971 in order to attain a more complete assessment at the concept definition level of several types of reusable nuclear stages.

The two basic stage concepts under investigation were large single-tank configurations that could be launched by the Saturn V Intermediate-21 or by the space shuttle booster with an orbit insertion stage, and a multitank configuration in which the stage modules could be launched in the cargo bay of the space shuttle orbiter. Studies centered on operational requirements and systems definition, and the establishment of the manufacturing and facilities requirements necessary to define a total development program. Cost and cost-

sensitivity factors were generated simultaneously with concept definition and will be used later in the studies to find ways in which both development and operational costs can be reduced without sacrifices in performance or reliability.

Preliminary study results indicated that both concepts were reasonably comparable in performance and cost effective for both logistic support of lunar exploration and high energy deep space missions. The preferred concept will not be selected until the size and configuration of the space shuttle have been determined and the direction of the future long range space program is more fully resolved.

Vehicle Technology.—This program provides technology to meet the requirements for the nuclear stage. Several technology programs started previously in support of the 33-foot diameter nuclear stage were completed during the year. One involved a small hydrogen reliquefier designed to reliquefy about 1 to 1½ lb./hr. out of a total of 3 lb./hr. of hydrogen vent gas. All components operated satisfactorily except for the piston seals; they are being redesigned. An experimental investigation was completed on the properties of colloidal hydrocarbon suspensions, and hydrocarbon gelling agents in liquid hydrogen. Of several hydrocarbons investigated, cyclopropane proved the most promising, in concentrations of about ½ percent by weight. Ethane proved to be the most effective gelling agent in liquid hydrogen, in minimum concentrations of 10 weight percent. These data will be useful for tailoring propellant properties to eliminate slush problems, to improve storage characteristics, and to allow effective use of slush hydrogen.

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 formidable problems. The dust-bed reactor, on the other hand, appears to offer the potential for increased life, engine thrust-to-weight ratios of 10 or greater, and reduced operational problems. Research on the feasibility of such a system stresses three problems: the amount of power that can be expected without blowing the fuel particles out of the system; the amount of fuel required to make the reactor critical; and the highest temperature at which the system can be operated.

The research on gaseous-core reactors concentrated on propellant heating, the development of high-heat-flux radiant energy source, radiation damage, and fluid mechanics. Progress was made in all these areas.

Space Nuclear System Office.—In October, NASA and the Atomic Energy Commission (AEC) agreed to consolidate related NASA and AEC nuclear space power and power conversion technology activities under a single joint NASA-AEC office, the Nuclear Systems Office, by expanding the joint NASA-AEC Space Nuclear Propulsion Office.

Tracking and Data Acquisition

The NASA tracking and data acquisition networks supported over 50 ongoing space missions and some 20 new flight projects launched by NASA in 1970.

During the year, the networks established a new distance record for two-way deep space communications—250 million miles—and rendered outstanding support to the crippled Apollo 13 spacecraft. In addition, construction progressed on schedule for the 210-foot-diameter antennas being built in Spain and Australia.

Manned Space Flight Network.—The operations of the Manned Space Flight Network were highlighted by the safe return of Apollo 13. During that mission, the network demonstrated that it is, in fact, the astronauts' lifeline to the earth.

From the initial warning by the crew—"Houston, we've got a problem here"—until splashdown some 3½ days later, the network continuously received and transmitted data between the astronauts and the Mission Control Center (MCC) in Houston, Tex. The continuous stream of data carried by the network during this emergency period enabled ground personnel to evaluate the spacecraft systems and the condition of the astronauts and to simulate on the ground the problems experienced by Apollo 13. Ground-based scientific and engineering personnel were then able to explore alternate modes of operations for the astronauts and to send the necessary commands to the spacecraft via the network. The apparatus designed to purify the air in the lunar module was one example of such a ground-determined solution to an in-flight difficulty.

To assure maximum protection for spacecraft communications during Apollo 13's return to earth, NASA asked the Department of State to solicit international cooperation in avoiding radio operation in frequencies which might interfere with reception of the spacecraft transmissions.

The response was immediate and unanimously favorable, with many governments ordering suspension of all frequencies utilized by the spacecraft until after splashdown and recovery.

In addition to providing real-time voice communications between the astronauts and the MCC, the network continuously received and recorded telemetry

from Apollo 13. Much of what occurred up to the time of the explosion went unseen and unheard but not unrecorded. Invaluable clues to the origin of the explosion, which were found through analyses of the telemetry data, gave the Apollo 13 Review Board the basis for its detailed investigations, and aided significantly in pinpointing the events that led to the explosion.

The network also supported seven unmanned spacecraft launched by NASA and 21 missions conducted by the Department of Defense. In addition, the network's tracking ship, the USNS *Vanguard*, was used in an ocean surface mapping expedition. The purpose of the expedition was to obtain accurate measurements of a huge depression in the ocean surface directly over the Atlantic's deepest spot—the 5-mile-deep Puerto Rico Trench. The *Vanguard*, together with the Department of Defense stations at Grand Bahama and Antigua, provided C-band radar tracking of the GEOS satellite to obtain triangulation data.

As the year ended, the network was undergoing mission simulation tests designed to insure network integrity and work reliability for the launch of Apollo 14.

Deep Space Network.—This network supported the the Mariners 6 and 7 spacecraft in the extended mission phase and the Apollo 13 mission. The network also continued to support the on-going Pioneer 6, 7, 8, and 9 missions. The network tracked Mariners 6 and 7 as they passed behind the sun at a distance of some 250 million miles from earth. The passage provided an opportunity to test Einstein's General Theory of Relativity and established a new distance record for two-way communications.

In the test of Einstein's Theory, radio signals were transmitted to the spacecraft along a path close to the sun. The effect of solar gravitation on the signals was determined by comparing the elapsed time for the signal to reach the spacecraft and return to earth along this path with the time required for a signal to be sent to the spacecraft and returned along a path outside the influence of the sun. Calculations based on the Einstein Theory indicate the time should be 200-millionths of a second slower due to the influence of the gravitational field of the sun. The data acquired thus far indicate verification of the Einstein Theory. However, to fully determine the effect of the solar gravity, extremely precise calculations derived from longer term tracking of the spacecraft are required. To obtain these data support will continue into 1971 to ensure that the orbits of the two Mariners have been precisely determined.

The network also provided vital support of the Apollo 13 mission, primarily through the 210-foot-diameter antenna at Goldstone, Calif. Original mission plans called for the 210-foot antenna to support only

the close-in lunar phase of the mission. (This antenna allows about a sixfold increase in performance over the standard 85-foot antennas of the Manned Space Flight Network.) After the explosion aboard Apollo 13, the 210-foot antenna supported the mission until splashdown. Its added capability permitted voice communications with the astronauts in spite of the reduced spacecraft power during the emergency.

The four ongoing Pioneer spacecraft continued to furnish important solar particle data. Early in the year, Pioneers 6 and 7 were aligned in a manner which allowed the network to receive, for the first time, data simultaneously from two planetary spacecraft. The beamwidth of the 210-foot antenna which made this possible also made possible the collection of unprecedented scientific information on propagation of the higher energy particles from the sun.

The network also participated in several radio astronomy experiments. One was the successful demonstration of radar techniques at planetary distances in the X-band frequencies. The Goldstone 210-foot antenna worked jointly with the Lincoln Laboratory's 120-foot Haystack antenna (near Boston, Mass.) to conduct the experiment, using as radar targets the planets Mercury and Venus and the moons of Jupiter. The Haystack antenna transmitted radio frequency energy to the planets, and the Goldstone antenna received the returned signals. The results of the X-band performance may have applications in mission planning and spacecraft design of future planetary programs.

Construction work continued throughout the year on a second 210-foot antenna at Tidbinbilla, near Canberra, Australia, and in June, ground was broken about 40 miles west of Madrid, Spain, for construction of the network's third 210-foot antenna. Both antennas are essentially duplicates of the Goldstone antenna and are expected to become operational in 1973. Spaced at approximately equal distances around the earth, the three-antenna subnetwork will have the capability for continuous tracking of spacecraft billions of miles into space.

Satellite Network.—This network continued supporting an average daily workload of over 40 satellites, which in terms of total missions supported is the heaviest workload of all the NASA tracking and data acquisition facilities. In addition to supporting the majority of NASA's scientific and applications satellites, the network services a wide variety of space projects conducted by other Government agencies and foreign countries through cooperative international programs.

Among the major flight projects launched during the year and supported by the network are Tiros-M, SERT-2, Nimbus-4, and SAS-A. /

The Tiros-M mission, now designated ITOS-1, was launched January 23, and represents the first in a series of second-generation operational meteorological satellites launched by NASA for the National Oceanic and Atmospheric Administration (NOAA). The network was responsible for all support activities of the spacecraft until it was completely checked out and ready for operational use. After some 5 months of extensive checkout, ITOS-1 was officially turned over to NOAA.

The Space Electric Rocket Test (SERT-2) had as its prime mission objective the evaluation of an ion engine in a space environment. Due to the presence of the active element onboard the spacecraft, the early postlaunch period of SERT-2 was extremely critical. To ensure maximum coverage for this period, supplemental support was obtained from the Department of Defense and the Manned Space Flight Network. The supplemental tracking facilities aided greatly in the rapid determination of the satellite's orbit and attitude. Once the spacecraft was verified to be gravity-gradient captured, the ion engines and other related experiments were activated. Both engines were operated and provided important new data on ion thruster performance in the space environment.

The Nimbus-4 mission was launched April 8. Its prime data acquisition stations are those at Rosman, N.C., and Fairbanks, Alaska. The network is participating in the Interrogation, Recording, and Location System experiment aboard the spacecraft. Weather balloons, launched from Christchurch, New Zealand, and Ascension Island, are interrogated by Nimbus-4 and transmit magnetic, meteorological, and oceanographic data for recording aboard the spacecraft. The data are later transmitted to the ground stations and relayed to the project control center at GSFC. From these data, balloon locations are calculated and the precise conditions existing at these points are determined. This information is furnished to the principal scientific investigators, including NOAA, the Smithsonian Institution, and the National Science Foundation.

International cooperative projects supported during the year included the first successful Japanese satellite, OHSUMI, and the DIAL-WIKA satellite, a joint development of France and Germany. In another type of international cooperation, arrangements were completed for mutual satellite tracking support by the French Centre National d'Etudes Spatiales (CNES) and NASA. Each agency will provide net work support in tracking, data acquisition, and command activities when their respective workloads permit. The arrangement applies to support by the French stations in Canary Islands, Upper Volta, Congo, South Africa, French Guiana, and France. The NASA stations involved are in Australia, Madagascar, South Africa, Ecuador, Chile, England, and the United States.

SAS-A was successfully launched on December 12, 1970, from the San Marco platform, a modified oil rig in the Indian Ocean off Kenya. It was launched by Italian personnel, the first American satellite to be launched by scientists from another country. The Network is collecting data on X-ray sources in space from SAS-A.

International Affairs

NASA continued to develop international cooperative projects and to arrange for foreign support in the exploration of space. At the same time, the agency has undertaken a major effort to assure substantial participation by other nations in post-Apollo programs, with the United States sharing the costs as well as the benefits of future space activities. As part of this effort, principal potential overseas participants were briefed on NASA plans and provided with reports and other documents.

The European Space Conference (ESC) studied possibilities for substantive involvement with NASA, principally through groups such as the European Launcher Development Organization (ELDO) and the European Space Research Organization (ESRO). Both organizations now have full-time liaison personnel in Washington and have sent teams to visit NASA centers and contractor facilities. Special committees and panels were set up within ESC, ELDO, and ESRO management for preparatory studies by European industry. ESC voted several million dollars to support these studies, assigned observers to work with NASA in the area of supporting technology for the shuttle and space station, and formed working groups with the agency to coordinate European and American studies of space transportation systems and space stations.

In September, ESC ministers indicated that major participation in the U.S. space transportation system program would strain Europe's resources and probably mean an end to the Europa III launcher program. They were assured that the United States would make reimbursable launch services available for European payloads for peaceful purposes in exchange for their substantial participation in our program. Such participation was understood to mean at least 10 percent of the developmental costs of the space transportation system, or about \$1 billion.

In a November ESC meeting, the results of the previous meeting were reviewed and a special committee was organized to formulate questions for further discussion with the United States. Also, Canada and Japan established special committees to assist their Governments in determining whether they should take part in the post-Apollo program.

In line with a 1969 Presidential pledge to share the benefits of earth resources survey techniques, the

United States invited the Secretary General of the U.N., Member States, and Specialized Agencies to send representatives to an International Workshop on Earth Resources Survey Systems at the University of Michigan, May 3-14, 1971. Other activities included briefings for representatives of the United Nations Outer Space Committee and Secretariat and liaison with the Office of the U.N. Space Applications Expert.

Discussions were underway with Brazil, Canada, and Mexico on agreements to extend cooperation in the earth resources area. In addition, over 70 experimenters from 28 countries responded to a worldwide request for letters of intent to submit proposals to analyze data acquired by Earth Resources Technology Satellites.

Joint working group meetings were held in India and the United States on the Satellite Instructional Television Experiment planned for the ATS-F spacecraft. Work in the United States on the satellite and in India on the ground segment moved forward. The objective is to begin the 1-year experiment in early 1974.

NASA and the Agency for International Development began an 18-month experimental project with Korea in the applications of aerospace technology to Korean economic problems. The project, which involves visits by specialists of both countries, calls for the Korean Institute of Science and Technology to examine the technology utilization system and identify aerospace-generated technology potentially applicable to Korean industrial needs and then to adjust these techniques to Korean needs.

An agreement was made under which NASA and the Canadian Department of Industry, Trade, and Commerce are to study the "augmentor wing" concept and its possible application to STOL aircraft. An agreement was also concluded with the United Kingdom Ministry of Aviation Supply to test fly NASA's XH-51 rigid rotor helicopter in the U.K. and to share the resultant data.

NASA and the Netherlands Astronomy Satellite Program Authority agreed in June to the cooperative development and launching in 1974 of a small astronomical satellite (ANS), which will carry two Dutch and one U.S. experiment to investigate stellar UV and X-ray radiations. International cooperation in astronomy was also extended by an agreement with the Science Research Council in Great Britain to launch a British X-ray satellite (UK-5) in 1973. It will be the fifth in the Ariel series which began with Ariel I, the first international cooperative satellite. The Italians launched NASA's Small Astronomy Satellite (SAS-A) from the San Marco platform, and an agreement was concluded in June establishing the principles under which NASA will launch, on a reimbursable basis, the Italian satellite SIRIO which will study wave propagation and electron flows in the magnetosphere. Preliminary discussions between Indian and

NASA scientists took place in September on 13 experiments proposed by Indian scientists for inclusion in a cooperative scientific satellite, designated RS-2, to be launched on a NASA-supplied Scout vehicle.

An experiment to study stellar UV emissions for Skylab A was accepted from the French National Laboratory for Space Astronomy. An instrument developed by the French National Laboratory for Stellar and Planetary Physics will investigate the fine structure of the solar chromosphere from the OSO-1 spacecraft, scheduled for launching in 1972, and Britain's Jodrell Bank Observatory will assist in the planning activities of the radio science team for Project Viking, the Mars probe planned for 1975.

New sounding rocket agreements were signed with Australia, India, Spain, and Sweden, and negotiations with the French were nearing completion for cooperative upper-atmosphere sounding rocket launchings at Kourou, French Guiana. Under previous agreements, launchings took place in Argentina, Australia, Brazil, India, Norway, Pakistan, Spain, and Sweden.

Lunar material, returned by the Apollo 11 and 12 missions, is under study by 54 foreign principal investigators in 16 countries. They will present the results of their analyses at the Second Lunar Science Conference in January 1971.

Continuing efforts to expand U.S.-U.S.S.R. cooperation beyond the limited projects provided for in the Bilateral Space Agreement of 1962 led to preliminary technical discussions in October between representatives of NASA and the Soviet Academy of Sciences on possible compatible space docking arrangements. An agreement was reached on procedure and a schedule set for joint efforts to design compatible rendezvous and docking arrangements. Each nation will provide the other with supplementary technical information and a draft of technical requirements for those systems which it is judged should be made compatible. In March-April 1971, three joint working groups will meet to refine the requirements and attempt to develop a single set of requirements for compatibility. The two countries will then independently work out preliminary system designs, following which NASA and the Soviet Academy will jointly consider appropriate implementing action.

The BC-4 camera observations of the PAGEOS balloon satellite, under the National Geodetic Satellite Program were concluded. The observations were made under arrangements with 23 countries for the temporary stationing of Coast and Geodetic Survey and Army Map Service camera teams at 42 sites. The foreign sites provided the geographic distribution essential to the success of the observation program, whose objective is to increase man's knowledge of the size and shape of the earth.

Agreements for NASA tracking stations in Australia and the Malagasy Republic were extended, assuring

continued support from these key locations. As a consequence of changed requirements, the manned flight tracking stations at Guaymas, Mexico, and Antigua and the scientific satellite station in Newfoundland were discontinued. The ATS transportable ground station, at Cooby Creek, Australia, was withdrawn and was being modified to support future ATS satellites. The transportable Apollo support facility at Grand Bahama Island was placed in caretaker status. An agreement was concluded between the United States and Canada concerning accommodation of U.S. sounding rocket and other scientific activities at Canada's Churchill Research Range. Since July the range was funded, operated, and maintained entirely as a Canadian venture following expiration of a 1965 agreement providing for joint United States-Canada funding.

Cooperation in the utilization of the tracking station capabilities of NASA and the space agencies of other countries increased. An agreement between NASA and the French space agency was completed in June for mutual tracking and data acquisition support from one agency's facilities to the others. Under the terms of this agreement and in accord with arrangements with agencies of the United Kingdom and Italy, NASA expects to receive support as necessary from tracking facilities of those agencies for the Small Astronomy Satellite. NASA facilities provided tracking assistance to support the successful Japanese satellite (OHSUMI) in February and also provided telemetry support to the German scientific satellite DIAL launched on a French DIAMANT-B vehicle from French Guiana in March.

Many offers of assistance in astronaut recovery were extended from nations around the world during Apollo 13. During the critical reentry period, the Parkes 210-foot-diameter antenna in Australia was voluntarily placed at NASA's service.

Mexico again hosted an astronaut training exercise in its Pinnacate area where the surface is similar to that of the moon.

Industry Affairs

Activities reported in this section are varied but industrially related. In each area, NASA efforts have been directed toward improvements in economy and efficiency of operations.

Inventions and Contributions.—The Inventions and Contributions Board completed action and made recommendations on 105 petitions for patent waiver received from NASA contractors during the year. The Board recommended the granting of monetary awards totaling approximately \$85,000 for inventions and other scientific and technical contributions made by

NASA and NASA contractor employees. In September the Board held an oral hearing on the application for a monetary award for a scientific contribution submitted by a member of the general public. A comprehensive report summarizing the activities of NASA contractors granted patent waivers showed a 50-percent increase over 1969 in the number of inventions fully commercialized by NASA contractors or their licensees.

Research Grants.—The “Research Grant Handbook,” incorporating all of NASA’s regulations in this field, was published in January. With the distribution of the handbook, a new procedure was instituted to simplify and expedite the research grant process. Now the authority to award and administer grants is being delegated to each NASA field installation.

Procurement Processing.—In a step designed to streamline decision making, NASA established a Master Buy Plan procedure and a Simplified Procurement Plan procedure and began using them on a trial basis. The Master Buy Plan procedure is designed to enable management to focus its attention on a representative selection of high dollar value and sensitive procurement actions without compromising headquarters’ visibility or control over essential management functions. It is also intended to reduce the number of procurements requiring headquarters review and approval, permit better planning of workload and better use of personnel resources, shorten the procurement review and approval cycle, and increase the delegation of procurement responsibility and authority to each field installation. The Simplified Procurement Plan procedure will reduce the number of offices reviewing procurement plans, simplify and reduce the contents of plans, and reduce the review time in the acquisition cycle.

Unanticipated Research and Development Clause.—NASA developed a new contract clause to provide for prompt administrative resolution of problems caused by a substantial amount of unexpected R & D work under fixed-price contracts for non-R & D projects considered at contracting time to be reasonably within the state of the art. The clause is expected to help prevent delays, extra costs, and other adverse program impacts.

Labor Relations.—The number of man-days lost due to strikes on all NASA contracts in 1970 decreased from 4,427 in 1969 to 3,627 in 1970. Man-days lost due to strikes at Kennedy Space Center in 1970 were reduced from 337 in 1969 to 90 in 1970. Over half the man-days lost were attributable to strikes during negotiations of labor agreements. The remaining man-days lost were the result of unresolved grievances over

the presence of nonunion contractors and working rules. They were of short duration and involved a minimum of lost time. Strikes by construction craft unions in 1970 accounted for 2,767 of the 3,627 man-days lost on all contracts. The Labor Relations Office worked with Center management to eliminate or minimize the impact of labor problems on NASA programs, and as a result, labor problems did not interfere with program schedules.

Reliability and Quality Assurance.—NASA developed a microelectronics reliability program which, through the cooperation of the Department of Defense, is reflected in a military specification and accompanying standards for the acquisition of high reliability microcircuits. NASA cooperated with the Education and Training Institute of the American Society for Quality Control by participating in five seminars to further industry and Government understanding of NASA reliability and quality assurance programs.

Technology Utilization

The NASA Technology Utilization Program has as a primary goal the expeditious transfer of technology from NASA’s varied R & D programs to all sectors of the economy. To do this, the Technology Utilization Program seeks to identify and evaluate new technology and to actively assist in its transfer to other sectors.

New Technology Publications.—NASA continued its efforts to identify new technology resulting from ongoing R & D activities, selecting and reporting nearly 4,000 items this year. To facilitate the new technology identification process, prospective searching was emphasized. Over 700 “Tech Briefs” were published in 1970, and over 12,000 requests for backup material on the “Tech Briefs” and more than 7,000 requests for general information were received. Upward of 8,000 organizations routinely request “Tech Briefs”. Technology utilization reports and surveys published during the year covered such topics as hydrogen leak detection, materials in fire safety, teleoperator systems, and new high-strength metal alloys.

Regional Dissemination.—The Centers continued to provide scientific and technical information services based on the NASA technical data system to industrial, academic, and Government users. Technical data bases in such areas as chemistry, engineering, electronics, plastics, and metallurgy were expanded.

The Computer Software Management and Information Center (COSMIC) program was aided by the Regional Dissemination Centers, as was the distribution of earth photography from space flights. The Cen-

ters also cooperated with the Small Business Administration, the Department of Commerce, and several State and local governmental units.

Technology and Biomedical Applications Teams.—

A fourth Technology Applications Team was formed at a multidisciplinary research and consulting firm. This team is concentrating on transferring aerospace technology to urban planning and construction.

A fourth Biomedical Applications Team was created at the Stanford University Medical School in California. This and the other three teams continued to concentrate on seeking solutions to problems in clinical and medical research.

COSMIC.—The COSMIC continued to disseminate computer software from its expanding inventory of documented programs. The initial input of software developed under Department of Defense sponsorship was made this year. Announcement of software in the "Computer Program Abstracts"—a quarterly journal available through the Government Printing Office—and distribution through Regional Dissemination Centers contributed to the steadily increasing level of user interest and involvement.

Relationship 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 during the year: actions necessary to acquire new aeronautical facilities; on-going research in electronic components; development of data relay satellites; long term research leading to advanced aeronautical systems; areas where advance coordination and pooling of effort between NASA and DOD may be essential; current approaches used in funding the operation of R. & D. test facilities; air traffic control satellite issues; space transportation system status; and State Department views of international aeronautics and space cooperation.

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.

The military services continued to collaborate with NASA in assigning military personnel to NASA for 2- to 3-year tours. In addition, arrangements were made with the Air Force Systems Command (AFSC)

for a USAF Research Associate Program at Ames Research Center (ARC). The program provides for 3-year assignments of up to three Air Force officers who will work in research areas agreeable to ARC and AFSC. NASA also made an agreement with the Department of the Army for increasing the number of Army personnel assigned to NASA aeronautical centers for joint participation in aeronautical technology work.

Additional agreements concluded between NASA and other Federal agencies covered such activities as the NASA-Air Force Committee to coordinate the space transportation system; the use of the NASA Mississippi test facility for the Coast Guard National Data Buoy Program and the Bureau of Commercial Fisheries Marine Resources Assessment and Harvesting Program; Air Force support for the NASA YF-12 aircraft and Applications Technology Satellite Programs; AEC support to the Pioneer program; Navy tracking and transportation support; NASA-DOD operation of the White Sands Test Facility; Navy extension of the F-8C aircraft loan; GSA operation of the NASA Central Motion Picture Film Depository; and NASA support of FAA's information systems.

NASA and DOD continued joint studies on ways and means of achieving economies in manpower and other resources in common endeavors. As a result, the two agencies consolidated additional activities at the Kennedy Space Center and the Air Force Eastern Test Range. Action to consolidate NASA and Air Force tracking stations in Hawaii was deferred.

This office continued to coordinate special reviews by the Astronautics and Space Engineering Board and the National Academy of Sciences of NASA's Space Transportation System Development and Life Sciences Programs, respectively. It also assumed chairmanship of the White Sands Task Force group which identified additional uses of NASA's White Sands Test Facility, thus allowing the facility to be maintained at a moderate level of effort rather than reduced to a caretaker status in 1971.

Communications activities included NASA support of the Department of Commerce investigation of communications satellites for Alaska. This looks toward expansion of a NASA study on broadcast satellites conducted under the auspices of the Office of Telecommunications Policy; studies of the problems of aeronautical satellites in conjunction with the FAA, Department of Transportation, Office of Telecommunications Management, and National Aeronautics and Space Council. NASA also continued liaison with the Department of Health, Education, and Welfare in connection with the possible use of communications satellites in education.

Also coordinated was NASA assistance to the U.S. Bureau of Standards in studies to determine the impact on the Nation of the increasing use of the metric

system. As a result of this activity, NASA adopted a policy making the metric system the primary method of expressing measurements for the agency.

The NASA Safety Program

NASA continued to formalize and strengthen its system for the identification and control of hazards in space systems, aircraft operations, and facilities. New concepts in risk management and system safety were implemented and are being evaluated for effectiveness. A reorganization combining all elements of safety under one office increased the capability and effectiveness of the program.

Safety Management Approach.—A standardized safety contract clause was instituted as a firm requirement for all major contracts. This action makes contract safety requirements an agency position in contrast with the previous method of letting each Center set forth safety requirements in each contract awarded by the Center.

A scheduled safety review and evaluation of each major field installation was completed during the year. The results and recommendations for corrective action were sent to the appropriate field installation or headquarters office for resolution. The overall evaluation and review indicated a continuing improvement in safety practices at each installation and increased awareness of accident prevention through safety analysis and recognition of risk management techniques. The reviews have provided management with an appraisal of the safety efforts and highlighted areas for improvement and corrective action.

System Safety.—The System Safety approach, which includes identification and analysis of hazards, is stressed equally in manned and unmanned programs. Safety office personnel are colocated in all of the headquarters manned flight program offices, and a close working relationship is maintained with the unmanned programs. A training course in system safety technology was held at George Washington University and will be offered again in early 1971.

Industrial Safety.—NASA continued its reviews of each field installation in industrial accident prevention. Special emphasis was given to procurement plans to assure inclusion of the proper safety and fire protection requirements in plans and contracts, and to assure incorporation of proper safety and fire protection into the design and modification of NASA buildings and facilities. The Office of Facilities obtained funding for many safety and fire protection projects to correct existing deficiencies. The Safety Office cooperated in this effort by developing justification guidelines and priorities.

Fire protection seminars were held at two field centers to give supervisory and engineering personnel a better understanding of fire safety and its applications on NASA field installations. Four films on NASA fire safety program elements were provided to all field installations for orientation and training.

In a cooperative effort by the Manned Space Flight Tracking Network and the Goddard Space Flight Center's Health and Safety Engineering Office, a 5-week safety training course for instructors was held at GSFC's Network Training and Test Facility. Twenty contractor representatives, including at least one representative from each of the 15 MSFN stations, received broad safety training, and after return to their stations will train all other station personnel. All new employees for stations will be given this training at GSFC before assignment to tracking stations. The applicability of this program to the other tracking network is being investigated.

Aviation Safety.—Aviation Safety was expanded with the reorganization of the Safety Office, and the creation and filling of the position of Assistant Director for Aviation. The NASA Aviation Safety and Standardization Committee submitted a draft NASA Aircraft Operations Manual.

An aviation safety survey was made of each installation with aviation capabilities. Its purpose was to review and assess the effectiveness of aviation safety and accident prevention programs throughout NASA and to assist in developing NASA-wide standards for aviation operations. Safety programs have been improved, and NASA has had an aircraft flight accident-free year. Reports of the survey were sent to each installation, and a summary of observations and recommendations for all NASA segments was in preparation.

General Activities.—The 1970 NASA Safety and Risk Management Conference, held at Lewis Research Center in September, emphasized aviation and flight safety. Seventy NASA personnel in all safety disciplines and from all centers participated in a 2-day exchange of experiences, ideas, and new procedures in accident control, hazard identification, and risk management.

NASA sponsored a 2-day conference on "Materials for Improved Fire Safety" at Houston. A combined Government-industry review of NASA's technology developments that provide improved fire safety was presented for the 500 non-NASA people who attended. As a result of the conference, NASA has been asked to assist the International Association of Fire Fighters to design a universal fire suit and to assist both a major airline and the USAF in installing a noncombustible interior on one of their aircraft.

Action was taken to expand the Awareness Program to activities at all NASA Centers and their contractors

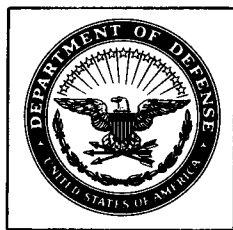
to reduce human errors. The "Awareness" newsletter format was changed to reflect the agency's continuing concern with both safety and the morale of the Space Team. An Advisory Panel, comprised of agency and industry motivation representatives, began to identify mutual problems and take cooperative remedial actions. A program designed to call attention to the importance of Apollo 14 to the future of the Space Team was initiated and will be carried through to completion of the mission. Special posters were prepared for the Flight Crew Medical Director and for the "ZERO IN on Federal Safety" campaign due to

begin January 1971. A number of Federal agencies have requested NASA permission to use these "ZERO IN" posters and arrangements have been made with the Department of Labor for printing and distribution throughout the Government.

A joint NASA-USAF Space Safety Escape, Rescue, and Recovery planning group was formed with the Assistant Director for Programs and Research Safety as a co-chairman with the representative of the USAF Space and Missile Systems Office.

The NASA Safety Office also participated in discussions concerning international rescue capabilities.

IV



Department of Defense

Introduction

The Department of Defense concluded 1970 with a growing list of achievements in space and aeronautics. During the year, the space efforts of the DOD encompassed communications, nuclear detection, navigation, geophysics, solar radiation monitoring, and efforts in numerous areas of space technology. Testing of terminal equipment and the development of operational procedures, doctrine, and multiple access techniques advanced satellite communications capabilities. The sixth pair of Vela nuclear detection satellites were successfully launched from Cape Kennedy by a Titan IIIC space booster on April 8. These spacecraft provide an extended capability to view surface and low altitude detonations while still maintaining a constant monitoring of deep space. Continued operational use was made of the Transit navigation satellite system. An improved satellite (SOLRAD) for monitoring electromagnetic and particle emissions from the sun was prepared for launch. Data from a SOLRAD satellite in orbit since 1968 was monitored throughout 1970 and passed to other users in support of military communications operations and research, scientific research efforts, and the Apollo program.

During 1970, significant progress was made toward fulfilling the country's need for modern military aircraft. Engineering development of the advanced carrier-based fighter (F-14) produced a test version which has made its first flight. The new engine for an improved tactical antisubmarine warfare aircraft (S-3A) was readied for in-flight evaluation. Fabrica-

tion of evaluation models of key avionics systems began, and early in 1970 a highly successful mockup review of the aircraft was held. Continued development of carrier-based aircraft with sophisticated electronic warfare capabilities (EA-6B) and with the capability of an improved airborne early warning system (E-2C) is leading to an improved readiness of the fleet to operate in any warfare environment. Many hours of operational flight experience during 1970 by Marine Corps pilots utilizing British Harrier (AV-8A) close-support aircraft has laid the essential groundwork for systematically adding this aircraft and the V/STOL concept of operations to our fleet capability during the upcoming year. The Air Force's F-15 successfully completed its aircraft preliminary design review in September and is proceeding on schedule. The F-15 will be a twin-engine fighter optimized for air superiority. Contracts were awarded in June for development of a new Air Force bomber, the B-1. This aircraft will take advantage of the many advances that have been made in airframe and engine technology during the past few years. The Air Force completed a feasibility demonstration of the radar techniques to be employed on the AWACS aircraft. That aircraft will provide command and control for interceptor forces as well as sustaining air operations such as counterair interdiction, close air support, rescue, airlift, etc. Recent flight tests of the Army's Cheyenne helicopter have shown none of the technical problems that plagued earlier development efforts. In firing tests all Cheyenne weapons subsystems have demonstrated excellent accuracy.

Space Activities

DOD Communications Satellite Program.—The DOD communications satellite program is currently divided into two broad categories, long distance and tactical. The long distance systems are characterized by communications involving a controlled network and are an integral part of the Defense Communications System. Tactical satellite communications networks provide multiple access service to many small terminal users such as airplanes, ships, and mobile land vehicles operating in a relatively undisciplined communications environment.

Defense Satellite Communications System.—The long distance satellite communications capability is provided by the Defense Satellite Communications System (DSCS). The mission of the DSCS is to provide secure communications in support of critical command, control, intelligence, warning, presidential, and other special user requirements.

Phase I of the program, the Initial Defense Satellite Communications System, has continued to perform satisfactorily during the past year. The Phase I DSCS now consists of 23 operational satellites and 29 earth terminals. Phase I DSCS satellites have a low power capability and limited bandwidth and operate in near synchronous orbits. They are designed for automatic turnoff during the time frame 1972-74.

Operational use of the Phase I DSCS continues to satisfy unique and vital communications requirements in accordance with the DSCS mission. One of these requirements being provided by the Phase I DSCS is the transmission of high resolution photographs.

Acquisition of Phase II of the DSCS, an improvement of the initial system, has proceeded satisfactorily during the past year. This effort was started in early 1969 with the award of a contract for procurement of six high-power geostationary satellites equipped with both earth coverage and steerable narrow beam antennas. The initial launch of two satellites, on a Titan IIIC space booster, is scheduled for mid-1971. The Phase II satellites will have significantly higher power and bandwidth capability permitting the provision of many additional channels of communications. Further improvement in satellite communications service will result from positioning Phase II satellites in synchronous equatorial orbit. The Phase I terminals will be modified to capitalize on the greatly increased capability of the Phase II satellites. Improved terminal performance and the full-time availability of a synchronous satellite will provide significant improvement in satellite communications service.

New Phase II ground and shipboard terminals including more efficient modulation equipment are now being developed by the Army and the Navy respec-

tively. The new terminals will be much more reliable and have large communications capacity.

The numbers of Phase II satellites and new terminals to be initially deployed are now being studied. Other Government agencies and certain allied governments will also be provided service through the Phase II satellites using their own earth terminals.

Tactical Satellite Communication Program.—The initial phase of this experimental program was to investigate the use of spaceborne communication repeaters to satisfy selected communication needs of our mobile forces. The effort involved the Lincoln Experimental Satellite No. 6 (LES-6), the TACSAT I satellite, and 65 terminals installed in aircraft, jeeps, trucks, ships, and submarines. Operational testing will continue. The data obtained during the test program is being analyzed to determine the design of future operational systems. The orbital performance of LES-6 and TACSAT I has been satisfactory. LES-6 is located over the mid-Atlantic in a geostationary orbit. TACSAT I is being moved to a new position. At these locations, communication links with the CONUS and overseas locations are being established.

International Cooperation.—The United States has negotiated agreements with the United Kingdom and NATO whereby we will develop, procure, and launch advanced communications satellites for their use. Two satellites each were procured on a reimbursement basis for the United Kingdom and NATO. The spacecraft are nearly identical except that the NATO version has a squinted antenna to focus more output power in the NATO area of interest while the United Kingdom satellites have full earth coverage antennas to provide service from the United Kingdom as far away as Singapore. Both satellite systems are useable with the DSCS and, if required, the United States, United Kingdom, and NATO could supplement each other's individual capability.

The first United Kingdom SKYNET satellite was launched late in 1969. Tests have been conducted since that time aimed at the operational implementation of the full SKYNET space and ground system. The second SKYNET satellite was launched in August 1970, but failed to achieve orbit. A new Memorandum of Understanding covering the implementation of the next generation SKYNET II system was signed by the United States and the United Kingdom in April 1970. Under this Memorandum of Understanding the follow-on satellites will be 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 1972.

The first NATO communications satellite was successfully launched by the United States in March 1970. The NATO ground system is being produced and the

initial system operation is expected early in 1971. The second NATO satellite is due to be launched early in 1971. Planning is proceeding within NATO on a follow-on satellite communication program which will be required by 1975.

The DOD continued its participation in the North Atlantic Treaty Organization's cooperative tactical satellite communications test program, using the synchronous LES-6 satellite and a network of small, tactical terminals built and operated by the program participants Belgium, Canada, the Federal Republic of Germany, Italy, the Netherlands, Norway, the United Kingdom, the United States, and the Technical Centre, Supreme Headquarters, Allied Powers Europe.

Spaceborne Nuclear Detection (Vela).—Two new Vela satellites were launched by means of a Titan IIIC launch vehicle into circular orbits at approximately 18 earth radii in April of 1970. The new Vela satellites were the sixth pair in a series that began in 1963 and included launches in 1964, 1965, 1967, and 1969.

The Vela satellite program is a joint responsibility of the Department of Defense and the Atomic Energy Commission and is managed by the Advanced Research Projects Agency (ARPA). The purpose of the program is to demonstrate the feasibility of using satellite-borne sensors to detect nuclear explosions in the atmosphere and in space.

Vela satellites also carry sensors that monitor the radiation background at their altitudes. Data on the radiation background is used by Department of Defense and civilian meteorologists in preparing space radiation forecasts; NASA has used the data during Apollo flights.

Titan III Space Booster.—The Titan III family of launch vehicles continues to be used extensively for DOD payloads. A common buy of the Titan III B, C, and D configuration vehicles, made this year, included for the first time three vehicles for NASA use in launching their future application and scientific satellites. To date 48 Titan III launches have been made, 25 vehicles are now in production and 22 additional vehicles have been approved for follow-on production.

Geodetic Satellites.—DOD completed the observational phase of the DOD Geodetic Satellite Program during 1970. Data reduction and the integration of the results obtained from the four systems used in the program, i.e. the BC-4 Camera, the PC-1,000 Camera system, and the SECOR and Doppler systems, are planned for completion by June 1972. The goal of the DOD Geodetic Satellite Program is to define more precisely the earth's size, shape, and gravity field, in addition to providing geodetic positions for points on the earth's surface. DOD has phased out the BC-4 Camera system, the PC-1,000 Camera system, and the SECOR

electronic system. The Doppler system, using the Navy navigational satellites as well as geodetic doppler satellites, has been selected as the single system for continued DOD efforts in the geodetic satellite area. Geodetic satellite activities will be directed toward meeting special requirements for worldwide geodetic positioning and for additional defining and verifying of the results obtained to date. In 1970, the Air Force continued the South American geodetic net densification program in support of mapping and charting efforts in South America. The Army Corps of Engineers completed the remainder of the SECOR equatorial network in 1970. The observational data is now being reduced and analyzed. The PAGEOS program utilizing the BC-4 Camera system was also completed in 1970 and data reduction and analysis is now underway. DOD efforts in the geodetic satellite area will be directed to specific positioning requirements using the commercial type geodetic receiver doppler system (Geoceivers) now available and in use. A joint Army and Marine test program using Navy developed doppler backpack ground equipment was initiated during 1970 to continue the investigation of the potential application of satellite systems to tactical positioning requirements of the services. During 1970 the Navy Doppler Tracking Network (TRANET) tracked the Transit satellites from 13 permanent stations and 8 mobile vans to improve the earth's gravity model and center of mass coordinates. The satellite geodesy program has now determined the harmonic coefficients of the gravity model to the equivalent of the 14th degree and order and selected higher terms. In addition, the positions of nine global sites were determined this past year.

Navigation Satellite Activity.—The Navy navigation satellite system (Transit), which became fully operational in 1968, continued its operation during the year in support of the fleet. In addition, studies and limited experiments have been conducted to help define the next generation of defense navigation satellite system. Initial results indicate that a precision, three-dimension spaceborne position-fixing and navigation system should be feasible. Application analysis and cost effectiveness studies will continue before a decision is made on the next generation navigation satellite system.

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 avail-

able to any Government user who may require its support.

Eastern Test Range.—During the past year the Eastern Test Range (ETR) continued its resizing to a posture for support of the primary DOD mission workload. As a result of this action the ETR is expected to evolve into a modest, but modern and efficient ballistic missile and space launch support facility capable of expansion if necessary. Support to other agencies such as NASA continues, but all additive costs to the ETR (those costs over the costs of supporting the primary DOD mission workload) in providing this support are reimbursable.

A joint DOD and NASA study concerning consolidation of common support services at the ETR and the NASA Kennedy Space Center (KSC) was also conducted during the year. As a result, actions are currently underway at the ETR and KSC to consolidate eight support services by fiscal year 1972. Five services will be consolidated under KSC and three under the ETR. After implementation, this consolidation is expected to save the Government over \$1 million per year in the operation of these two facilities.

Western Test Range.—In April 1970 the Air Force organized the Space and Missile Test Center (SAMTEC). SAMTEC operates the Western Test Range and the Aerospace Test Wing launch organizations at both Patrick AFB, Fla., and Vandenberg AFB, Calif.

During 1970 several changes were made to SAMTEC's range capability. The range instrumentation ship fleet has continued to be reduced with the transfer of the one remaining Apollo ship, the USNS *Vanguard*, to full NASA control. The range has developed a new instrumented site in the Pacific for terminal support. During 1970, the Broad Ocean Scoring System (BOSS) installed on the range ship USNS *Watertown* was used for the first time. Under the redistribution of resources made available because of the cancellation of the Manned Orbiting Laboratory Program (MOL) the range acquired the MOL computerized aerospace ground equipment. This system used to display vehicle telemetry data during prelaunch and launch phases, is being phased into operation and will replace similar leased equipment.

Satellite Control Facility.—During 1970 satellite support activities showed no marked change from previous years. There were no major facility constructions at any of the stations. The Space Ground Link Subsystem and Univac 1230 computer installation was made at the Indian Ocean station, Seychelles Islands, thus completing the upgrading of all network stations. A major procurement action was initiated for three 46-foot antennas to replace the 14-foot antennas at the New Hampshire Station, Hawaii Tracking Station and

Vandenberg Tracking Station. Study and analysis continues in order to improve the reliability and responsiveness of the overall systems.

Aeronautics Activities

C-5 Heavy Logistics Transport Aircraft.—The C-5A is the product of a successful development and procurement program that has extended over several years. It will provide for the first time a capability to deploy 100 percent of the Army's outsize combat equipment by air. Because of its large payload capacity and unique flotation characteristic, the C-5A is capable of rapidly airlifting large quantities of equipment and combat personnel to meet worldwide contingencies.

The research, development, test, and evaluation phase of the C-5A program is nearing completion. Major static structural testing should be completed in May 1971 and flight demonstrations of 100 percent structural integrity will follow. Aircraft participating in the flight test program have accumulated over 5,132 hours of flying time as of October 31, 1970. Contractor and Air Force flight testing is scheduled for completion by the end of calendar year 1971 and using command operational suitability testing is already well underway.

Results of the flight test program indicate that the C-5A will meet or exceed all operational requirements. It has flown at a maximum gross takeoff weight of almost 400 tons—a world record, 17 tons in excess of its designed maximum takeoff weight. In addition, the C-5A has achieved a maximum speed of 0.89 Mach, a maximum altitude of 40,200 feet, a flight duration of 21 hours and has landed in less than 1,300 feet.

The first of six C-5A's was delivered to the MAC Transition Training Unit at Altus AFB on December 17, 1969. A total of 10 additional aircraft, delivered to operational units at Charleston AFB and Travis AFB are now flying regularly scheduled channel traffic missions to the Pacific and European theaters. Deliveries to operational units are scheduled to continue at a two-per-month rate and the last of the total planned procurement of 81 C-5A's will be delivered in February 1973.

The total cost of the C-5A program is currently estimated at \$4.6 billion, including the cost of research and development, support equipment, and initial spares.

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

All F-111A's have been delivered. Production delivery of F-111E and FB-111 aircraft will be completed during 1971. Contractor and Air Force test efforts at Fort Worth, Tex., Eglin AFB, Fla. and Edwards AFB, Calif., are continuing in those areas which normally proceed throughout the production delivery phase. The bulk of this continuing work is in the areas of weapons clearances, static, and fatigue testing and performance parameters for altitude and airspeed.

Since the development and testing of the airframe and the airplane's general subsystems are essentially complete, development of advanced U.S. models of the F-111 has concentrated largely on the avionics system. The F-111D model which incorporates the expensive and more advanced Mark II avionics package is in production with delivery of the first aircraft scheduled for mid-1971. A less expensive and less advanced avionics system is being designed into the F-111F. This mission design series will not have the Mark II attack radar and integrated displays but will retain the Mark II inertial navigation set and digital computer system. In addition, the F-111F aircraft will have an improved propulsion system, utilizing new higher thrust TF-30-P-100 engines.

An F-111 accident in December 1969 resulted in the establishment of an extensive inspection program and a cold proof test of the airframe. This effort is proceeding as planned and a great deal of progress has been made. Considerable experience has been gained in the nondestructive inspection of critical parts and the cold proof test of the aircraft. Although some parts have been found to be in need of rework because of welding flaws and surface discontinuities due to tool marks, grinder burns, and corrosion pitting, no forging defects similar to the one which caused the December 1969 accident have been found. The first aircraft to complete the inspection program was returned to the using command in July 1970. Program completion is scheduled in July 1971.

The Tactical Air Command has resumed extensive combat crew training and operational mission qualification at Nellis AFB, Nev. The first deployment of F-111E aircraft to USAFE occurred in September 1970. Delivery of FB-111 aircraft to SAC at Carswell AFB, Tex., for use in the Combat Crew Training Wing was also resumed.

The first F-111C was accepted in September 1968. Subsequent acceptances were delayed because of modification work but are now anticipated after the modifications are satisfactorily completed.

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 con-

trol 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. The development is on schedule. First flight of the F-14A occurred on December 21, 1970.

Engineering development of an advanced technology engine, sponsored jointly by the Navy and Air Force, was initiated early in 1970. This program will provide a very high thrust-to-weight ratio engine for the F-14B. The F-14B with its significantly improved performance will be capable of countering the predicted threats in the late 1970's and early 1980's.

F-15 Advanced Tactical Fighter.—The F-15 is a new twin-engine single place Air Force fighter, optimized for air superiority and designed to replace the F-4E as the Air Force's first line fighter in the mid-1970s. Air superiority design features emphasized in the F-15 include outstanding turn, climb, and acceleration characteristics and outstanding pilot visibility. The airframe development contract was awarded on December 31, 1969, after a 1-year contract definition competition among vying contractors. In March 1970 a contract was awarded for development of engines for both the F-15 and the Navy F-14B fighters. A contract for the F-15 radar was also awarded in September. The F-15 program is proceeding on schedule and successfully completed the first major review milestone in September 1970 which was the aircraft preliminary design review.

A-7 Attack Aircraft.—The joint Air Force-Navy development program has resulted in the operational deployment of the versatile A-7 light attack aircraft. Navy A7E's were employed in combat just 18 months after the first flight of the aircraft. Its performance in combat amply demonstrated the flexibility and capability that were design requirements. The Air Force A7D is being delivered to the Tactical Air Command, having completed the basic contractor and Air Force test programs with marked success. Pilot training is being conducted at Luke Air Force Base, and the first operational squadron at Myrtle Beach Air Force Base will soon reach a combat-ready status.

B-1 Bomber.—Engineering development of the basic B-1 airframe and engine was begun after contract award on June 5, 1970. The first development test is presently scheduled for late calendar year 1974. This date is subject to change if the planned funding profile is changed.

No production decision has been made. The present pace of the development program, however, is such as to permit achieving an initial operational capability in the late 1970's, if so desired.

Detailed design of the airframe and engine is now underway and has produced some configuration changes, particularly in the empennage and wing root areas. Cost versus performance tradeoffs have resulted in some modifications in the initial design concept without sacrifice of any significant performance characteristics.

The major improvements provided by the B-1 as compared to the characteristics of the B-52 are: greater low-level penetration speed; greater range vs. payload; reduced radar cross section and infrared signature; and an ability to operate from relatively short runways thereby permitting greater dispersal capability.

Carrier-Based Anti-Submarine Warfare Aircraft (S-3A).—The engineering development of the S-3A continued throughout 1970. The full system mockup review was held on schedule in March 1970. The TF-34 high bypass engine which is being designed specifically for the S-3A completed 4,000 hours of running time on the ground and is now ready in flight tests mounted on an engine test bed aircraft. Through the use of advanced ASW sensors and a digital computer, the S-3A will be able to provide significant improvement over the S-2 capability in searching large areas of the ocean, detecting modern nuclear submarines and in localizing and destroying submarines. Avionics subsystems including MAD, radar, and an infrared classification device progressed according to the planned development schedule with the fabrication of models for evaluation. The S-3A, with a four man crew, will operate in the 400-knot speed range at altitudes over 30,000 feet en route to operating areas and still be able to operate economically at the lower altitudes required during certain phases of antisubmarine operations.

E-2C Development.—The E-2C aircraft will provide carrier based airborne early warning (AEW) for air defense of the fleet and command and control of Navy aircraft in air-to-air combat, air-to-surface strikes, search and rescue operations, and general air traffic control.

Continued development and procurement of the E-2C, which is the latest of the E-2 family of AEW systems, will result in increased operational reliability and availability, improved radar performance (including an additional operational capability over and near land), and will alleviate quantitative AEW aircraft shortages.

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. The

development is proceeding on schedule. Operational type testing conducted in 1970 has been very successful.

A-X Aircraft.—The Air Force is initiating development of the A-X, a new close air support aircraft optimized for effective support of friendly ground forces. The conceptual A-X, a single-place twin-engine aircraft providing STOL characteristics and excellent maneuverability, emphasizes long loiter, large payloads, and ease of maintenance. A Development Concept Paper was approved by the Deputy Secretary of Defense in April 1970 and request for proposals released to industry in May 1970. Six proposals, submitted in August 1970, have been evaluated and two contractors have been selected to build two prototype aircraft each for a competitive flyoff phase leading to the selection of the final contractor for full development and production.

Airborne Warning and Control System (AWACS).—In 1967 the Air Force completed the Overland Radar Technology program which demonstrated feasibility of the proposed radar techniques for AWACS. The Air Force completed a long lead radar component program in 1970 and recently selected a contractor for the AWACS program.

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

Helicopter Research.—Army has continued research to improve rotor craft capabilities. Progress has been made in providing rotor wing technology for future engineering development and in providing technology for specific helicopter concepts. A better understanding of the fundamental boundary layer flow over rotor blades has contributed to obtaining improved performance and control of helicopters. Advances have been made in basic air foil shapes that have provided new insight into the aerodynamics of rotor blades; the results permit improved payload performance. Contributions have also been made to the understanding of the rotor dynamics and control of hingeless rotor systems.

On specific concepts, progress has been made in a compound helicopter research program. Various configurations were flight tested including teetering, servo-flap hingeless and flapping main rotors in conjunction with lifting wings and auxiliary power sources. Maximum speeds of 185 to 236 knots were demonstrated. Vibrational levels lower than those of conventional helicopters operating at the same air speeds were noted. The results showed that increased air speed and payload capabilities are possible with insignificant increases in vibration levels.

The Advance Research Projects Agency's Quiet Helicopter Program, which is under the technical direction of the Army, continues to make very satisfactory progress. The first phase of the program was completed early in 1970 and all technical objectives were either attained or exceeded.

The second and final phase of the Quiet Helicopter Program is in progress and is scheduled for completion early in 1971. It is expected that the noise level of the test vehicle, the OH-6 helicopter, will be reduced to less than 10 percent of its original level.

Heavy Lift Helicopter (HLH).—The Army is initiating a development program of full size critical helicopter components using competing concepts to establish a technology and cost base for future HLH aircraft. Typical components which might be selected for development include large rotors, propulsion and transmission drive systems, flight control systems, and load handling devices. The HLH is envisioned as a 110,000-pound gross weight tactical and logistics helicopter with a sea level payload capability of 22½ tons based on shipboard and standard C-5A pallet size loads. It would be able to transport virtually all of the Army and Marine tactical ground equipment. Recent test results using the largest available competing concepts in helicopters and standard military sea and ground vehicles confirmed the feasibility of using helicopters to unload large shipboard loads under adverse sea state during both day and night at a high productivity rate.

A Development Concept Paper was approved by the Deputy Secretary of Defense in September 1970 and requests for quotations were issued on November 14, 1970.

AH-56A Cheyenne.—The Cheyenne helicopter development program is nearing completion of the contractor phase of testing. Aimed at the Army's requirement for an advanced attack helicopter to seek out and destroy enemy armor by day, night or in adverse weather, the Cheyenne now offers great promise of fulfilling those objectives. In recent firing tests all Cheyenne weapons subsystems have demonstrated excellent accuracy. In flight tests its improved rotor control system has shown none of the technical problems

which plagued earlier development efforts. The night vision system, while not yet flight tested, has demonstrated very sharp picture quality. Within the coming year the Army expects to be able to make a Cheyenne production recommendation based on successful demonstrated performance and cost-effectiveness.

AV-8A Harrier.—The Harrier is a single-seat, single fan jet transonic aircraft, manufactured in the United Kingdom. It is the operational version of the P-1127 Kestrel which was funded, developed, and evaluated by the United States, United Kingdom, and Federal Republic of Germany. The Royal Air Force has equipped two operating squadrons with the Harrier, and the U.S. Marine Corps and U.S. Air Force are actively participating in the British operational employment to take full advantage of their experience. During 1970 flight experience with Harrier passed the 7,000 hour mark. The U.S. Marine Corps will receive 12 AV-8A Harrier V/STOL aircraft commencing in 1971, for use in the close air support role. During 1970 detailed plans were formulated for a Navy-Marine Corps large scale investigation into the concept of V/STOL operations, and this investigation will commence in September 1971 utilizing the Harrier.

CX-84.—The Canadian Government was originally planning to fabricate and flight test three CX-84, tilt-wing aircraft. Flight testing was to be followed by military operational suitability testing. A shortage of program funds has forced the Canadians to reduce the program scope and they now plan to test and evaluate only one aircraft. This aircraft has been under contractor testing since its maiden flight in February 1970. Contractor testing will be completed in October 1971, and the Government operational suitability trials that follow will be completed in March 1972. The Army is monitoring the program.

Supporting Research and Technology

Continental United States Over-the-Horizon Radar System (CONUS OTH).—During 1970, the Air Force initiated program contract definition activities aimed at defining a CONUS OTH backscatter radar system for future development and deployment. This planned system will provide surveillance, detection, and early warning of a manned bomber attack against the CONUS. The radar system promises a significant increase in range and low altitude coverage in comparison to our present line-of-sight radar systems.

Advanced Liquid Rocket Technology.—In 1970, Air Force development of liquid rocket engine technology continued with emphasis upon demonstration of component performance critical to development of an

engine for reusable space launch vehicle application. Specific task objectives of this project were continuously coordinated with NASA through the joint Advanced Chemical Rocket Engine (ACRE) working group to assure proper phasing of technology development. In August 1970, the Air Force project was concluded successfully, and the technology phased into the NASA space shuttle engine development program. This accomplishment by the Air Force has been a keystone in the implementation of the 1969 Space Task Group proposals to initiate development of a national reusable space transportation system, and provides confidence that the propulsion objectives for development of a reusable space launch vehicle can be met.

Upper Atmosphere Investigation.—The U.S. Army Ballistic Research Laboratory has been analyzing the data obtained during rocket firings conducted during 1969. From firings made in Alaska, electron density profiles have been obtained for those parts of the rocket flights where the ray paths did not pass through the barium clouds. From the cooperative polar-cap absorption data, electron density profiles have been constructed for the frequency pair 36 and 144 MHz, preliminary electron currents have been determined from the Langmuir probe observations, and preliminary absorption and absorption rate values have been obtained for the frequency pair 9 and 18 MHz. These results will contribute to the understanding of events occurring when radars look toward the polar horizon or when communications pass to or from the polar regions such that the signal passes through that part of the atmosphere where the aurora and polar cap absorption occurs.

Space Object Identification.—During 1970, ARPA continued to measure physical characteristics of objects in earth orbit. These measurements include radiation signatures in both the visible and infrared regions of the spectrum. This program is carried out at the ARPA Maui Optical Station, on Mount Haleakala in Maui.

Solar Radiation Monitoring Satellite Program (SOLRAD).—The Navy's SOLRAD program is an excellent example of a space science effort which has provided high operational utility. SOLRAD IX, launched in 1968, is continuing solar radiation monitoring to broaden knowledge of the physics of the sun and the mechanism of emission of solar particle, ultra-violet and X-ray radiation. This knowledge, in turn, will lead to development of techniques for predicting solar-induced disturbances affecting some electronic and space systems operations. During 1970 preparation continued to orbit SOLRAD X in January 1971, to further develop equipment and techniques for space

environment monitoring while providing data for research, development, and operating efforts. During 1970 SOLRAD provided solar activity information in direct support of Apollo activities.

Telemetered data received at the Navy research laboratory acquisition facility is relayed to the SOLRAD Data Operations Center at NRL. Real-time analog and stored digital telemetry data are converted to flux values. Daily pass-by-pass and flare profile messages are transmitted via the USAF operated Solar Observing and Forecasting Network for use by the National Oceanic and Atmospheric Administration Space Disturbance Forecast Center at Boulder, Colo., and the USAF Solar Forecast Center at the NORAD Cheyenne Mountain Complex, Colo. Predictions of periods of solar activity, which are likely to cause ionospheric disturbances, are transmitted to the Naval Communications Command for use in the formulation of Navy alerts to all communicators.

Advanced Satellite Secondary Propulsion Systems.—In 1970 the Air Force initiated development of an electric colloid thruster which will operate in the high micropound and low millipound thrust range to perform satellite attitude control and station keeping functions. The colloid thruster will have a specific impulse which is at least four times higher than current state-of-the-art thrusters, and will be designed to operate in the pulse and steady state modes. Design and fabrication of colloid thruster critical components are underway for integrated test and evaluation. Subsequent development phases provide for the fabrication of a prototype thruster, life testing, and space flight to demonstrate performance and compatibility of this advanced concept thruster in a satellite system.

Spacecraft Technology and Advanced Reentry Tests (START).—The Air Force's current efforts in developing technology for maneuverable reentry spacecraft consists of the PILOT (PIloted LOw-speed Tests) program and the Space Transportation System (STS) studies. PILOT was instituted to provide aerodynamic and stability and control data from Mach 2.0 to horizontal landing. It is a follow-on to the PRIME program which provided flight data from reentry conditions to approximately Mach 2. A total of 18 flights of the X-24A PILOT vehicle from 40,000 to 47,000 feet launch altitudes have been completed successfully. Eight were powered flights with the XLR-11 rocket engine and a supersonic speed of 1.15 Mach was achieved on October 14, 1970. Flow separation and stability characteristics of the X-24A vehicle at supersonic speed and during low-speed maneuvering are being investigated. A total of 30 X-24A flights are scheduled to be completed by the end of fiscal year 1971. The STS studies were undertaken by the Air Force to evaluate the capability of various system con-

cepts, primarily developed under NASA Phase B studies, to meet Air Force mission requirements (payload, cross range, etc.). Follow-on studies and technology work in this area will depend on the results of the current space shuttle effort.

Space Experiments Support Program.—The Air Force Space Experiments Support Program (SESP) provides spaceflights for proof tests of advanced technology applicable to new military space systems and for DOD research and development experiments. In 1970, an Army spacecraft to test a tactical positioning system rode into orbit as a secondary payload on the NASA launch of a weather satellite. Contracts were let for three launches for 1971 to orbit eight technological payloads and seven scientific experiments expected to provide demonstrations and data that will contribute to new or improved DOD systems.

Advanced Space Power Supply Technology.—Mission analyses show that next generation military satellite systems will need larger, longer life power supplies to attain mission performance and reliability requirements. To meet these requirements development efforts are underway to increase the power level and lifetime capabilities of spacecraft solar arrays and rechargeable battery systems. In 1970, development of a flexible, rollup type solar cell array has continued with emphasis on fabrication of a qualification model for ground test. In parallel with this test, fabrication of a flight model is proceeding on schedule for demonstration of this high performance array on a Space Experiments Support Program flight vehicle in late 1971. Successful demonstration of this technology will enable a 50-percent reduction in weight and volume over current solar cell array power systems in the 500 watts to 20 kilowatt power range.

Advanced Turbine Engine Gas Generator (ATEGG).—The ATEGG program is an Air Force advanced development program in which advanced state-of-the-art turbine engine components are assembled into demonstrator engines and tested. It is based on the fact that individual component operation in an isolated rig test environment is not completely representative of that component's operation when integrated into a high-performance engine and used in widely varying operational conditions.

The latest component technology and engine design philosophy for future weapon systems are demonstrated in these turbine engine demonstrators to provide an advanced realistic performance base from which to plan future weapon systems.

Over the past year, four participating engine contractors have demonstrated advances in thrust-to-weight ratio, overall efficiencies, smaller combustors

and higher operating temperatures and pressure ratios. By including four participants, the Air Force achieves a secondary objective which is to maintain a broad, competitive industrial base from which to procure advanced engines for future weapon systems.

Advanced Propulsion Subsystem Integration (ASPI).—The ASPI program is an Air Force advanced development program for developing criteria, capability and techniques for integrating airframe and propulsion systems.

The goal of this program is to minimize engine-airframe interface problems. Starting with the forebody engine inlet and inlet interaction, all of the components through the engine and airframe back through the exhaust nozzle are analyzed.

The program has made significant contributions to the F-15 and B-1 system developments. As an example, one test effort in this program provided valuable data on airframe-inlet integration and inlet-engine interaction to each engine and airframe contractor involved in F-15 work. Efforts are also being conducted to improve the capability to correlate data between wind tunnel model testing and actual flight testing. Flight prediction techniques will be conducted during the same time period as the B-1 aircraft and engine development programs. This will provide a valuable tool in systems development and provide a data source for insuring the early resolution of integration problems.

This program also includes engine component development to adapt the advanced turbine engine gas generator cores to specific system requirements. Components in this program include a high tip-speed fan, composite material application to turbine engines, and a controlled output turbine for future turbine engines.

Turbine Engine Development.—The Army has conducted an advanced development program consisting of two 1,500 shaft horsepower demonstrator gas turbine engines to update helicopter propulsion system technology. Preliminary goals are 40 percent lower weight, 25 percent less fuel consumption, and significantly improved maintainability and reliability as compared to present day production engines.

The testing program to date has shown considerable promise of attaining these goals. Engineering development is planned to begin in fiscal year 1972.

Survivable Flight Control System Development Program (SFCS).—The SFCS advanced development program was initiated by the Air Force Flight Dynamics Laboratory (AFFDL) in July 1969 with the award of a contract to an industrial contractor. The objective of this program is to develop technology to increase the tactical survivability of future aircraft through reduction in vulnerability of present complex hydro-

mechanical flight control systems. This program will demonstrate by flight tests the principles of component separation, redundancy, and hardening as they are applied to the aircraft primary flight control system through use of an all-electronic control system and integrated hydraulic servo-actuator package techniques. This system will decrease vulnerability of the control linkages from the pilot's control stick to the surface actuators, and the integrated servo-actuator package will decrease vulnerability of the power source to 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.

In the flight tests the actuator exceeded performance expectations appreciably beyond the required emergency flight envelope. Flights have included speeds up to Mach 1.6 and 5g windup maneuvers.

Demonstration of this unit represents a significant step in the development of the complete fly-by-electrical-wire control system. Contracts for the complete control system have been awarded, and laboratory testing of the system is scheduled for November of 1971 with flight tests to begin early in 1972.

Seek Storm.—Project Seek Storm was established to provide an improved Air Force severe weather (hurricane, typhoon, extra tropical storm) reconnaissance capability. The project is designed to develop an improved weather radar which will provide military and civilian forecasters more precise intensity and location information on which to base storm path and strength predictions. The Air Force currently has two aircraft with experimental radar on board for hurricane reconnaissance. After sufficient data has been collected on radar characteristics, physical structure of storms, aircraft structural limitations, and potential antenna designs, the final development design of a new radar will begin in fiscal year 1972.

Medical Projects.—The Naval Aerospace Medical Institute at Pensacola, Fla., continued to conduct space-related medical tasks which includes: preflight aspects of long duration weightless flights with primates; hazards of proton radiation; techniques of in-flight electrocardiography; and effects of gravitational forces, inertial forces, and extended weightlessness upon man with particular emphasis on his vestibular system.

The School of Aerospace Medicine, San Antonio, Tex., has been studying the problems of the closed environment in terms of habitable atmospheres (carbon

dioxide levels and partial pressures of oxygen) and in terms of the acute and chronic toxicological effects of trace contaminants.

Fluidics.—Application of fluidic technology to aeronautics was continued in several areas. Successful flight tests of a three-axis stability augmentation system (SAS) were accomplished on a UH-1 helicopter. An improved model of the fluidic turbine inlet temperature sensor was successfully tested in a T55 gas turbine engine. An application of fluidic devices to jet flaps on low-speed aircraft is being investigated at the Ames Research Center. In addition, the Army's Harry Diamond Laboratories is assigned a NASA effort to develop a fluidic shock wave control sensor. The device will sense and control the position of the shock wave in supersonic inlets on high-speed aircraft.

Relationship With Other Government Agencies

The Department of Defense continued close coordination and cooperation with other Government activities. There are presently six military officers assigned to the National Aeronautics and Space Council in the Executive Office of the President (three Air Force, two Navy, and one Army) and 208 military personnel assigned to NASA (131 Air Force, 24 Navy, 50 Army, and three Marine Corps). Described below are examples of types of cooperation and coordination.

Aeronautics and Astronautics Coordinating Board (AACB).—The AACB continues as the principal formal coordinating mechanism between DOD and NASA in the space and aeronautics areas. While a number of problems were considered by the Board, emphasis was placed on the Space Transportation System activity and on future large aeronautical facilities. The Board examined broadly the progress on the NASA Space Shuttle, the projected DOD use for the Shuttle, including considerations of possible impact on Shuttle design, and the interrelationship between the current launch vehicle families, their growth versions and the Space Shuttle launch program. In the area of large aeronautical facilities to meet future national needs, the Board determined that the large engine test facility and the large scale V/STOL wind tunnel were of highest priority and supported a limited effort to firm up facility designs. The Board will review the results of such study efforts prior to any decision to acquire such facilities.

Lunar and Planetary Activities.—The Corps of Engineers continued to assist NASA with large scale lunar topographic maps of scientific sites, photomaps, and landmark graphics for use in the Apollo program. Con-

struction of a 1:2,000 scale relief model for Astronaut training for Apollo 13 was completed, and was used in the training simulator at the Manned Spacecraft Center in Houston, Texas. An investigation of the potential of automated photogrammetric equipment to reduce Lunar Orbiter photography more effectively and accurately than by present methods was completed. The Corps of Engineers continues to provide professional counsel and other technical assistance in support of extraterrestrial research.

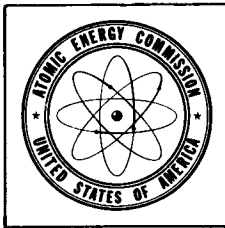
Construction Support.—The U.S. Army Corps of Engineers continued to provide construction support of NASA at a reduced level during 1970. The work was accomplished on a reimbursable basis primarily at the Kennedy Space Center at a cost of \$15 million. Cumulatively since 1961, the support provided totals \$1.2 billion.

Aerospace Feeding Systems.—A sixth flexible-packaged, thermally processed, eat-with-a-spoon product—

meat balls and tomato sauce—was developed by the U.S. Army Natick Laboratories and used aboard Apollo 13. Five such items were developed earlier and used on previous Apollo flights. Flexibly packaged peanut butter and jelly, originally developed for a combat meal, were also used on Apollo 13. Storage tests for retention of nutritional quality and periodic evaluations for texture and flavor are in progress on a variety of dehydrated foods used aboard the different space flights. Exploratory studies during the past year have indicated the feasibility of heating prepackaged foods by microwave energy and simulated space flight conditions.

Apollo.—During 1970 the Army, Navy, and Air Force continued to provide fundamental support to NASA which is essential for manned space flight activities. These support services included: recovery ships, aircraft, and personnel; assistance with communications; SOLRAD solar activity data; and other supplementary forces.

V



Atomic Energy Commission

Introduction

Effort continued during 1970 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.—The SNAP-19 and SNAP-27 radioisotope generators (RTG's) launched in 1969 both passed 1 year of continuous operation.

Disassembly of a flight type zirconium hydride reactor (S8DR) was completed after 7,000 hours of continuous testing.

Nuclear Rockets.—NERVA development activities concentrated on the definition and preliminary design of the flight rated NERVA engine.

A candidate fuel element for NERVA successfully completed 10 hours of electrical corrosion testing including 60 thermal cycles.

The Pewee-2 experimental reactor was fabricated and delivered for testing in early 1971.

Space Electric Power

Space Radioisotope Power Systems

SNAP-19 and SNAP-27.—Both the SNAP-27 and SNAP-19 systems which were launched during 1969 achieved 1 year of continuous operation during 1970. The SNAP-27 deployed on the moon in November 1969 has performed extremely well during its first year of operation and has been producing about 73 watts (higher than the mission requirement) since deployment on the moon. The stable operation of the SNAP-27 has enabled the ALSEP experiments to operate continuously during both the lunar day and lunar night and will allow for continued operation as long as the experiments themselves are functional. Important scientific data is being generated which will aid in understanding the structure, evolution, and history of the moon. An additional SNAP-27 unit was launched in 1970 aboard the Apollo 13 spacecraft but it returned to earth as a consequence of the subsequent aborting of that mission. Two units are scheduled for launch in 1971 with the Apollo 14 and 15 flights. An addi-

tional SNAP-27 has been ordered by NASA and it will be delivered in 1971. The SNAP-19 which provides supplementary power for the Nimbus spacecraft experiments is also performing well, though it has experienced some performance degradation because it is not a hermetically sealed unit.

Transit Generator.—Fabrication and testing of the 5-year life Transit generator for the Navy's advanced navigational satellite continued. The first complete electrically heated unit was fabricated and tested and will be delivered to the Navy for spacecraft integration efforts early in 1971. Fabrication of a nuclear fuel ground test unit was near completion—with testing scheduled to begin early in 1971. The Transit generator is the prime power source and will supply 30 watts of power to the Navy's advanced Transit navigational satellite.

Pioneer Generator.—The design of the modified SNAP-19 generator for application with NASA's Pioneer Jupiter probe missions was completed during 1970. Five electrically heated prototype generators were delivered to NASA and fabrication of four plutonium-238 fueled prototype generators for NASA spacecraft integration efforts was also near completion. These generators are scheduled for shipment early in 1971. Pioneer launches are scheduled in 1972 and 1973. Use of nuclear power on this mission reduces total power system weight and eliminates uncertainties concerning operation at extended distances from the sun which would be inherent with solar array systems. The reduced weight allows for including additional experiment packages which increases the total value of the mission.

Viking.—Early in 1970 the Viking program launch dates were deferred from 1973 to 1975. Consequently the Viking effort during this year was directed primarily towards spacecraft integration and study efforts using the SNAP-19 system.

Multi-Hundred Watt Generator Module.—Effort continued on development of a Multi-Hundred Watt (MHW) generator module which will form a basic building block for isotopic space power systems in the 100 to 1,000 electrical watt range. Specialized DOD satellites and NASA missions to the outer planets will require nuclear power systems and the projected power level requirements for these missions can be satisfied with the MHW system. Preliminary design studies were completed and fabrication of test components was initiated. The first converter should go on test in mid-1971. A fueled module demonstration is currently scheduled for the 1973-74 time period.

Isotope Brayton System.—NASA has given considerable emphasis to development of a plutonium-238 fueled radioisotope Brayton system for application in the electrical power range of a few kilowatts. The AEC has been pursuing the development of the fueled isotope capsule for application with this system. A nuclear safety feasibility study was conducted by the AEC with participation by both AEC and NASA laboratories.

Space Isotopic Fuel Development

Plutonium-238.—Plutonium-238 is currently the heat producing isotope being used or planned in all major space applications. Efforts continued towards development of improved cermet fuel forms and a plutonium molybdenum cermet fuel form was selected for use in the Pioneer, Transit, and Viking programs.

Curium-244.—A heat source loaded with Curium-244 successfully completed 1 year of test operation at the AEC's Oak Ridge National Laboratory. Curium-244 will be produced as a natural byproduct of the commercial reactors and has the potential of significantly reducing radioisotope fuel costs.

Space Reactor Power Systems

Zirconium-Hydride Reactor.—Disassembly of the second generation high power, high temperature uranium-zirconium hydride reactor (S8DR) was completed. Testing of the S8DR was begun in late 1968 and the reactor was shut down in late 1969 after about 7,000 hours of operation. Data collected during operation indicated that cracking of a number of fuel element claddings had occurred. Information obtained from the disassembly and detailed examination of this reactor is being incorporated into a planned core test which is to verify the adequacy of this reactor concept for long term (several years) operation. This test is currently scheduled to begin in 1973.

The zirconium-hydride reactor can be used with any of several conversion systems and the AEC is pursuing development of one of these: a compact thermoelectric conversion system. During 1970, thermal distortion of the thermoelectric converted module during operation was eliminated through the use of a refractory metal inner liner. The reactor-thermoelectric system will provide a power system of high reliability and simplicity from a few kilowatts up to around 35 kilowatts of electricity.

Thermionic Reactor.—A prime contractor was selected to continue the development of a thermionic fuel element and to construct an experimental reactor planned for operation in the mid-to-late 1970's. This reactor

will be based on use of fuel elements which convert heat to electricity within the reactor core and which must be capable of long endurance operation at extremely high temperatures. Program emphasis is currently directed toward demonstration of a full length thermionic fuel element. In-pile partial length fuel elements achieved 5,000 hours of operation during 1970 and out-of-pile electrically heated diodes achieved 25,000 hours of operation.

Nuclear Rocket Program

The nuclear rocket program is a joint endeavor of the AEC and NASA aimed at providing a significant increase in propulsion capability for future space activities. The major program objective is to develop a 75,000-pound-thrust engine, called NERVA (Nuclear Engine for Rocket Vehicle Application) for space flight missions. The program includes a variety of advanced and supporting research and technology activities in which the aims are to extend the technology needed to improve nuclear rocket performance and to investigate advanced propulsion concepts.

NERVA Engine Development.—During 1970, the NERVA engine system development activities were concentrated on the completion of engine systems engineering analyses, the preparation of engine system specifications, and the conduct of detailed engine design. The work on the engine system and its related non-nuclear components (turbopumps, valves, nozzle) is described in the NASA section of this report. Activities related to development of the engine nuclear subsystem (the reactor) are described here.

Nuclear Subsystem Development.—Reactor systems engineering activities conducted during the past year were directed toward the selection, test, and evaluation of candidate materials and the evaluation of alternate component designs for incorporation in the referenced reactor design. Selection of the reference reactor design was accomplished through the examination of technology reactor systems tested earlier in the nuclear rocket program. From the analyses of these systems and their test data and the results from the systems engineering studies, system and component specifications were prepared and detailed reactor design was initiated.

The activities denoted above describe the iterative process which was applied to all reactor hardware to insure that the best design approaches and engineering procedures were being utilized to define the design of the NERVA flight reactor subsystem. These activities are now rapidly converging on a major milestone: the NERVA reactor preliminary design review (PDR). The purpose of this review will be to formally examine every aspect of the work that has been performed and

to verify that the basic reactor design meets the performance and reliability requirements established for the NERVA engine system. Acceptance of the PDR results will be followed by the completion of the detailed design of reactor components and the fabrication of reactor hardware for development and qualification testing.

During the year, substantial progress was made on reactor fuel element research and development, the goals of which are to achieve a 10-hour operating duration and a recycling capability of up to 60 thermal cycles. As the nuclear fuel is the most critical part of the reactor subsystem, a rigorous fuel development program was pursued in several areas. The fuel element work is concentrated on two matrix materials: bead-loaded graphite and a graphite plus carbide composite. The former incorporates innovations in design and production processes reflecting the experience gained from laboratory evaluation and ground testing in prior reactors. The composite comprises a dispersion of the mixed carbide in a graphite matrix, which in laboratory studies to date has shown considerable promise for extended corrosion endurance under the cyclic operation required for the NERVA reactor. These composite fuel elements successfully completed 10 hours of electrical corrosion testing, including 60 thermal cycles. Fuel elements of both types were fabricated and a series of laboratory tests were conducted. Both types were fabricated for incorporation into a small experimental reactor called Pewee-2. The Pewee-2 reactor was assembled and shipped to the Nuclear Rocket Development Station for testing in early 1971. Performance data from this reactor will be used in making the selection of the optimum fuel element for the NERVA flight reactor series.

Advanced Research and Technology.—The program effort in advanced research and technology is directed toward improvement of the performance of nuclear rockets by increasing the operating time and operating temperature for solid-core reactors, and by investigation of advanced propulsion concepts. The major activities are the research, development, and laboratory evaluation of improved fuel elements and other special reactor materials, reactor fabrication and testing to evaluate both elements and reactor design features, and research and experimental effort in advanced fission and fusion propulsion concepts. This work is concentrated at the Agency's Los Alamos Scientific Laboratory in New Mexico.

In addition to the fuel element work described earlier, work also continued on the development of evaluation techniques for the composite and carbide fuel elements. The design of a nuclear furnace to be used for fuel element development and evaluation was completed, and fabrication of the parts for the first nuclear furnace test was initiated. Fabrication of the

hardware for the modification of Test Cell "C" to test the furnace was also initiated. The furnace provides a fuel-element test bed to explore and simulate the necessary operating conditions of time, temperature, and cycles that the fuel experiences in a reactor but which are difficult to simulate in the existing electrically heated corrosion test furnace. The first nuclear furnace (Nuclear Furnace 1) test is scheduled for 1971.

Efforts also continued during the year to improve reactors and core designs to optimize the use of solid solution carbides.

In the area of advanced propulsion, fundamental research was conducted on plasma arc and other advanced concepts. In plasma arc research, substantial progress was made in experimentally producing a specific impulse of approximately two to three times that achieved in solid core rockets.

Satellite-Based Detection of Nuclear Explosions in Space and the Atmosphere

The AEC-instrumented Vela satellite program continued in 1970 with the sixth and final launch in six attempts. The sixth launch of twin spacecraft, Vela

VB, was conducted by the Department of Defense on April 8, 1970, from Cape Kennedy, Fla., and utilized a Titan IIIC booster. The detector instrumentation on the 1970 satellites are performing well. The satellites are in near-circular orbits of approximately 65,000 nautical miles, comparable to the previously launched spacecraft. The complement of detectors on board includes those designed to record signals emanating from an atmospheric nuclear explosion and the X-rays, gamma rays, and neutrons generated by a high altitude or space nuclear explosion. The spacecraft on Launch I (1963), Launch II (1964), and Launch III (1965) were spin-stabilized while those on Launch IV (1967), Launch V (1969), and Launch VB are attitude-controlled to point continuously toward the earth which substantially increases the capability of the downward-looking detector systems.

In addition to performing their primary functions as "watchdogs" for possible nuclear testing in the atmosphere and in space, the Vela satellites have provided invaluable data to scientists on the nature of solar X-rays, the solar wind, and other astrological phenomena. The satellites have also assisted in the manned spaceflight program.

VI



Department of State

Introduction

The Department of State continued its efforts during 1970 to further the achievement of the objectives of the National Aeronautics and Space Act, particularly in terms of cooperation with other nations and groups of nations in the peaceful application of the results of aeronautical and space activities. Encouragement of greater international cooperation in space was an integral part of U.S. foreign policy and the conduct of our international relations during 1970.

Among the principal international developments in space affairs during 1970 were several new bilateral aeronautical and space cooperation agreements, discussions with foreign officials on participation in the post-Apollo program, expansion of possibilities for greater cooperation in space with the Soviet Union, further growth of international interest and cooperation in communication satellite systems, and increased interest in earth resources survey satellite programs.

Activities Within the United Nations.—The United Nations Committee on the Peaceful Uses of Outer Space and its Legal Subcommittee focused major efforts in 1970 on attempts to complete a draft convention on liability for damage caused by objects launched into outer space. The United States played an active role in these efforts as well as in the work of the Scientific and Technical Subcommittee and the Working Group on Direct Broadcast Satellites.

The Scientific and Technical Subcommittee meeting in April was marked by a cooperative approach to the promotion of the practical applications of space technology. Among proposals endorsed by the Subcommittee was a United States proposal that the new United Nations Expert on Space Applications assist in the creation of panels, including representatives from developing countries, to observe closely and report to the Outer Space Committee on such space application programs as the United States Earth Resources Survey program.

Meeting in May, the Working Group on Direct Broadcast Satellites considered further the social, cultural, legal, and other implications of satellite broadcasting. While agreeing on the promise of satellite broadcasting to contribute to economic, social, and cultural development in a context of international cooperation, the Working Group registered disagreement on the question of whether legal principles are needed to govern satellite broadcasting. The United States argued that adequate legal principles already exist in the Outer Space Treaty and other instruments.

In formal meetings and informal consultations during 1970, the Legal Subcommittee and the parent Outer Space Committee continued to seek agreement on provisions needed to complete the draft liability treaty. Agreement on the preamble and 13 articles was reached, but key questions on the settlement of disputed claims and the applicable law remained unresolved.

In January, at the invitation of the United States Ambassador to the United Nations, members of the Outer Space Committee and United Nations Secretariat officials visited NASA's Manned Spacecraft Center in Houston to hear briefings on NASA's Earth Resources Survey program and to view related facilities and equipment.

New Bilateral Agreements.—In March NASA signed an agreement with the Italian Space Commission (CNR) covering general arrangements for launching and associated services to be furnished by NASA to the Italian Space Commission for reimbursable launchings of Italian satellites on a case-by-case basis.

In May NASA and the Astronomical Netherlands Satellite (ANS) Program Authority concluded an agreement covering a cooperative project in which NASA will launch in 1974 or 1975 an astronomical satellite developed and constructed in The Netherlands which will explore stellar ultraviolet and X-ray radiations from a sun-synchronous orbit.

In November NASA and the British Science Research Council concluded an agreement for the launching of a fifth British scientific satellite by NASA in 1973 to study cosmic X-ray sources.

In December an existing agreement with Brazil for cooperative efforts on earth resources surveying experiments was being extended for an additional 2 years. This project, together with a similar cooperative effort with Mexico, has contributed valuable information to NASA's Earth Resources Survey program.

As the year closed, a new agreement was concluded with the Canadian Department of Industry, Trade, and Commerce for support of NASA sounding rockets and other scientific activities at the Churchill Research Range.

U.S.-Soviet Cooperation.—During 1970 the Department of State continued to support efforts to increase space cooperation with the Soviet Union. The most significant new development in 1970 was a meeting in Moscow in October in which Soviet and United States representatives discussed arrangements for compatible docking systems in future Soviet and NASA manned spacecraft. Agreement was reached on a series of further meetings and exchanges of technical information which could lead to compatible docking systems in future Soviet and NASA manned spaceflight programs.

Cooperative activities with the Soviet Union continued in the exchange of meteorological satellite data and aerospace biomedical information, and additional areas of possible cooperation are being explored.

Apollo Program Support.—During 1970 the Department of State and its overseas posts provided support for the Apollo 13 mission by arranging for basing of recovery forces at foreign installations and by coordinating offers of foreign assistance during the emergency return from the moon of the Apollo 13 astronauts. Cooperation on use of certain radio frequencies during the final phase of the Apollo 13 recovery operation was also sought and obtained from most nations in the world.

Post-Apollo.—Foreign interest in participation in NASA's post-Apollo program increased significantly during 1970. In September, the Chairman of the European Space Conference met with the Under Secretary for Political Affairs and other interested U.S. officials to discuss the political and economic aspects of possible European participation. The Department also supported NASA in obtaining European government assurances on protection of post-Apollo technical data that may be released by NASA.

Communications Satellites.—As stipulated in the Agreements of 1964 which created the International Telecommunications Satellite Consortium (Intelsat), the United States convened a conference in February 1969 to begin consideration of "definitive arrangements" for the global commercial communications system. The negotiations were continued by a Preparatory Committee which submitted its report to a resumed Plenipotentiary Conference in February 1970. The resumed Conference established an Intersessional Working Group to negotiate a single set of recommended texts of definitive arrangements. The United States served as host government for the Intersessional Working Group, which held three meetings (May, September, and November) in Washington and is expected to issue its report to a reconvened conference in 1971.

Intelsat added seven members in 1970, increasing its membership to 77 countries. Three Intelsat III satellites were launched in 1970, two of which were

successfully placed in orbit and have been serving the Atlantic Region. This has increased significantly the volume and variety of global telecommunication services that have been made available to all continents of the world. The next series of satellites, Intelsat IV, the first of which is scheduled for launch in 1971, will further increase the capacity of the global system.

The total number of full-time circuits using Intelsat satellites at the end of 1970 represents an increase of about 34 percent over those in use at the end of 1969. Television transmission hours, all temporary service, increased in 1970 about 26 percent over 1969. Because many transmissions were to multiple earth stations simultaneously, the number of receive hours indicates a larger increase of about 32 percent over 1969.

Worldwide usage of the Intelsat system will be stimulated even more by a decision of the Interim Communications Satellite Committee, the governing body of Intelsat, to reduce by 25 percent the charge for full-time leasing of an Intelsat circuit, effective January 1, 1971.

During 1970 a significant effort was put forth to develop United States proposals for consideration at the World Administrative Radio Conference for Space Telecommunications, which is being convened by the International Telecommunication Union, a specialized agency of the United Nations, in Geneva in June 1971. The Conference is expected to make far-reaching decisions on technical and regulatory aspects of space telecommunications and is expected to allocate, for the first time, frequency bands for the broadcasting satellite service.

Earth Resources Survey Satellite Program.—During 1970 the United States continued to distribute to foreign governments and agencies information on United States activities concerning earth resources surveying. Planning was undertaken for an International Workshop on Earth Resources Survey Systems which the Department of State is cosponsoring with NASA and other Government agencies. Invitations to attend the Workshop, which is to be held in May 1971 at the University of Michigan, were extended in December to all United Nations Member States, a number of other nations and several international organizations.

Aeronautical Service Satellites.—The United States continued to work with ICAO during 1970 in considering requirements and characteristics for an Aeronautical Service Satellite system that would provide air traffic control services. Requirements for surveillance and navigation services are also being considered. The Department of State also participated with other United States Government agencies during 1970 in the formulation of policies and studies of the requirements and technical characteristics of such a satellite system.

Meteorological Satellites.—The United States continued to participate in planning activities of the World Meteorological Organization for the Global Atmospheric Research Program (GARP) to be undertaken in the mid-1970's. The satellite portion of GARP involves four meteorological satellites to be operated in conjunction with land- and sea-based facilities and balloon-borne instruments. Two of the satellites are to be launched by NASA and one by France. Japan is considering a commitment to launch the fourth satellite.

National Geodetic Satellite Program.—The National Geodetic Satellite Program (NGSP) was concluded in 1970 with 28 countries having been involved in its activities. The Department of State assisted the National Ocean Survey of the National Oceanic and Atmospheric Administration in making arrangements for movement of NGSP equipment and personnel and additional geodetic satellite survey activities in several foreign countries.

Sounding Rocket Activities.—The United States continued during 1970 an extensive program of sounding rocket launches from the United States and several foreign locations. New agreements covering arrangements for sounding rocket launches were signed during 1970 with the governments of Australia, India, Spain, Sweden, and France.

Tracking Networks.—In June an agreement with France was concluded to provide the general framework for mutual tracking support of satellite activities by France and NASA. During 1970 agreements with Australia and Malagasy for the operation of NASA tracking stations in those countries were extended. The Department of State also assisted NASA in making arrangements for ceasing operation of its tracking station at Guaymas, Mexico, and for the movement of equipment and personnel to the United States. The NASA tracking network also supported launches of the French-German DIAL satellite and the Japanese satellite OHSUMI in 1970.

Technology Transfer.—During 1970 the Department of State's Office of Munitions Control continued discussions with other U.S. Government agencies aimed at reducing the number of space-related items governed by export controls in the International Traffic in Arms Regulations. The Office of Munitions Control processed in 1970 an increased number of license requests for export of space-related hardware and technology to foreign space programs. Included were technical assistance and equipment for the Japanese Launch Vehicle and Satellite Development Program, the NASA-German HELIOS satellite, the Italian SIRIO satellite, the Astronomical Netherlands Satellite Program, the United Kingdom Defense Communica-

tion Satellite, and technical cooperation between several foreign industries and U.S. industry on study contracts in the NASA post-Apollo Space Transportation System program.

Cooperation with the Department of Defense.—The Department of State worked closely with the Department of Defense throughout 1970 on those space related activities of the DOD which were international in character or operationally involved other nations. The NATO Satellite Communications System and the cooperative program with the United Kingdom for the development of the SKYNET space communications system were two of the major programs carried out during the year. The first NATO communication satellite was launched from Cape Kennedy on March 20. Two earth terminals, one in Germany and the other in Italy are expected to be completed early in 1971. The terminal in Norfolk, Va. is scheduled for completion in June 1971. A second SKYNET satellite was launched in August but malfunctioned after reaching initial orbit. An agreement covering the second phase of the SKYNET satellite communication program was signed by the United States and the United Kingdom in April. A United States-United Kingdom combine is now under contract to design and construct the second generation SKYNET satellite.

Aeronautics.—In December an agreement was concluded with the Canadian Department of Industry, Trade, and Commerce covering arrangements for a joint project to design, develop, and test a new aircraft wing flap concept known as the Wing Augmentor System. The concept involves a wing trailing edge flap system based on jet nozzle thrust augmentation. Successful development of this system will significantly reduce landing and takeoff distance for jet aircraft, particularly large commercial transport aircraft.

The United States continued to work in ICAO to solve environmental problems arising from aircraft noise in the vicinity of airports and sonic boom in connection with the commercial introduction of supersonic aircraft. The first meeting of the ICAO Com-

mittee on Aircraft Noise, held in the fall of 1970, decided to recommend that new ICAO noise certification standards should be made applicable to airplanes of the 747-type for which a certificate of airworthiness is first issued on or after March 1, 1972. The Committee also established a working group to study the technical and cost/benefit aspects of noise certification modification requirements for existing subsonic turbojet aircraft.

The ICAO Sonic Boom Panel held its second meeting in October 1970. This panel has the task of developing proposals which will meet the objectives of a resolution of the ICAO Assembly. The resolution reaffirms the importance of not creating an unacceptable situation for the public through sonic boom of commercial supersonic transport aircraft (SST's), invites nations to furnish information concerning the operating characteristics of their SST's and the results of research into the effects of sonic boom as soon as available, instructs the ICAO Council to review ICAO documents to ensure they take account of the public problems of SST's and sonic boom, and invites manufacturing nations to furnish ICAO with proposals on the manner in which any specifications it might establish could be met.

Air terrorism and hijacking took on new and more severe forms in 1970 which posed serious threats to the safety of air transport. The Department of State pressed for additional adherence to the Tokyo Convention on prompt return of aircraft and passengers and for the completion of two new Conventions which would require States to extradite or prosecute hijackers and those intending to damage aircraft or vital aviation facilities. The proposed Convention on hijackers is the subject of a conference which began in The Hague in December. A fourth Convention was proposed by the United States in October to provide for possible sanctions against States not promptly returning aircraft and passengers or failing to take appropriate action in the case of hijackers who acted for international blackmail purposes. This last Convention is being considered by the ICAO Legal Committee.



Introduction

The Secretary of Transportation and his Department are charged with the preservation of the role of the United States as a leader in air transportation through, among other means, the application of pertinent research and development performed by DOT and other Government agencies and departments, as well as by industry.

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 was established this year to facilitate the coordination efforts between the organizational elements of DOT. Its role is 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 Department's Transportation Systems Center in Cambridge, Mass., was transferred to it from NASA on July 1, 1970. The new organization was reoriented, and has already begun to contribute to the Department's work, particularly in electronic techniques for controlling traffic, both in the air and on the surface. This transfer of function and research personnel was a significant step in the improvement of the research and development relationships between DOT and NASA because its work contributes heavily to the programs of both.

The Civil Aviation Research and Development (CARD) policy study is a significant example of DOT-NASA collaboration; it is designed to explore and define the significance of civil aviation to the Nation, to forecast the research effort that will be needed to enable the United States to maintain its position of leadership in aviation, and to develop alter-

natives for Government and industry financing of such development.

The two agencies also collaborate in applying satellite capabilities in traffic control—both transoceanic aeronautical control and marine traffic control. Advanced satellite technology will be used to support deployment of an initial experimental/preoperational satellite system for operational evaluation of voice and data communications and for experimentation in independent traffic surveillance. A separate, but related, study has attempted to analyze the benefits of space techniques for data relay from a large system of ocean buoys.

Recommendations made early this year by the DOT Air Traffic Control Advisory Committee underlie plans for air traffic system improvements being implemented by the Federal Aviation Administration (FAA). The Fourth Generation Air Traffic Capacity Study, a new long-range forecasting effort, was designed to identify technological advances needed to develop a control system that will allow efficient operation of air traffic and still be relatively insensitive to changing levels of demand on the system, while constantly improving safety.

A further extensive study seeks to quantify maritime-space radio communications requirements by synthesizing international merchant vessel population and oceanic distribution through 1980, projecting that population's message volume, and determining the radio frequency bandwidth that message traffic will need.

The U.S. Coast Guard Office of Research and Development has under development a self-contained system for the emergency unloading of stricken oil tankers. In the event of grounding, collision, or similar incident, the system allows the tanker to be unloaded or lightened sufficiently so that it may be refloated. This Air-Deliverable Anti-Pollution Transfer System (ADAPTS) will be capable of unloading 20,000 tons of liquid cargo within 24 hours of a reported ship pollution incident. The system which is packaged for air delivery includes transfer pumps, diesel engine pump prime movers, 500-ton rubber temporary storage containers and transfer hose.

The system is designed to perform in 40-m.p.h. winds and 12-foot seas with all components capable of being air delivered at the spill site within 4 hours of notifi-

cation of an accident. The system is capable of deployment and initial operation without the use of surface craft and without support from the damaged ship. The first test of the entire system was conducted in February 1970. To date a total of four full system tests have been conducted, all under relatively calm conditions. Future tests of the system up to design environmental conditions are scheduled.

Aviation Safety Research and Development

En Route Operations.—The Department conducted significant research and development efforts during 1970 concerned with improving aviation safety in en route operations through the following typical programs:

(a) Aircraft wake turbulence.—A problem requiring a quick answer was addressed in February 1970: Whether the separation standard requiring following aircraft to stay at least 10 miles behind either of the two types of jumbo jets then in operation (747 and C-5A) should be retained or could be relaxed. The existing standard was based on theoretical calculations and early data. The conclusion—after FAA, the 747 manufacturer, NASA, and the U.S. Air Force had carried out a cooperative program that examined effects of wingtip vortexes generated not only by the jumbo jets but also by other types of jet aircraft—was that the longitudinal spacing behind the jumbo jets for following aircraft could safely be reduced to 5 miles, a spacing applying also to the wake of various other large jet aircraft. Further tests being conducted in this area will refine these results and determine more precise criteria of this kind for general aviation aircraft. Long-range work to characterize aircraft wake turbulence for any aircraft as a function of time and atmospheric variables is being continued in cooperation with the NASA vortex research program and others. Preliminary conclusions from these programs indicate that the extent of wingtip-generated vortex hazards can be reduced in various operational areas by: Air traffic control separation; flight procedures; improved vortex sensing, data processing, and pilot display; and improvements in airport taxiway and runway layout.

(b) Other air turbulence.—The FAA and the National Meteorological Center are cooperating in the work of forecasting clear air turbulence by combining probability analysis techniques developed for FAA with the Center's new model for forecasting winds and temperatures. The "unusual events recording systems," installed on three civil jet transports in previous years to obtain data on pilot and aircraft response to encounters with severe turbulence, recorded over 1,000 hours of inflight data without encountering any unusual event, which suggests that current flight pro-

cedures might be acceptable. The data obtained from this project will also be useful in other FAA programs.

(c) Flight characteristics criteria.—Two projects were completed and a third advanced during the year in this area, which serves aviation safety by developing and defining aircraft stability and control characteristics and the handling qualities of all forms of manned civil aircraft. This work, conducted in close coordination with the National Aeronautics and Space Administration and the Department of Defense, embraces both existing and new designs of aircraft, and is carried out by sponsoring analytical and experimental efforts with ground-based and inflight simulators for the wide range of civil aircraft and configurations involved. The program's objectives are to determine optimum characteristics of aircraft for use in system design and to promote the development of promising new aircraft control concepts. Achievements during 1970 applied to:

—Improving flight characteristics airworthiness requirements for certifying small general aviation aircraft.—The first phase of this project was carried out in 1967 under FAA sponsorship; the second—as part of a broader investigation jointly administered by NASA, the Naval Air Systems Command, and FAA—was conducted in 1968; and the final phase was completed in 1970 with the compilation of new stability and control data for designers and regulatory authorities.

—Establishing flight characteristics criteria for possible use in revising type certification standards for high performance business jets.—This two-phase project is jointly sponsored by the Air Force Flight Dynamics Laboratory and FAA. The first phase presented criteria for optimum lateral-directional handling qualities for cruising flight and minimum acceptable characteristics for setting airworthiness certification standards. The second phase determined lateral control requirements of executive jets and related military transport airplanes during landing approach in turbulence and crosswinds, as influenced by inertia, lateral directional coupling, and control-system characteristics.

—Investigating flight characteristics criteria for STOL (short takeoff and landing) transports.—This project uses a moving-base simulator to investigate flight characteristics of deflected jet and deflected slipstream STOL transports, and extends through three phases. The first phase, completed by an FAA contractor in 1970, was begun in July 1969 and carried out in close cooperation and coordination with the NASA Ames Research Center using the Ames moving-base simulator facilities.

The second phase will cover directional control and turn coordination criteria; the third, longitudinal dynamics and approach flight path control.

(d) Aircraft piracy and sabotage.—An antihijacking system was successfully field tested in 1969 and placed in limited airline use by the end of that year. This system consists of a weapon-detecting device used in conjunction with a hijacker behavioral profile based on study of the personal characteristics of known hijackers. Greatly expanded use of the system occurred in July at New Orleans' Moisant International Airport, which became the first airport subjecting all passengers to screening by this system prior to boarding their planes. The main impetus to wider use of the system came from the unprecedented international hijacking events of September. A device called a Chemosensor has been developed as a possible solution to the aircraft sabotage problem. Its intended function is to detect the presence of a bomb anywhere within an aircraft. While evaluation of the Chemosensor revealed much merit, it requires further development to meet acceptable operational performance requirements.

(e) Midair collision hazard.—FAA participated in flight testing of a promising collision-avoidance system developed in previous years by a private contractor for the Air Transport Association. Earliest possible operational use of the system was considered to be at least 2 years away. The FAA also further tested, through simulation techniques, the effects of interaction between the collision-avoidance system and the air traffic control system. Since a collision-avoidance system is highly sophisticated technologically and expensive, it will be used mainly by airline and corporate aircraft. Several pilot-warning instrument system concepts, much simpler and less expensive, are undergoing R. & D. for general aviation aircraft by FAA, NASA, and industry.

(f) Other developments.—Other R. & D. efforts concerned with making aircraft safer in flight were concerned with the following:

—Stall-warning system.—Technical and operational criteria for improved stall-warning systems were determined in a two-phase effort. In the first phase, the most effective pilot-alerting method was found to be a control-wheel shaker, the second most effective an intermittent horn, the least effective a steady horn. The second phase tested a standard installation of a stall-warning system certificated in accordance with the Federal Aviation Regulations and an improved system using a lift transducer that detects the rate of change of the angle of attack.

—Stability augmentation.—Under an interagency agreement, the U.S. Air Force Flight Dynamics

Laboratory completed flight testing of its automatic pilot-assisting equipment in a light, single-engine aircraft. The purpose was to assess the equipment's effectiveness in reducing accidents caused by pilot loss of control in bad weather.

—Improvement of static-pressure systems—Altimeter and airspeed systems reliability was tested and recommendations made to improve static-pressure systems of aircraft so that instruments would be more reliable while the aircraft are performing flight maneuvers or flying in bad weather.

—Inflight fire protection.—Criteria were distributed for installing and using equipment that records the concentration of fire-extinguishing agents in an aircraft's fire-extinguishing system. This equipment is the most reliable and feasible method of determining the effectiveness and performance of aircraft fire-extinguishing systems.

—General aviation exhaust system safety.—Accelerated procedures were developed for testing the airworthiness of general aviation aircraft exhaust systems. These procedures will preclude or significantly reduce the probability of carbon monoxide hazards resulting from high-temperature oxidizing or environment-caused corrosion of the exhaust system.

—Anti-icing wing-coating materials.—Although materials flight tested in 1970 were selected from materials tested previously in the icing research tunnel at NASA's Lewis Research Center, none was found to have effective anti-icing or de-icing properties.

Airport and Vicinity.—Significant efforts in this area were concerned with the following:

(a) Firefighting.—Basic data, usable for extrapolating fire-protection requirements for both smaller and larger aircraft, were obtained from full-scale fire tests performed at the Department's National Aviation Facilities Experimental Center, Atlantic City, N.J., with two obsolete U.S. Air Force B-47 Stratojet bombers. The data show requirements for type and number of firefighting vehicles, their strategic location around the aircraft, and type, quantity, and discharge rates of extinguishing agents.

(b) Runway friction.—Investigations of grooved runways yielded data on runway friction, environmental changes, and such effects on the using aircraft as vibrations induced in the airframe, wheel spin-up rates, and tire-chevron cutting. Investigations continue concerning seasonal environmental changes, wheel spin-up, and tire-chevron cutting.

Postcrash Safety.—Significant progress was made in the following areas:

(a) Gelled fuels.—Use of gelled fuels in aircraft has the potential for significantly reducing the hazard of fire following an aircraft crash. Chemical and physical research to improve gelled-fuel flow characteristics while maintaining their superior fire safety characteristics was performed after tests in a commercial jet transport fuel system had shown the most promising fuels developed from previous extensive research were too viscous. Two gelled fuels, however, were shown in short duration jet engine tests to be usable in modern jet engines without significant loss in engine efficiency. A study estimated that, over a 10-year period, industry-wide use of gelled fuel would raise airline operating costs by 4 percent.

(b) Crash-resistant fuel system.—This system, utilizing strong bladder cells and a crash-operated valve system with interconnecting lanyards, was tested in actual impacts against pole-type obstacles at speeds up to 80 miles per hour. In all cases, the bladder tanks remained intact and the valves operated properly. Progress was achieved toward establishing criteria for carrying fuel in leading edges of aircraft wings, and evaluations of elastomer liners to improve crashworthiness of integral wing tanks were performed.

(c) Fire test of titanium SST fuselage.—The predicted greater ability of a titanium skin to protect against external fires was verified by a full-scale fuselage fire test, which also showed that obtaining full benefit from titanium's inherent fire resistance requires the use of high-temperature sealing materials.

(d) Aircraft cabin interior materials.—Several space program fire-resistant materials developed by NASA were evaluated at NAFEC for possible use in aircraft cabins. In the same area, the Department and the National Bureau of Standards established the accuracy of the latter's smoke test chamber and supported its recommendation to the American Society for Testing and Materials for use in a standard test method. This method will be specified in future FAA smoke-rule requirements for aircraft cabin interior materials.

(e) Aircraft cabin crash resistance.—The nature of structural failures in aircraft fuselages and in the seat-and cargo-restraining systems is being evaluated by comparing data from a full-scale crash test of a four-engine piston-powered airliner with design criteria, current airworthiness standards in the Federal Aviation regulations, and recently developed dynamic seat test criteria.

(f) Explosively created emergency exits.—The feasibility of opening emergency exits in the fuselage of a crashed airplane by linear-shaped explosives (two liquids separately inert but explosive when mixed) was demonstrated in scrap fuselage structure but, according to test indications, such a system must be

incorporated in the aircraft design. The U.S. Army's Picatinny and Frankford Arsenals cooperated with FAA in accomplishing this project.

(g) Air-bag restraint system.—The feasibility of using inflatable air bags to minimize impact effects on occupants of general aviation aircraft in crashes was determined, but adaptation of automotive air bags presently under development to current general aviation aircraft will require major modifications.

(h) Jumbo jet emergency evacuation simulator.—An emergency evacuation simulator capable of accommodating airline passengers in numbers representing a significant portion of jumbo jet capacity was being operated during the year by the Civil Aeromedical Institute at the Department's Aeronautical Center in Oklahoma City. The adjustable pitch, roll, and elevation of the simulator enable safety personnel to assess the effectiveness of escape equipment, ditching equipment, and escape procedures.

Air Traffic Control and Navigation System

FAA progressed during 1970 in its long-range plan to introduce automation in both terminal and en route traffic control. In addition, the Agency continued to develop area navigation routes to supplement conventional air routes for aircraft flying under instrument flight rules by developing area navigation routes, and to explore the potential uses of satellite technology in air navigation and communication.

Automated Radar Terminal System (ARTS) II.—This system is an experimental automation program for low- to medium-activity terminal areas. One candidate system is modular, can employ either numerics or alpha-numerics, and is programable. It can also use components of ARTS III (see below), thus simplifying logistics, maintenance, and training. Another candidate system, known as the AN/TPX-42, is the result of a joint FAA-USAF development program, and is being procured for low-density civil and military terminal areas.

FAA completed the first field test of a programable ARTS II, at Knoxville, Tenn., a low- to medium-density terminal area, following feasibility tests of the system at NAFEC before its installation at Knoxville. The 6-month field evaluation encompassed three separate test phases: (1) A numerics-only phase; (2) an alpha-numerics phase; and (3) a two-display configuration phase. The judgment at the end of the evaluation was that the system had performed effectively and had improved the handling of traffic in the Knoxville area. At year's end, ARTS II was operating full time as Knoxville's primary ATC facility. Work will continue in 1971 to explore beacon problems in greater depth and exploit the system's programable capabilities.

ARTS III.—By the end of 1970, the first ARTS III, FAA's automated system for high-density terminal areas, had been delivered to Chicago's O'Hare International Airport for operational use. FAA expects to deliver eight additional ARTS III's to high-density airports by the middle of 1971; FAA also expects ARTS III systems to be operational at 62 high-density airports in 1973.

In other ARTS III developments during calendar year 1970, FAA awarded a \$500,000 contract for improving the tracking, air traffic control coverage, and computing capabilities of the system, and made an initial award on a contract to develop and implement an ARTS III computer program for metering and spacing air traffic.

NAS En Route Stage A.—FAA continued to install NAS En Route Stage A computers at air route traffic control centers (ARTCC's) for flight-data processing, the first step in automating en route air traffic control. At the end of the calendar year, such computers had been delivered to 15 centers. Five more centers are scheduled to receive this equipment. In addition, computer updating equipment for updating flight plans had been delivered to eight centers during 1970; three ARTCC's—Washington, Indianapolis, and Chicago—had put this equipment into operation by year's end.

Contracts awarded during the reporting period for NAS En Route Stage A equipment covered: Test consoles to house test equipment for computer display channels and computer updating equipment, two key elements of NAS En Route Stage A (March); design and development assistance, evaluation, and analysis (July); computers and computer components (June); a partial display channel processor (September); and modifying and expanding the en route operational air traffic control computer programs (November).

Aeronautical Satellites.—FAA continued to explore the potential usefulness of artificial satellites in aviation. This rapidly unfolding technology appears to be readily applicable to overwater surveillance and communication.

The increasing number and speed of air carrier aircraft flying international, overwater and polar routes has created problems in communication and surveillance. Because of fading, static, and other interference caused by natural phenomena, aircraft now flying such routes often lose radio contact with distant ground stations. Since this lack of reliable point-to-point communication makes air traffic surveillance over such aircraft impossible, flight separation requirements far exceeding those in use over land have been adopted for the safety of ocean-crossing aircraft. Air traffic capacity on these routes has thus been limited.

An aeronautical satellite system for transoceanic use could solve, or at least greatly ameliorate, these problems.

During 1970, FAA received proposals for launching a hybrid VHF/UHF satellite system for aeronautical use. One contractor proposed to conduct pre-operational tests with both frequencies and use the better testing one for the system's operational life. Another approach was to utilize the VHF portion of the system as an operational voice and data communication link, and the UHF portion for testing only.

Other ATC and Air Navigation Developments.—Among these were included the following:

(a) All-weather landing system.—This is a long-range undertaking involving the integration of a ground-based guidance system, an airborne system, and a lighting system. In 1970, NAFEC completed the evaluation of a ground-based guidance system—the STAN 37/38 ILS (instrument landing system)—borrowed from the United Kingdom. The purpose of the evaluation was to identify areas requiring further development. At year's end, the British-manufactured ILS was going through an airborne operational evaluation, scheduled for completion in August 1971. NAFEC had also completed flight testing of an airborne system capable of meeting category III weather minimums—that is weather conditions too poor for the pilot to: (1) Establish visual contact with the ground or runway before landing and (2) see along the runway beyond 1,200 feet.

(b) Area navigation.—FAA continued to pursue its long-range goal of developing area navigation routes for both en route and terminal IFR (instrument flight rules) traffic on a nationwide scale. Area navigation, by utilizing the full potential of VHF omnidirectional radio range/distance-measuring equipment (VOR/DME) navigation facilities, frees pilots from the need of flying a track to or from these facilities; this permits the establishment of new routes without installing ground-based navaids along each flight path. In June FAA established the first series of area navigation instrument approach procedures in the United States at six terminal areas—Longview, Tex., Kirksville, Mo., and Fullerton, Palm Springs, Lancaster, and Torrance, Calif. The new procedures permit pilots of aircraft equipped with area navigation equipment to make straight-in instrument approaches to runways without the use of runway-oriented electronic approach aids. This eliminates the need for pilots to conduct time-consuming procedure turns and circling maneuvers required by conventional IFR approaches. FAA also continued to test area navigation equipment. In March, NAFEC completed an evaluation of a private corporation's vector analog computer with the publication of a report describing

the equipment's signal-processing techniques. In May the airborne computer was certificated for use on a general aviation aircraft operated by the private corporation. In December, NAFEC completed an evaluation of an Avion roller map pictorial display.

Human Factors in Aviation

Pilots.—A study completed in 1970 in the area of airman standards, involving private and commercial pilots with flight experience ranging from 6 months to 9 years, showed a definite correlation between elapsed time from date of certification and loss of instrument proficiency.

Various pilot problems of a human-engineering type received attention in 1970. Examples are improvement of visual guidance by lights and paint patterns, effectiveness of cockpit instrument displays, collision-avoidance problems, visual illusions, and aircraft noise.

Air Traffic Controllers.—A study emphasizing human factors of equipment design, aiming to keep equipment-induced error to a minimum and to insure that controllers will be able to use with ease the new automated equipment being procured for towers and centers, will be made with a specialized radar display to be developed under a contract awarded in May 1970.

"Before and after" studies were underway during the year to determine quantitatively the effect on the controller's workload of introducing automation into the operational facilities.

An initial study of the accuracy of controllers in judging aircraft separation as represented on current analog radar displays showed nearly all estimates fell within 1.5 miles of the separation displayed. However, since the controllers were not burdened by the complete air traffic control job when making their estimates, these results were obtained under "best case" conditions; hence, further evidence will be required before serious consideration can be given to reducing the 3-mile separation standard for the terminal area.

Aviation and the Environment

FAA took a number of actions during 1970 addressed to maintaining or improving the quality of the environment. Among them were:

(a) Announcement, in October, of a program designed to reduce noise while increasing safety in the vicinity of airports serving jet aircraft.—Under the program, terminal air traffic controllers will delay the final landing descent of turbojets until these aircraft are relatively close to their destination airport; they will also instruct jet pilots taking off to climb out as

rapidly as aircraft's performance capability and passenger comfort permit. Arriving jets will generally be kept at 10,000 feet or higher until they are approximately 30 miles from the airport. They will then be kept at least 5,000 feet above the ground until they reach the final descent area. Keeping the jets and hence their noise high enhances safety by minimizing the mix of jet and small general aviation traffic near the airport. The program is scheduled to be implemented at 119 terminal radar control facilities by February 1971; at 246 nonradar airports with towers by July 1971; at airports without radar or towers that serve scheduled air carrier turbojet flights by November 1971; at all remaining airports that serve turbojets by February 1972.

(b) Issuance of an advance notice of proposed rule-making soliciting comments from the aviation community and the public at large on retrofitting existing jet aircraft with engine-noise-suppression devices, in November.—Recent research and development have demonstrated that devices capable of significantly reducing jet engine noise are within the state of the art. Still to be demonstrated, however, is the extent to which these devices may adversely affect aircraft airworthiness and whether they are economically feasible. This advance notice complements a December 1969 rule establishing allowable engine-noise levels for two classes of aircraft for which an application for a type certificate was made after January 1, 1967.

(c) Continuation of a project at the Civil Aero-medical Institute to determine the level of sonic booms tolerable to human sleep patterns by having instrumented subjects sleep in two specially installed sonic boom simulation rooms.

(d) Negotiation of an agreement with 31 airlines on the retrofit of JT8D engines with smoke-reducing combustors, in January.—These devices reduce the level of visible pollutants emitted by jet engines, but according to recent measurements do not help the problem of invisible pollutants. Under the retrofit plan, which was agreed to voluntarily by the airlines, combustors will be installed on some 3,000 engines on 737's, 727's, and DC-9's by late 1972. A public demonstration of the new combustor was conducted at Washington National Airport in September by a major air carrier with a combustor-equipped 727. The Department of Health, Education, and Welfare participated in negotiating the agreement.

(e) Awarding of a contract for the establishment of design criteria for the control and reduction of oxides of nitrogen (invisible pollutants) emitted by jet aircraft engines.—The study seeks to develop ways to reduce oxides of nitrogen without producing an increase in carbon monoxide, unburned hydrocarbons, and other jet engine emissions.

The Supersonic Transport

This has been another year of intense congressional interest in the supersonic transport program. House and Senate committees, in hearings on the fiscal year 1971 budget request for \$290 million, considered in depth concerns expressed about noise, sonic booms, and other environmental impacts. The budget request was under consideration by a Conference Committee of the Congress in its session on the last day of the year.

In April 1970 the FAA issued a notice of proposed rulemaking formalizing the decision of the President that no supersonic transport may fly over U.S. territory at a speed that would cause a sonic boom to reach the ground.

Although present information indicates that projected SST operations will not cause significant climatic changes, the Department, in conjunction with the National Oceanic and Atmospheric Administration, NASA and other agencies, has described a Government environmental research program. It includes study of noise reduction. This research will provide data expected to increase confidence that large-scale SST operations will not significantly affect the environment.

Two interdisciplinary committees, the Environmental Advisory Committee and the Noise Advisory Committee, have been established. These are teams of scientists and experts with a variety of backgrounds and experience. They will monitor research programs where there is either uncertainty or lack of information.

After approval of the fiscal year 1970 budget on December 29, 1969, contractor manpower built up from an average of 3,400 in January 1970 to approximately 5,500 by the year's end. Work on both the airframe and engine proceeded on schedule throughout the year. The class II mockup structure was completed on schedule in June. The contractor awarded contracts to its major subcontractor teams in midyear, and they initiated fabrication of the prototype parts immediately thereafter. Having demonstrated the engine's world record thrust of approximately 69,000 pounds under static sea level conditions, the manufacturer continued testing the engines to increase their durability and reliability.

The contractors are working according to a schedule planned to achieve first flight in November 1972 and airplane certification by 1978.

VIII



Arms Control and Disarmament Agency

Introduction

Outer Space Treaty.—The first two objectives of the U.S. space program,

- Continue to explore the moon;
- Move ahead with bold exploration of the planets and the universe;

are moving forward on the legal highway provided by the Outer Space Treaty, which has now been subscribed to by 58 governments. It is reassuring that prior legal and intellectual concern insures that these new regions of exploration are closed to the arms race, and that these further space explorations can proceed within a peaceful, internationally controlled environment. ACDA is concerned, along with other agencies, in the necessary follow-on actions to insure that a proper liability convention is also brought into effect.

Success in banning weapons of mass destruction from outer space has shown that closing new environments to the arms race is an effective way of achieving international agreement on arms control. This success

pointed the way for a similar effort to ban such weapons from the seabed. The Conference of the Committee on Disarmament presented a draft treaty in this area to the U.N. General Assembly in September 1970, and that body passed a resolution supporting the treaty in December.

Space Cooperation.—The development of international cooperation in space activities can improve the political climate for a number of collateral goals, including arms control. The positive experiences of cooperative space program planning demonstrate ways in which countries can deal constructively with each other on technical problems. The experience of space cooperation and the manner in which it develops may also be a useful indicator as to the prospects for expanded cooperation in arms control, especially in the strategic area.

ACDA has continued its efforts to insure that space technology or equipment transferred by U.S. agencies

or industries to other nations will be used solely for peaceful purposes. This procedure implements the U.S. policy of nonproliferation of missile and weapons technology.

Aerial and Space Systems in Support of Arms Control.—ACDA maintains an active interest in the improvement of technological and organizational capabilities for verifying arms control agreements. The space programs of other agencies are monitored for technological developments that can be adapted to

arms control verification. Space-borne platforms with nonintrusive sensors, as well as data links and data processing systems, are of particular interest. Since confidence in future treaty arrangements will depend on how well the agreed provisions can be verified, ACDA devotes considerable effort to these activities. In addition, communication satellites can facilitate rapid exchange of information between governments during crisis situations. Such systems have enhanced reliability because they are not dependent on cooperation of other countries for passage of land lines.

IX



Department of the Interior

Introduction

The U.S. Department of the Interior has long utilized aircraft in the performance of its missions for exploration, development, and management of the Nation's natural and cultural resources. Aircraft of several bureaus of the Department, contractor-owned aircraft, and other Federal agency-owned aircraft of all types are used operationally and experimentally. Experiments are conducted to test and develop improved capabilities that the aircraft themselves afford in support of Department programs and to test new ways in which use of airborne surveying and analytical instruments from cameras to radioactivity counters can improve the efficiency and effectiveness of departmental performance.

The Department has played an important role, also, throughout the past decade in support of the Nation's space exploration and lunar landing programs, and in support of the development of peaceful applications of space technology. Such support has included research of applications of satellites as unique platforms from which to make observations for research and monitoring of earth's environments and of remote sensing instruments to make the observations. Operational support has been provided to the NASA in lunar mapping, analysis of lunar materials, the development of lunar sampling programs and equipment, in the development of equipment and processes for life support systems in spacecraft, and in the calibration of equipment for the Earth Resources Technology Satellite (ERTS).

Aeronautics

During 1970, the Department employed fixed-wing aircraft and helicopters—its own, those of other agencies, and of private contractors—in support of both operations and research activities.

Operations.—Operational uses of aircraft and helicopters among bureaus of the Department have been as follows:

The Bonneville Power Administration.—For aerial patrol of power lines, transport of men, tools, and equipment to emergency spots to achieve rapid resumption of vital power service, and ferry of men to remote microwave stations.

The Bureau of Reclamation.—For reconnaissance of reclamation study areas and engineering sites, the acquisition of aerial photography for the planning of engineering works and alignments. Development of repair kits is under way at present, including lightweight aluminum towers, conductors, and accessories for the emergency repair of damaged 230- and 345-kilovolt power lines. These kits will be transported and erected by employment of helicopters. The Bureau also employed aircraft in the conduct of cloud seeding in its Atmospheric Water Resources Management Program and in support of the operations of the Bonneville Power Administration at Hungry Horse Basin, Idaho.

The Bureau of Mines.—To support mineral resource surveys in remote areas for the National Wilderness program.

The National Park Service.—For aerial photography and aerial visual observation in planning road align-

ments, site development, and engineering. It also used aircraft to obtain data for master plan development, vegetation mapping, fire patrol, archeological studies, and for survey of large mammal populations—moose, elk, bison, grizzly bear, and caribou—in large park areas such as Yellowstone, Glacier, Mount McKinley, and Katmai.

The Federal Water Quality Administration.—For detecting oil pollution, thermal loading and evaluating waste outfall characteristics in ocean waters.

The Geological Survey.—To obtain aerial photography for the national topographic mapping programs. In 1970, standard mapping photography was acquired for 227,000 square miles of the United States and high altitude aerial photography of more than 50,000 square miles was acquired, including 30,000 square miles in the Brooks Range and North Slope areas of Alaska. Aircraft were used also in the management of Federal Outer Continental Shelf mineral resources, to transport petroleum engineers and technicians to oil and gas drilling and producing operations, to perform inspection of such operations and search for the presence and sources of oil spills.

Research.—Research uses of aircraft involve their employment logistically in the movement of men and materials as discussed above, and as platforms for remote sensors—cameras, multiband scanning photometers, thermal infrared scanning radiometers, and radar mappers—to determine their applicability to the resources research and management functions of the several bureaus and offices of the Department of the Interior.

The Bonneville Power Administration is cooperating with the Bureau of Reclamation and the U.S. Corps of Engineers employing aircraft in conduct of a successful experiment in cloud seeding in the Hungry Horse Basin, Idaho.

The National Park Service is cooperating with Geological Survey, NASA, and other Federal, State, and municipal groups in remote sensing studies of Biscayne Bay and the Everglades National Park, Fla., the Hawaii Volcano, and the Grand Teton and Yellowstone National Parks. These studies are aimed at developing new methods for assessing both natural conditions of environments and the effects on them of natural hazards and the works of man.

The Geological Survey is cooperating with the NASA in conducting research of uses of special types and conditions of remote sensor data for conventional mapping and for new map products for topographic, geographic, geologic, and water resources surveys. It has instituted a program with New York State to use an airborne thermal infrared scanning radiometer to monitor the thermal effects on inland and estuary waters of urbanization and the ensuing natural and artificial discharge and circulation patterns. Studies in connection with the

Biscayne Bay and Everglades projects and with research in the Tampa sinkhole areas, in cooperation with the University of Michigan, have shown the feasibility of computer processing of airborne radiometer data for recognition and mapping of surface and shallow submarine biotic communities, and of an incipient sinkhole condition. High altitude aircraft data have been employed to prepare land use maps and data bases of selected 1970 Census cities, and both aircraft and Gemini and Apollo photography have been used to support analyses of the economic potential of an economically depressed area in southern Mississippi. Sidelooking airborne radar was employed to support geological research and mapping of the island of Hawaii, of Massachusetts, Connecticut, Rhode Island, and much of New York. Color and color infrared high altitude aerial photography are being used to study surface circulation patterns in San Francisco Bay, complex near-shore currents along the coast of Puerto Rico, sedimentation patterns along the south Texas coast and, with the Air Force Cambridge Research Laboratory, the sedimentary history of the Monomoy Point area of Massachusetts. Color, color infrared; and thermal infrared aerial data are providing bases for new studies of sedimentation and the effects of discharge of artificially heated water on the northern coast of Washington.

The Bureau of Mines, with the West Virginia Geological and Economic Survey, used NASA supplied radar data to develop a new understanding of regional structure and local oil producing area relationships in the Burning Springs, Va., area. Airborne thermal mapping surveys were conducted over burning culm banks in Pennsylvania and over areas of underground fire in the Eastern United States; they were also conducted in Colorado and Wyoming to determine usefulness of the systems in combating these very wasteful and hazardous conditions.

The Office of Water Resources Research supported research at the University of Rhode Island on aerial photography for remote sensing of pollution in Narragansett Bay; at the University of Montana on aerial photography and thermal infrared mapping to detect conditions of surface soil moisture before and after irrigation; at Cornell University on the use of aerial photography for prediction of water discharge for small watersheds; at the University of Wisconsin on the use of remote sensors for delineating flood plains in areas of deficient hydrologic data; and, at the University of Hawaii on the use of aeromagnetism and multiband photography for aid in the study of ground water resources.

The Federal Water Quality Administration funded research projects through grants and contracts at several universities and firms to develop remote sensing techniques for detecting and measuring agricultural pollution, pipeline leaks, and the discharge of pulp

and paper mill effluents. An extensive evaluation is also under way on present aerial sensing techniques and their applicability to the detection and measurement of water characteristics.

Space

Research.—The Department of the Interior, through its Earth Resources Observation Systems (EROS) program, is cooperating with NASA, the Department of Defense, other Federal, State, and local governments, and educational and private research groups to develop useful applications of space and aeronautical remote sensing systems for resources exploration, analysis, and management. Research needs, projects, priorities, and support are defined and coordinated through working groups comprised of representatives of all Interior Bureaus and Offices. Working groups in Mineral and Land Resources, Water Resources, Human Resources and Activities, Marine Resources, and Mapping Requirements assure attention to all Department of the Interior areas of responsibility, balance among programs, and avoidance of duplicatory effort in a burgeoning and farflung field of activity.

Major efforts are going toward preparation to use data from ERTS-A scheduled for 1972 launching. Planning is underway for an EROS Data Center near Sioux Falls, S. Dak. The data center will have four major functions: (1) to process, disseminate, and store data from the ERTS satellites for the broad user community; (2) to extract generally useful resource information from the ERTS data and disseminate it for users; (3) to provide some facilities for user training and assistance in data use; and (4) to develop methods and produce resources maps and statistics from satellite and aerial data for basic research and planning and regularly updated information on changing conditions of environment for management.

In addition, the EROS program will conduct a large number of experiments with ERTS data to determine its usefulness in helping to fulfill the resource missions of the Department of the Interior.

The Bureau of Reclamation, the Geological Survey, and the Bonneville Power Administration are initiating a research program in the Stanford Research Institute to develop applications of satellite data to the systematic observation of snowfall, rainfall, and drought, their effects upon natural and artificial water catchment and distribution systems and the environment as a whole.

The Bureau of Mines is studying Gemini and Apollo photography to determine the applicability of space systems to analysis and prediction of regional effects of large scale mining operations, and surface effects of underground fires.

The National Park Service is using Apollo 9 multi-band photography of the barrier islands of the United States to aid in determination of management objectives there. It also uses Apollo 9 photography to enhance knowledge of the geology and topography of the Tucson-Phoenix area prior to the location of new roads and the realignment of old roads in the Saguaro National Monument. Gemini and Apollo photographs are used for in-service training programs for environment awareness.

The Geological Survey produced experimental photomaps of the Tucson, Arizona Quadrangle incorporating Apollo 9 photographs and the latest information obtainable by conventional mapping methods. It also supported the design of a computer program at the Ohio State University to locate photo coordinates on unrectified space photographs to make them immediately useful as working maps. Research is being conducted and facilities provided for enhancement of photographic data to enable correlation, combination, and selective separation for analysis of special information relative to depths of water and snow, types and condition of vegetation, works of man, and changes of these through time. Using Apollo 9 photographs, a photomosaic of the Southwest United States was developed for analysis of soil, rock, and vegetation relationships. From this, evidence was derived of recent arroyo formation and accelerated erosion in the desert as results of overgrazing and increasing aridity. One volcano in the Cascade Range was instrumented with temperature sensing devices and data are received from them eight times per week by relay through the Nimbus 4 satellite. A cooperative program is being developed with the Delaware River Basin Commission to design and implement a space data link through ERTS-A to provide simultaneous surface sensor and space observation data on the quality and movement of water. A Chesapeake Bay research project has been initiated involving Maryland, Delaware, and Virginia governmental agencies and universities and the U.S. Geological Survey geography, hydrology, geology, and cartography applications programs. Its goal is to develop a systematic and coordinated approach to the analysis and solution of regional environmental problems involving water resources, vegetation, the works of man, and the interactions among them. Supporting research at American University has indicated a very promising capability for relating marsh and estuarine vegetation to water conditions. In cooperation with the Geological Survey of Alabama, Apollo 9 photography was used to map hitherto undetermined shear zones, thereby demonstrating a value of space data for providing knowledge of great value to the study of water resources and the planning of dams and reservoirs. Supporting photometric research has shown a relationship between anomalous soil mineralization and vegetation conditions in a selected copper-

molybdenum area in Maine, and radiometric research in a selected field area has distinguished limestone from dolomite. Research of passive microwave radiometer systems is being supported to determine their potential for measuring moisture content of snow fields to enable more accurate forecasting and more effective management of regional water resources. Programs were initiated using Gemini, Apollo, and high altitude aircraft multiband photography to develop methods of mapping land use and of monitoring and mapping environmental change. These methods will be incorporated into ERTS experiment and applications programs in 1972. Using Apollo and Gemini photographs, a map was prepared at 1:1,000,000 showing 11 categories of land use in the Southwestern United States. Research is being sponsored to develop the use of satellite and high altitude aircraft remote sensor data for archeological research and for analysis of the impact of urban development on local climates.

The Alaska Power Administration is examining the potential value of communications satellites for internal and external communications and for educational as well as standard television.

Operations.—The Geological Survey, in direct support of NASA, continued the analysis and mapping of the moon using Lunar Orbiter IV and Apollo 12 photographs. The potential values of radar for mapping lunar surface materials and of a lunar rover mounted magnetometer for analysis of rock types were demonstrated. Samples of the moon were analyzed and evidence was developed suggesting that the earth and the moon were formed about the same time, providing new support for a theory that the moon developed independently and had not spun-off from earth. The principal differences between lunar and earth materials compared to date appear to be in relative percentages of auxiliary minerals and in the effects of physical impact on rocks in the lunar environment. Support is being given to NASA in the calibration of return beam vidicon tubes being produced for ERTS-A. Through contract at the University of Illinois, studies are being made to determine the geometry of return beam vidicons and the systems and procedures to be employed to attain best possible geometry and fidelity in the data obtained by them. Administrative, review, and teaching support are being provided to the International Workshop on Remote Sensing to be presented at the University of Michigan May 3-14, 1971 under the sponsorship of NASA, the Departments of Agriculture, Interior and State, AID, and the Naval Oceanographic Office.

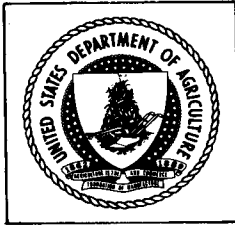
The Bureau of Mines conducted research on drilling, explosive, rock fracture, and materials handling processes in simulated lunar environment and performed analyses of mineral values of lunar rock samples.

The Office of Saline Water, jointly with NASA, funded research of the reverse osmosis process and of porous glass membranes for recovery of potable water from urine and wash water in closed systems. The development of a novel, lightweight, flexible, braided fiberglass support for the reverse osmosis process was an important result and will be the subject of continuing research.

International Cooperative Activities.—The Geological Survey and NASA are cooperating with Canada in connection with the International Field Year for the Great Lakes in the study of the applicability of air and spaceborne remote sensing systems for monitoring pollution and the natural and artificial processes of the Great Lakes. A study of geothermal conditions east of Lake Chapala, Mexico was conducted with NASA and Mexico. With the cooperation of the U.S.S.R., proton magnetometer measurements from Cosmos-49 were analyzed for application to the study of regional crustal conditions. Airborne and spaceborne remote sensor studies of Iceland's volcanic and geothermal fields were continued with the Air Force Cambridge Research Laboratory and Iceland's National Resource Council and National Energy Authority. In connection with these, a field study of the 1970 eruption of Hekla Volcano was made. In cooperation with the U.S. Department of State and the Government of Saudi Arabia, airborne magnetic, photographic, and radiometric surveys were made in support of geologic mapping to define the mineral resources base of Saudi Arabia. Similar work was conducted in cooperation with the Administration for International Development (AID) and the governments of Liberia and Indonesia. As a result of this work, several areas for oil exploration have been defined in Liberia. In Indonesia all resources are being studied, but special interest has been developed in potential geothermal power sources in central Java. Geological Survey support is being given to Brazil, Venezuela, Guyana, and other Latin American nations in the planning of projects to use airborne and spaceborne systems for resources analysis in both research and operations. Research of factors and effects of crater formation in natural crater areas and by artificial propagation was conducted cooperatively with the Department of Defense, the Geological Survey of Canada, and the Bureau of Mineral Resources of Australia. These studies are aimed at a better understanding of the geology of the moon.

The Bureau of Reclamation, with the cooperation of the Advanced Research Projects Agency, has begun research of remote sensor system applications to analyses of soil, drainage, water occurrence, and vegetation for reclamation planning in the United States AID-supported Pa Mong Project cooperative with the governments of Thailand and Laos.

X



Department of Agriculture

Introduction

The U.S. Department of Agriculture (USDA) continued its efforts in 1970 to develop applications of remote sensing and to improve its capability to collect and analyze the growing variety of earth resources data and information via remote sensing techniques. Its sensor-signature research extended from laboratories and field observations to aircraft and spacecraft platforms. Its objectives are to: (1) determine and evaluate the feasibilities and potentials for the improvement of agricultural, forestry, and range programs which depend upon the rapid accumulation, analysis, and application of information on crops, forests and wildlands, soils, and water conditions; (2) to assess the synoptic changes in man's nonurban environment; and (3) to identify in particular those applications where the benefits achieved would have a major impact on the national agricultural economy. The National Academy of Sciences has estimated that the losses incurred in agriculture in the United States due to insects, disease, and fire alone exceed \$13 billion annually. A system of remote sensors that would be capable of early detection of these plant stress factors can have an immediate impact on control programs as well as the national economy. In order to provide optimum long-term benefits, the Department of Agriculture has initiated appropriate remote sensing research and development programs in the attempt to improve the ability and capability to obtain and analyze greater amounts of data of improved quality on a near realtime basis. It is believed that remote sensing techniques can add significant dimensions in the acquisition of both United States and world agricultural and wildland resources information. As one specific example, Forest Service Fire Research developed a new airborne thermal infrared system for both detection and mapping of forest fires. Operational tests in an 8,000 square mile forest area show that the system has outstanding efficiency. On a single night patrol flight, 59 new forest fires were rapidly detected following a dry lightning storm. In addition, during this critical fire season scores of spreading forest fires were mapped under conditions of dense smoke that prevented usual reconnaissance.

Cooperative Activities in Aerospace Programs

In recognizing the immediate need for a technically feasible and economically sound earth resources remote sensing program that can effectively utilize aerospace technology to collect near realtime data, the Department of Agriculture engaged in a number of Federal interagency activities.

In cooperation with NASA, USDA through its Agricultural Research Service and Forest Service continued its remote sensing research investigations pertinent to agricultural, forestry, and range problems. A large part of the research is being devoted to a better understanding of the interaction of radiant energy with plant tissues and soils. USDA continued to develop U.S. regional multidisciplinary experimental test sites for the future NASA high flight earth resources survey aircraft that would simulate the Earth Resources Technology Satellite (ERTS) overflights scheduled for orbit in 1972. In order to provide an adequate and effective data flow from ERTS to USDA, the Department also continued studies with NASA to assist in the development of a data network concept, including data acquisition, processing, reproduction, dissemination, analysis, evaluation, cataloging, storage, retrieval, and feedback.

Assistance was also provided NASA by USDA in the development of an International Workshop Program on remote sensing of earth resources scheduled for May 1971. USDA is expected to contribute 10 to 12 lecture topics.

USDA was a member of an interagency task group in a definitive policy study toward the establishment of a national earth resources survey program aimed at the full utilization of ground, aircraft, and satellite remote sensing data.

USDA was a member of a joint task force in which a study was made to determine the most effective and expeditious manner in which to monitor and evaluate national natural disasters and catastrophies via aerospace and other systems.

In order to determine the feasibility and potentiality of utilizing aerospace remote sensing technology for less developed countries USDA participated in an Agency for International Development symposium.

The interest of many countries has been aroused by USDA's remote sensing research activities. During 1970 visitors from Argentina, Australia, Belgium,

Brazil, Canada, England, France, Germany, India, Israel, Italy, Mexico, Netherlands, and South Africa came to the Department to be briefed. Briefings were also given to some 50 foreign agricultural counselors based at their Washington, D.C. embassies.

Remote Sensing Program

The Department, during 1970, recognized its need to continue its efforts to develop the capability to collect, analyze, and utilize the near realtime synoptic and sequential data to be obtained from remote sensing experimental satellites, in preparation for future operational satellite systems. It established an Earth Resources Survey Committee to aid in the coordination of effort and the formulation of guidelines for the Department's effective participation in a national earth resources program. It further assessed its in-house capabilities to handle the anticipated large quantities of data which will be acquired from the experimental Earth Resources Technology Satellites A and B, Skylab, and high flight aircraft systems proposed by NASA. Concomitantly, USDA further identified its data and information needs to effect the greater usage of aircraft and satellite systems of the future. It continued in the

attempt to acquire and properly equip a multi-instrumented remote sensing research aircraft in order to more effectively acquire, analyze, evaluate, and utilize data obtained on crops, forests, ranges, and on soils and water conditions in a more accurate, rapid, and timely manner. Possession of its own airborne remote sensing research platform will lessen considerably the Department's dependence upon others for the acquisition of data. Several approaches to the problem are being considered. An expanded effort was also made to apprise not only its agencies but also its 53 affiliated Federal and State experiment stations and 17 State schools of forestry, agribusinesses, and the agricultural community at large of the feasibility and the potential benefits to be derived from a remote sensing earth resources survey program. USDA, in cooperation with NASA and the National Academy of Sciences, published a 424-page treatise entitled "Remote Sensing—With Special Reference to Agriculture and Forestry." The purpose, in part, was to bridge the communications gap that exists among agricultural and forestry scientists, physical scientists, and data processing specialists. It also provides background information on the potential uses of remote sensing in agriculture and wildland resources and a technical appraisal of state-of-the-art sensors and discrimination techniques.

XI



Department of Commerce

Introduction

The Department of Commerce has four major organizational units engaged in activities that contribute to the national aeronautics and space program. These are the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Maritime Administration, and the Office of Telecommunications. Other units of the Department contribute indirectly. The U.S. Patent Office, for example, issues patents on inventions with space applications, and the National Technical Information Service collects and distributes scientific and technical information produced under the aeronautics and space program.

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) was created within the U.S. Depart-

ment of Commerce on October 3, 1970, pursuant to Presidential Reorganization Plan No. 4 of 1970. The NOAA is composed of organizational entities from the Department of Commerce, the Department of the Interior, the Department of Transportation, the National Science Foundation, and the Department of Defense. The Environmental Science Services Administration (ESSA) of the Department of Commerce was abolished and its major units were incorporated into the NOAA. Current NOAA organizational elements and the organizations from which they were derived are shown below:

<i>NOAA organizational elements</i>	<i>From</i>
National Weather Service.	ESSA Weather Bureau.
National Marine Fisheries Service.	Bureau of Commercial Fisheries and the Marine Sport Fish Research Program, both from Department of the Interior.

<i>NOAA organizational elements</i>	<i>From</i>
Environmental Research Laboratories.	ESSA Research Laboratories.
National Ocean Survey	ESSA Coast and Geodetic Survey, and the U.S. Lake Survey from the U.S. Army Corps of Engineers.
National Environmental Satellite Service.	ESSA National Environmental Satellite Center.
Environmental Data Service.	ESSA Environmental Data Service, and the National Oceanographic Data Service from the U.S. Navy.
Office of Sea Grant	National Sea Grant Program of the National Science Foundation.
Data Buoy Project Office	National Data Buoy Project of the Coast Guard, Department of Transportation.
National Oceanographic Instrumentation Center.	Same name, U.S. Navy.
Marine Minerals Technology.	Same name, Department of the Interior.

The NOAA mission is to explore, map, and chart the global oceans, their basins, their geophysical forces and fields, and their biological and mineral resources. New physical and biological knowledge will be translated into systems to assess the sea's potential yield, and into techniques which the Nation and its industries can employ to manage, use, and conserve these animal and mineral resources. NOAA will monitor and predict the quickly changing elements of the physical environment in real time. The atmosphere, oceans, sun and the solid earth will be under constant surveillance. Predictions will be made of weather, tides, solar flares, and changes in gravity and geomagnetism. Warnings will be given on impending environmental hazards to ease the burden caused by hurricanes and floods, tornadoes, tidal waves, and other natural disaster conditions. NOAA also will monitor and predict the gradual and inexorable changes of climate, seismicity, marine-life distributions, earth tides, continental position, and the planet's internal circulations, and will note and examine the effects of civilization and industry on the environment and life. To accomplish these objectives, NOAA will draw upon the knowledge, talent, and experience of its personnel, and its wide range of facilities, and will strengthen the mutually important links between government, universities, and industry. NOAA and its institutional partners will develop technology and systems for more effective assessment of resources, utilization of environmental data, environmental monitoring and prediction, and possibly for environmental modification and control. Thus, the growing family of satellites, sensors, ships, data buoys, computers, and simulators, will be used to extend man's capability for observing his environment and to provide the technology for

essential environmental services. In these ways NOAA will seek to improve the safety and the quality of life, and man's comprehension, use, and preservation of his home, the planet Earth.

Highlights of 1970.—On January 23, 1970, an Improved Tiros Operational Satellite, I-TOS 1, was successfully launched by NASA. This satellite is the operational prototype of the second generation of polar-orbiting operational environmental satellites. I-TOS 1 meets major National Operational Meteorological Satellite System (NOMSS) objectives in that it has the capability to obtain nighttime observations, temperature measurements of cloud tops and the earth's surface, and is equipped with a solar proton monitor.

ESSA-2, the first Automatic Picture Transmission (APT) spacecraft of the Tiros Operational Satellite system was retired after almost 5 years of continuous service. This spacecraft was launched February 28, 1966, and was deactivated October 16, 1970, after 1,691 days in orbit.

The improved Satellite Infrared Spectrometer (SIRS-B) on Nimbus 4, launched April 8, 1970, obtains measurements of atmospheric water vapor content and vertical temperature profiles. SIRS-B also provides a more dense network of observations than did the earlier SIRS-A carried on Nimbus 3.

NOAA-1, designated I-TOS A prior to launch, was placed in orbit on December 11. This is the first operational satellite of the ITOS system.

Intensive, realtime operational experiments to use Applications Technology Satellite (ATS) pictures were conducted by the National Environmental Satellite Service, the National Severe Weather Warning Center, Kansas City, and the National Hurricane Center, Miami. The purpose was to test the utility of near-continuous cloud cover observations for severe weather warnings, and for hurricane surveillance, advisory, and warning operations.

NOAA and NASA initiated procurement for the Geostationary Operational Environmental Satellite (GOES) system. NASA will produce the operational prototype spacecraft in its Synchronous Meteorological Satellite (SMS) project.

Solar proton data, obtained in near real-time from the I-TOS 1 satellite, were used to support the Apollo 13 mission in the critical hours prior to reentry.

The National Marine Fisheries Service started investigations on the uses of aerospace sensors for charting the oceanic environment of marine life, and for locating and tracking fish stocks.

NOAA National Weather Service has furnished support, under the World Meteorological Organization Voluntary Assistance Program, for the installation in foreign countries of 10 ground stations for receiving data directly from U.S. environmental satellites.

National Weather Service

The National Weather Service (NWS) is involved in the aeronautics and space program in two ways. NWS furnishes weather support to the space program through its Space Operations Support Division and to civil and military aviation through its forecasting services and research programs. The NWS also is involved in determining the usefulness of space technology for its data gathering and dissemination systems, and the usefulness of space-acquired data for weather analysis and forecasting. During 1970 the National Weather Service has expanded its operational use of space technology using satellite-acquired data in its routine analysis and forecasting procedures, and satellite telemetry systems to relay information expeditiously. The NWS also provides meteorological guidance and support for space test facilities and operations.

Collection and Relay of Data by Satellites.—The Applications Technology Satellite ATS-1 has been used experimentally for the past 2 years to collect river stage and rainfall measurements from untended automatic stations and to relay these data to a central point for analysis. This successful experiment will become operational with the planned 1972 launch of the prototype GOES. These data will be used routinely in the preparation of flood forecasts, and for research into many water resources problems. The telemetry system will also be used to broadcast timely warnings of flood conditions. As the system develops, other hydrological sensor equipment will be added to the GOES data collection and relay system.

The ATS-3 satellite transponder is in use in a continuing operational experiment, testing an inexpensive shipboard data transmitter as part of the design of system for rapid collection of weather data from ships at sea.

Snow Mapping by Satellite.—Studies performed under contract for the National Environmental Satellite Service (NESS) and NWS have materially aided in providing a better understanding of the benefits and limitations of visual photographic mapping by satellite of snow-covered areas. Timely data on the areal extent and water equivalent of snowfields are required by hydrologists in the preparation of river and water supply forecasts for the nation. NWS River Forecast Centers are receiving satellite products for application to these operational problems.

Remote Sensing of the Water Equivalent of Snow.—Techniques are being tested for remote measurement of the water equivalent of snow cover from sensors aboard aircraft. Sensing techniques are based on the changes in attenuation of natural earth-emitted gamma

radiation due to variations in the water equivalent of snow. The results of the first year of research are promising for future application of the method to operational river forecasting.

Cloud pictures collected routinely from the ATS satellites by NOAA's Wallops Station command and Data Acquisition Station are processed for retransmission by the ATS transponders to local Automatic Picture Transmission (APT) ground stations at Honolulu and San Francisco where they are used in the daily operations of the forecast offices.

Special receivers for ATS pictures were established at the National Severe Storm Forecast Center (NSSFC) at Kansas City and the National Hurricane Center (NHC) in Miami. The installations are complete, with high quality photographic recorders, special receiving equipment, and a complete photographic laboratory. In addition to photographic prints, 16-mm. movie loops are produced, by which the evolution and motion of the storms can be observed and studied. This represents a breakthrough for the field forecasters. It enabled the NHC to program reconnaissance flights more efficiently and the NSSFC to evaluate the radar weather data more effectively.

Digitized Cloud Mosaics.—Digitized mosaics of satellite cloud pictures are transmitted routinely from the National Meteorological Center to NWS forecast offices throughout the United States. The mosaics, now prepared and transmitted once a day, will be replaced with mosaics prepared and transmitted on an orbit-to-orbit basis (approximately once every 2 hours).

Automatic Picture Transmission.—Early in 1968 the National Weather Service began the transmission of raw APT signals in an existing central facsimile network. The APT data acquired at Wallops Station, Va., San Francisco, Calif., and Kunia, Hawaii, are transmitted to stations on the network within minutes after receipt from the satellite. Transmission of infrared nighttime imagery was added in November 1970. This operational network has been expanded to include a large number of Air Force and Navy installations in the conterminous United States. The number of APT stations needed for Government weather stations has decreased materially as a result of this network operation.

Under the voluntary assistance program the Weather Service has provided technical assistance and advice for installation of complete APT systems in 10 underdeveloped countries. More installations are planned.

Nimbus 4 Satellite Infrared Spectrometer.—The SIRS-B spectrometer, an improved version of the SIRS-A used on Nimbus 3, is furnishing global vertical temperature and moisture profiles daily. These data

are used as experimental operational input to the numerical (computer) weather analysis programs, and are being evaluated for their accuracy. Availability of these data globally in realtime conceivably could lead not only to improvement in the computer forecasts but also to economic savings from reprogramming of the current ground-based upper-air observation network.

Meteorological Support to Space Operations and Test Facilities.—Through its Space Operations Support Division, NWS furnished the primary meteorological guidance for several NASA activities. NWS provided staff and local forecasting support for the Kennedy Space Center and the Manned Spacecraft Center, and forecasts of weather and sea conditions for the Apollo 13 flight.

After the Apollo 13 in-flight explosion, forecasts were required for many possible emergency landing areas in the Southern Hemisphere and finally for the actual landing some 500 miles south of the Samoan Islands. Weather satellites again provided a principal source of data on which these remote area forecasts were based. A new global prognosis chart prepared by the National Meteorological Center also was useful for the predictions in the Southern Hemisphere tropics.

At the NASA Mississippi Test Facility, the NWS team made weather observations and forecasts for the ground testing of the final nine Apollo-Saturn rocket engines scheduled at the facility.

At the NASA Wallops Stations, NWS provided weather support for the varied activities of that facility. In support of the scientific program conducted during the total solar eclipse on March 7, 1970, 24 rocket probes were fired, 13 in a 15-minute period. A vast number of surface and upper air weather observations were recorded before, during, and after the eclipse, in support of the rocket firings.

Utilization of Aircraft.—Meteorologist-pilots of the quality control staffs at NWS headquarters fly light, 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 evaluations.

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

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

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

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

National Marine Fisheries Service

The National Marine Fisheries Service (NMFS) plays a major role in the development and utilization of national fisheries resources. The NMFS mission is to discover, describe, develop, and conserve the living resources of the oceans, particularly those that affect the economy and food supplies of the United States. To this end the NMFS conducts biological and ecological research on fish and marine organisms, analyzes the economics of fishery operations and marketing, develops methods for improving catches, and conducts a voluntary grading and inspection program of fishery catches. The NMFS and the U.S. Coast Guard conduct joint enforcement and surveillance operations in territorial waters of the United States and on the high seas. Twenty-nine vessels, 30 laboratories, and 50 offices across the Nation are used to carry out the NMFS mission.

Aerospace Program for Remote Sensing.—Since the ocean environment determines the activity and movement of fishes and other marine life, it is necessary to study this environment in as much detail as possible. In the past such measurements were, of necessity, limited to those that could be acquired by ships and shore stations. Remote sensors, developed concurrently with aerospace technology, have great potential as means for acquiring detailed, timely measurements over large areas of the ocean. The NMFS signed an agreement with NASA on August 21, 1970, that initiated a program to assess the value of remote sensing to their mission. This is the National Marine Fisheries Aerospace Remote Sensing Program at NASA's Mississippi Test Facility. Sensors mounted on aircraft will be tested to determine their utility for measuring patterns of ocean surface temperature and for locating fish stocks. Instruments to be tested include low-light-level image intensifiers, lasers, aerial cameras, and spectrometers. As tests proceed, existing instruments may be modified

and new instruments may be developed. In addition, observations of oceanic patterns over large areas will be studied by using measurements obtained from spacecraft sensors. The NASA is cooperating with and advising the NMFS in the development of instrumentation and sensor systems to gather data from spacecraft during the proposed Earth Resources Technology Satellite (ERTS) and Skylab programs. The NMFS has also started studies of the surface temperature patterns of the oceans using infrared data obtained by NOAA's Environmental Survey Satellites. These studies are part of a general program being developed by NMFS to relate space-acquired oceanic data to the NMFS mission requirement for assessing and monitoring living marine resources. The NMFS requirements for ocean surface data closely matches the requirements of the NWS and of the National Ocean Survey in that the data required in common are ocean surface temperatures, sea state (wave conditions), winds, sea currents, storm locations, salinity, and other phenomena.

Environmental Research Laboratories

The Environmental Research Laboratories (ERL), with headquarters in Boulder, Colo., conduct the fundamental investigations needed to improve man's understanding of the physical environment. Ten laboratories conduct research in the various scientific disciplines required in support of NOAA missions.

Office of the Director.—Two geophysical studies were conducted in support of systems design for geostationary satellites for aeronautical communications. One was to determine the effects of ionospheric irregularities in polar regions on S-band (1,700 MegaHertz) radio signals passing through the ionosphere. Transmissions received at Gilmore Creek, Alaska, from ESSA 8 and I-TOS 1 at both 1,700 MHz and 137 MHz were used to detect these effects (known as scintillations). Comparisons showed that scintillations at the higher frequency are considerably smaller than those at the lower frequencies usually used for satellite communications.

The second study was to determine what effects polar region solar proton events have on satellite signals. Although such events, known as polar cap absorption (PCA), are rare, they can absorb radio signals transmitted through the ionosphere. Such absorption can be considerable and can last many hours. Calculations of the effects of PCA on 137 MHz transmissions at the elevation angles to be used with geostationary satellites established the probable amount of such absorption and its geographical extent. Analysis of PCA events over the past 15 years also established the

probability of occurrence of various amounts of such absorption.

A cooperative program to study the interaction of mountain waves and clear air turbulence was undertaken by NOAA units, the National Center for Atmospheric Research (NCAR), the U.S. Air Force, and the Canadian Research Establishment. Aircraft used in the investigation included two USAF and one NOAA RB-57, NCAR's Saberliner and Buffalo, and the NOAA high-altitude glider. Measurements of turbulence and wind conditions in mountain waves were made at 25 levels, ranging from 13,000 to 65,000 feet, to obtain vertical profiles of these phenomena. Severe turbulence was encountered primarily at 60,000 feet, and wind direction reversals occurred in two cases. The new understanding of clear air turbulence gained from these investigations will be particularly useful to those flying high altitude and supersonic aircraft.

Atmospheric Physics and Chemistry Laboratory (Boulder).—In a program to study inadvertent weather modification caused by jet contrail "clouds," infrared radiometers carried aboard a NASA 990 aircraft were used to obtain thermal measurements. Immediately beneath the contrails, a decrease of about 7 percent in net incoming radiation was observed at the earth's surface. However, these effects were found to decrease rapidly as one moved 50 miles on either side of the jet corridor. A recent pilot program was conducted with a stratospheric jet aircraft carrying a down-looking spectrometer to measure atmospheric effects of infrared radiant emission from vapor trails. This experiment, conducted at 65,000 feet, showed essentially no effect at altitude and no effect at the earth's surface. These measurements are expected to be important in evaluating the effect of increasing jet aircraft traffic on local and worldwide climate.

Possibilities for eliminating the hazard to manned spacecraft launches caused by lightning discharges are being studied. One approach is to predict the possibility of natural electrical discharges, using measurements of electric field conditions in the launch area just prior to launch. The other approach is to discharge potential lightning by artificial means just prior to launch of a vehicle; this should greatly reduce the possibility of hazardous discharges during launch. Small rockets were launched into thunderclouds to test this idea. The rockets did trigger discharges, and aircraft measurements obtained in the cloud shortly after the rocket firings indicated a significant reduction in electrical field strengths.

Air Resources Laboratory (Washington, D.C.).—The laboratory and the FAA conducted studies on the effects of the sonic boom produced by supersonic aircraft. A study was done at Pendleton, Oreg., on the effect of sonic boom on the space-time variability of

atmospheric parameters. A significant small-scale space variability in overpressure was detected.

A quantitative study was conducted on the geometry and intensity of wing tip vortices produced by heavy aircraft such as the 747 and C-5A flying at low altitudes. These measurements, gathered by sophisticated meteorological instruments mounted on low-flying aircraft, were used by the FAA for establishing regulations to guarantee safe distances between aircraft in flight.

ERL Research Flight Facility (Miami, Fla.).—The facility provided and operated aircraft in support of weather modification experiments, hurricane surveillance, and experiments requiring collection of data.

During the solar eclipse of March 7 RFF aircraft seeded stratiform clouds with dry ice in the vicinity of Langley AFB. The seeding was done to dissipate the cloud so the NASA facility could photograph the eclipse.

During the period April 15–May 31, RFF participated, with other research groups, in an experiment over south Florida using pyrotechnics to seed cumulus cloud with silver iodide. The objectives of the experiment were to repeat the single-cloud seeding experiment of May 1968 to obtain a statistically significant cloud sample (30 clouds) and to use massive silver iodide pyrotechnic seedings of individual cumulus clouds. The latter part of the experiment was to permit recognition and documentation of any changes in meso-scale structure and precipitation resulting from seeding.

Extensive reconnaissance and research was conducted on cyclogenesis on the Atlantic coast of the northeastern United States during the fall and winter of 1969. The main objective was to provide real-time data to the operational forecaster in an attempt to improve forecasts of coastal storms.

Aeronomy Laboratory (Boulder).—This laboratory studies the physical and chemical processes of the ionosphere, upper atmosphere, and exosphere of the earth and other planets.

One accomplishment of 1970 was the first completely successful rocket flight of an atomic-oxygen sensor for the upper atmosphere. Atomic oxygen is an important constituent of the atmosphere at altitudes above the stratopause; prior to the development of this new rocket-borne sensor, measurements of its concentration have not been obtainable. The new measurements will permit a definitive choice of a theory of the production and loss of atomic oxygen, thus promoting our understanding of the interaction between the upper and lower atmosphere.

A continuing extensive program of laboratory measurements of atmospheric ion-molecule reaction rates has resulted in major advances in understanding the importance of water vapor in the lower ionosphere

and the role of carbon dioxide in the ionospheres of Mars and Venus.

Experimental studies in upper-atmosphere plasma physics are continuing. Under investigation is the structure of radio-frequency fields within the nonuniform plasma sheaths that surround spacecraft reentering the atmosphere.

Earth Sciences Laboratory (Boulder).—ESL conducts research in geomagnetism, seismology, geodesy, and related technologies.

Hydromagnetic wave emissions at 0.33 Hz were observed at the Dodge satellite as it drifted across the geomagnetic field line connecting Byrd (Antarctica) and Great Whale River (Canada). These data are being used in studies of rapid variations in the geomagnetic field, and to test current theories on the origin of such emissions. The use of satellite observations will be increased as a result of the successful detection described above.

Space Disturbances Laboratory (Boulder).—This laboratory conducts research on solar-terrestrial physics, and develops techniques for accurate forecasting of solar disturbances, and their effects on the earth environment. SDL is the national and international focal point for current information on the solar-terrestrial environment; SDL disseminates this information and current forecasts to a wide variety of users.

Studies of solar physics are conducted to gain understanding of solar energy release mechanisms with the aim of improving forecasts of the times and locations of solar flares that can produce geophysical disturbances. Recent findings include:

- Analyses of high resolution magnetograms show that the magnetic field of the solar surface can be resolved into small elements with strengths of about 20 gauss.
- Periodic brightenings on the solar disc of hydrogen alpha mottles, with a period of about 5 minutes and phase coherence over regions 30,000 KM broad have been identified with solar acoustic-gravity waves.
- It has been found that energetic ultraviolet (EUV) radiation and hard X-ray bursts from solar flares are correlated. The energy of electrons required to produce hard X-rays appears sufficiently strong to account for the EUV, through ionization and subsequent radiative recombination in the lower chromosphere.
- The intensity variations of white light emission in some large flares were found to be well correlated with a strong flux of EUV at 10 to 1030 Angstroms, and that the flux increase in white light is approximately equal to that in the EUV

range. This correlation is of interest since the occurrence of white-light flares seems to be directly connected with collisions between two sunspot groups.

Studies continue on the interactions between the magnetosphere and the solar wind, the transfer of energy from the solar wind into the earth's magnetosphere, and the behavior and transport of this energy within the magnetosphere ionosphere and upper atmosphere. Satellite measurements appear to confirm current theories on magnetosphere shock wave formation.

Experimental ground-based observation of interplanetary scintillations at 11.4-meter wavelengths yielded daily information from September 1969 through April 1970. This information on the velocity and small scale structure of the solar wind complements the suprathreshold observations obtained by particle detectors aboard scientific satellites. These measurement techniques can be used to detect and fix the location of an interplanetary magnetic field sector boundary between the sun and the earth; such information could be used to predict when the boundary will sweep past the earth. If such observations became available routinely, they would be of great use in forecasting magnetic and ionospheric activity.

The SDL cooperated with a Canadian research group at York University in flying photometric sensors on two Black Brant III rockets. The start of an infrared aurora was measured by this instrumentation, yielding valuable information on the energy characteristics of a unique excited state of the oxygen molecule. This newly observed phenomenon suggests the existence of a source, other than particle precipitation, for infrared emissions. Auroral studies using rocket sensors are being planned with the University of Bergen and four launches are planned.

Data from the solar proton monitor aboard the I-TOS 1 were available for operational use during the Apollo 13 mission. Real-time data from this instrument are becoming available for routine use in space environment monitoring and forecasting. Solar proton and magnetic data, now available continuously from the ATS-1 and Pioneer satellites are particularly useful to the Space Disturbances Forecast Center for early detection and real-time analysis of solar proton events.

SDL assumed operation of the solar proton alert network (SPAN), under a contract with NASA. The SPAN network consists of four ground-based solar observation stations spaced to permit continuous observation of the sun with radio and optical telescopes. Data from this network are used to detect solar proton events. With the inclusion of this activity, the SDL has become a world data center for ground-observed solar data.

A new spectrohelioscope built and installed at SDL in 1970 permits routine observations of sunspot and plage magnetic polarities. This instrument has made possible the collection of a data base adequate for routine sunspot forecasting. It is now possible to predict the location of about 80 percent of all flares.

SDL is involved in determining specifications for a beacon to be flown on NASA's ATS F for use in studies of the magnetosphere and ionospheric electron densities. Signals from the beacon will be received by scientific groups in other nations; SDL is coordinating international scientific activities on the use of the signals.

SDL participates, under NASA contract, in the International Satellite for Ionospheric Studies (ISIS) program. The satellite data acquisition station at Boulder receives data from ISIS 1, and Alouette 1 and 2, and reduces the data to ionograms for dissemination to participating scientific groups.

Other ongoing programs of SDL include analysis of data from the Interplanetary Monitoring Platform (IMP) and Orbiting Geophysical Observatory (OGO) satellites, and support to NASA for the Apollo Telescope Mount program.

National Ocean Survey

The National Ocean Survey (NOS) continues to make steady progress in support of the aeronautical and space programs of the United States. The basic programs of the NOS in this area 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. In addition, NOS provides seismic and geomagnetic support to space facilities and activities.

Aeronautical Charts.—Aeronautical charts published by NOS play a key role in the management and use of the national airspace. They are a means for implementing regulations and air traffic control procedures to make possible safe and efficient aerial navigation.

In 1970 considerable progress was made by NOS in converting all domestic aeronautical charts to specifications approved by the Inter-Agency Air Cartographic Committee. The specifications are designed to assure a single, uniform air cartographic product for use by both military and civil aviation.

Geometric Satellite Triangulation.—Data acquisition for the worldwide satellite triangulation network was completed during mid-November 1970. This program designed to establish a world data system connecting all of the continental data systems is based on the strictly geometric technique of photographing sun-reflective satellites against the star background. It be-

gan with the launch of PAGEOS in June 1966 as an integral part of the National Geodetic Satellite Program (NGSP), and will serve as the primary geometric framework for other phases of the program.

Forty-five stations in 23 countries have been established through the joint efforts of NASA, the U.S. Departments of Commerce and Defense, and the 23 host countries. This national program, under the technical direction of NOS will provide a unified three-dimensional framework encircling the earth and connecting all major land masses of the world within the extremely close tolerances in all three positional components.

NASA has overall management responsibility for the NGSP; they designed and launched the PAGEOS satellite and furnished orbital elements for computation of observation predictions. The Topographic Command (TOPOCOM) of the U.S. Army Corps of Engineers, has the primary responsibility for logistics. They furnished four field observation teams and equipment. NOS has the technical responsibility for data acquisition, reduction, analysis, and initial publication of results. NOS provided for personnel training and furnished operation manuals and up to 10 field observation teams at a time.

International cooperation has been generous and substantial, indicating the interest in and the recognized need for an accurate, three-dimensional worldwide geodetic control network. The following nations participated by permitting the establishment of from one to seven camera stations within the country or its territories: Argentina, Australia, Brazil, Chad, Chile, Denmark, Ecuador, Ethiopia, Federal Republic of Germany, Iran, Italy, Japan, Mascarene Islands, Mexico, New Zealand, Norway, the Philippines, Portugal, Senegal, South Africa, Surinam, Thailand, the United Kingdom, and the United States.

During the program, the Federal Republic of Germany furnished two camera teams and two observation systems. The United Kingdom supplied a field team. The Republic of South Africa, Australia, and Mexico furnished observation teams during operations in their countries. In addition, Australia provided complete logistic support for two stations at their Antarctic bases.

To scale the satellite triangulation properly, at least four base lines spaced around the world were essential to meet NGSP accuracy requirements. In the U.S. work continued on the measurement of a precise geodimeter traverse network with connections to two of the worldwide network stations and to several of the supplemental network stations. Geodetic organizations in Norway, Sweden, Denmark, Federal Republic of Germany, Austria, Italy, Australia, Nigeria, and France cooperated by measuring the required scale lines.

The PAGEOS and Echo II satellites were utilized as observational targets for all data acquisition. Of the almost 10,000 simultaneous photographic observations scheduled during the program, almost 1,500 were successful, resulting in about 3,000 useful plates. Photogrammetric processing during 1970 included 192 new plates measured, 427 old plates remeasured to conform to new criteria, and 256 plates processed through analysis and computation. To date in the program, a total of 1,550 plates has been measured and processed through analysis and computation. New computer programmed data reduction and analysis methods have been introduced to provide a final accuracy of at least one part per million in terms of earth dimensions.

The measuring and processing of photographic plates will continue as planned, with completion of data processing scheduled to occur during 1972.

Many developments and improvements in methods and equipment were adopted during the period 1967 to 1970. Precise transfer of epoch time was accomplished at first by use of portable crystal clocks and later replaced by portable cesium clocks. Transponders aboard geostationary satellites of the ATS type were utilized for time transfer to remote islands in the Atlantic and Pacific Oceans. A time reset capability using polar-orbiting doppler satellites was developed and successfully used at stations in the Antarctic. As Loran C chains became synchronized and available, they were used to provide time reset capabilities without the necessity for carrying portable clocks from station to station.

As data acquisition for the world net drew to a close in the fall of 1970, NOS continued the Cooperative Program of Satellite Triangulation Densification in North America which was established in 1963. TOPOCOM and Canadian interests furnished airlifts and observer personnel. The United Kingdom is continuing support by providing two observation teams.

Observations were conducted from July through September 1970 at five stations in the southern United States. Currently, field teams are on station in Alaska, Canada, and Greenland. Current plans call for the completion of the field work during 1972 and the computations during 1974.

Photogrammetric Applications.—In the area of aerial photography technical and theoretical assistance was provided in support of the NASA Apollo Program. A metric camera experiment was designed to determine geometric as well as gravimetric conditions on the moon.

NOS operates two aircraft to conduct aerial photographic missions required for NOAA programs. One aircraft is a Government-owned, twin-turboprop; the other is a leased, twin-engine aircraft. Both are manned by specially trained NOAA pilots and aerial photographers.

The aerial metric photography, in which panchromatic, infrared, and color film is used, supports aeronautical and nautical charting programs, seaward boundary surveys, and coastal inundation mapping. Photogrammetry is also used in surveys of areas devastated by earthquakes and hurricanes, surveys of estuarine and ocean currents, and for monitoring crustal movements in areas of high seismicity.

Seismological Activities.—Expansion of the Tsunami Warning System continued. The eventual goal is a network of 30 seismograph stations and 84 tsunami detectors (tide gage and wave sensors). It is planned that elements in the network will eventually telemeter actual recordings to an analysis center in Hawaii via a geostationary satellite. Automatic transmission—by triggering or on query from the satellite—automatic signal identification, and on-line earthquake hypocenter and tsunami arrival-time computations are being planned.

Seismic background characteristics were determined for the Goldstone, Calif., NASA facility where a proposed laser satellite communication installation would be located. Vibrations caused by local industrial sources were identified and documented, and an optimum location for the installation was selected on the basis of this information.

A site evaluation study was made at White Sands, N. Mex., using shallow seismic refraction techniques. NASA plans to use the selected site for a project to determine the feasibility of using energy from rocket thrust plumes as a seismic energy source for the moon.

Geomagnetism.—NOS continued its long-term cooperation with NASA in the development of geophysical instrumentation for space applications. A controlled magnetic environment test chamber, the NOS Fredericksburg Geomagnetic Center, is used in this work. NOS also provided facilities and technical assistance to the U.S. Naval Oceanographic Office for testing and calibrating instrumentation employed on Project Magnet, a worldwide, airborne geomagnetic survey.

In a joint effort with NASA, NOS is using computers to process geomagnetic analog records from some 50 worldwide magnetic observatories and geomagnetic data collected by satellite and space probes. These cooperative efforts have been in progress for the past 7 years.

NOS published a Technical Report (C. & G.S. 38) containing a description of a Fortran II computer program for deriving magnetic values at points near and above the earth's surface. The mathematical model is the International Geomagnetic Reference Field for 1965; this model is used as a common base by scientists around the world in studies of the earth's main magnetic field and in studies of related atmospheric, iono-

spheric, and outer space parameters. The report also includes tables of total magnetic intensity and annual change data on a worldwide grid, and small scale world charts of total magnetic intensity.

The 1970 issue of the *World Magnetic Charts* was published; for the first time analytical methods were used to describe secular change patterns as well as distribution of the magnetic field. Among other important uses, these charts provide basic magnetic data for worldwide nautical and aeronautical charts.

Use of Navigation Satellites.—Five NOAA survey vessels are equipped with satellite navigation systems to provide the accuracy in position fixing necessary for deep sea surveys.

Satellite Telemetry Applications.—The Coast Survey Marine Observation System is a stable, moored, sub-surface platform from which oceanographic and atmospheric measurements can be collected. A surface float with attached telemetry antenna provides the capability for telemetering data in real time via the ATS-3 satellite. The telemetry package was provided through a cooperative agreement with NASA. The power source is a radioisotope thermoelectric generator provided through a cooperative agreement with the U.S. Navy. One of the first applications planned for the platform is its use as a tsunami detection station in the mid-Pacific Ocean.

Plans are being made for development of a system for telemetering geomagnetic data in real time via satellite from a network of magnetic observatories to a central receiving station in College, Alaska.

National Environmental Satellite Service

The National Environmental Satellite Service (NESS) plans and operates environmental satellite systems, gathers and analyzes satellite data, and develops new methods of using satellites to obtain environmental data. As environmental satellite technology matures, sensors will be added to measure additional atmospheric characteristics, and to provide data on solar, ionospheric, oceanographic, and other geophysical phenomena.

Environmental Satellites.—The operational environmental satellite system inaugurated the second generation operational spacecraft with the launch of the NASA-funded I-TOS 1 in January 1970. The Improved Tiros Operational Satellite (I-TOS) replaces both the Automatic Picture Transmission (APT) and Advanced Vidicon Camera System (AVCS) satellites of the first-generation Tiros Operational Satellite (TOS) system which have been used since 1966. NOAA 1 (I-TOS A), the first of the NOAA-funded

second-generation satellites, was launched in December 1970.

The I-TOS satellites fulfill a major service objective—daily observation of global weather conditions, day and night.

Operations of NOAA Satellites.—At yearend, two of the first-generation TOS satellites—ESSA 8 (APT) and ESSA 9 (AVCS)—remain in operable condition: ESSA 8 is used regularly to supplement the direct readout service from I-TOS 1 and NOAA 1. ESSA 9 is held in standby status to supplement the global observing services of the I-TOS spacecraft if needed.

The I-TOS satellite provides both full global coverage and direct local readout services. Observations are provided twice daily at 12-hour intervals. In addition to vidicon camera systems of the type used in the earlier TOS satellites, the I-TOS satellite carries a two-channel scanning radiometer. This sensor provides daytime and nighttime (infrared) observations of the earth's cloud cover. In addition, the data from the infrared sensor can be converted to temperature; in cloudy areas this information provides a measure of cloud top height. In clear and partly cloudy areas, sea surface temperatures may be derived from the infrared observations for use by environmental service agencies.

Both global and direct readout services are provided by I-TOS. Observations by the vidicon camera system and/or the scanning radiometer are recorded as the satellite proceeds along its orbit. The stored data are transmitted to ground stations in Alaska and Virginia, relayed to a central processing unit at Suitland, Md., processed, and made available to environmental service agencies nationally and internationally.

Data from the APT camera and the scanning-radiometer are broadcast continuously for reception by simply equipped ground stations within a 2,000-mile range of the satellite. A given station can obtain observations from the satellite during a period centered on 3 p.m., local standard time, and again around 3 a.m., local standard time. These data are acquired and used daily at some 500 locations in over 50 countries around the world. The pictures are used as a basis for local, area, and air-route forecasts, to illustrate television weather programs and newspaper weather reporting, and to support a variety of operations. In addition to the imaging and temperature sensors, the I-TOS carries a solar proton monitor (SPM) as part of its complement of operational instruments. This sensor provides a measure of the solar proton flux in the polar regions. These measurements are used in providing support to telecommunications agencies. Data from SPM were used to support Apollo 13 during critical hours before reentry.

Applications Technology Satellites.—NOAA has cooperated with NASA to continue the experimental

operation of ATS-1 and ATS-3. During this past year, intensive operational experiments have been conducted in the application of geostationary satellite observations to severe storm advisory services and to hurricane surveillance, advisory, and warning services. Results of these experiments demonstrate the utility of near continuous observations to vital public warning and advisory services. For example:

One—At the National Severe Storms Center, on July 14, 1970, a line of clouds of the type associated with the early stages of severe weather was observed in the ATS picture. These clouds were in an area known to have high potential for the development of severe weather, but were undetected in the conventional network at this time. This interpretation of the satellite pictures led to an early issuance of a severe weather watch for the area downstream from where the cloud line was located. It was some 4 hours later that radar detected the squall line. This early warning was of particular value to the public as 26 events of severe weather occurred in the forecast area later in the day.

Two—On August 13 and 14, 1970, a tropical disturbance moved across the Atlantic from off Africa to just north of Puerto Rico. As it moved toward the U.S. mainland, it was observed by both satellites and aircraft. This storm contained unusually strong easterly winds, which the aircraft measured, ranging between 50 and 70 miles per hour in local areas. Normally, whenever winds this strong are observed in a tropical disturbance, it is named and warnings are issued so that all interests in its path can take hurricane precautions. However, the satellite showed that this was not a rotating storm and, therefore, did not cause immediate danger. On the basis of these satellite observations the decision was made at the National Hurricane Center in Miami not to name the storm and not to forecast that it would become a hurricane. The storm subsequently broke up, reformed, broke up again, and finally passed into the U.S. mainland near Cape Hatteras without becoming a hurricane.

An operational version of these stationary satellites, the Geostationary Operational Environmental Satellite (GOES) is being developed in NASA's Synchronous Meteorological Satellite (SMS) program. Launch of the first GOES prototype, SMS-A, is planned for mid-1972.

Nimbus IV.—This NASA research and development satellite, launched April 8, 1970, carried an improved version (SIRS-B) of the Satellite Infrared Spectrometer (SIRS-A) first flown in 1969 on Nimbus III. SIRS-A provided measurements along the satellite track from which atmospheric temperature profiles could be derived. The SIRS-B provides measurements along and to either side of the satellite track, from which both atmospheric temperature profiles and at-

ospheric water vapor content can be calculated. Temperature soundings obtained routinely from SIRS-B are used daily in the numerical upper air analyses and forecasts prepared by the NWS. The SIRS soundings are now being disseminated for use by other national and international environmental service agencies.

Environmental Service Products.—The NESS has continued the daily production and distribution of global and sectional cloud cover mosaics for use by environmental service agencies. Production of the average brightness and minimum brightness charts has continued also. These show 5-, 10-, 30-, and 90-day average cloud cover conditions, and the extent of snow and ice fields, respectively.

During the past year, techniques have been developed for deriving sea surface temperature analyses, and depictions of vertical and horizontal cloud distribution from the I-TOS infrared measurements. Production and evaluation of these new environmental service products have begun on a trial basis.

Operational Applications.—Meteorologists continue to find the satellite photographs particularly useful for detecting and tracking weather systems over about 80 percent of the earth where conventional observations are not available. This worldwide weather surveillance continues to contribute to more reliable and timely environmental service—forecasts, advisories, warnings—to maritime operations and to communities located within and around the ocean basins. For example, the 45 named tropical cyclones that occurred in the Northern Hemisphere in 1970 were all detected and tracked by satellites. Advisories concerning these storms and a larger number of unnamed tropical storms in both hemispheres, were sent to U.S. installations and foreign meteorological services worldwide.

Winds derived routinely from cloud motions observed by ATS 1 and 3 are used daily in numerical weather analyses produced by the National Weather Service and by U.S. military weather services.

Solar proton observations are used by the Space Disturbance Forecast Center in Boulder to support telecommunications and space activities. The data also are distributed to other space environment service agencies.

Research and Development Programs of the National Environmental Satellite Service.—The NESS devotes its research and development efforts toward applications studies to increase the utility of satellite observations to environmental services and development of techniques and sensors for measuring environmental variables from a satellite platform.

Major emphasis during this past year has been placed on studies to develop and refine techniques for extracting and using quantitative data from satellite observations for weather, oceanography, and hydrology service programs.

Some progress has been made toward automating methods for extracting winds from cloud motions observed by ATS 1 and 3.

Techniques for deriving temperature and geopotential height fields from SIRS data have been refined to eliminate dependence on the short-term statistical history of conventional observations.

Techniques currently available for remote sensing of the earth's surface are ineffective when the earth is cloud-covered. Microwave technology shows some promise of reducing or removing this restriction. Basic microwave physics has been examined and microwave observations obtained from the NASA aircraft program have been analysed during 1970 as part of a program to evaluate the utility of microwave sensors for acquiring data to meet NOAA requirements.

Major effort has been devoted to the design and development of the Vertical Temperature Profile Radiometer (VTPR) and the Infrared Temperature Profile Radiometer (ITPR). The VTPR is scheduled to begin operation on I-TOS in 1972. The ITPR, an advanced version of the VTPR type atmospheric temperature sounder, has completed aircraft tests and is scheduled to fly on a NASA Nimbus satellite in 1972. A team of United States and British scientists, under the leadership of NESS, has begun preliminary studies to specify the next generation atmospheric sounder for operational use in the latter half of the 1970's.

International Cooperation.—Worldwide direct read-out service via APT continued during 1970 and direct nighttime observations from the scanning radiometer were added. Some 50 countries own and operate ground stations to receive these satellite observations. Weather facsimile experiment transmissions through ATS 1 and 3 have continued on a semioperational basis providing APT ground stations with a variety of satellite products.

The NESS provided training and study facilities for WMO and AID Fellows from Turkey, Japan, Korea, Indonesia, Chile, Argentina, the Philippines, India, Poland, Vietnam, and Pakistan.

International Cooperation Plans.—The United States is cooperating with countries engaged in space activities, as well as with other countries of the world, in the application of satellites to meteorology. This cooperation presently manifests itself in two major international programs, the Global Atmospheric Research Program (GARP) and the World Weather Watch (WWW).

During March 1970, a planning conference on GARP was held in Brussels, Belgium, to review plans and to ascertain the possible national contributions to the experiments. Environmental data from satellites will play a major role in the data requirements for the experiments. At this conference the United States reported that present plans call for one geostationary environmental satellite to be launched in mid to late 1972, and possibly another by mid-1973. In addition to the plans for geostationary satellites, the program for the polar orbiting ITOS operational meteorological satellites will be continued.

The WWW plan for 1972-75 calls for two or three near-polar orbiting meteorological satellites in continuous operation during the period. The plan also includes four geostationary satellites to provide for reasonably complete near-global cloud coverage, and for wind determinations in the tropics from cloud displacement measurements. The United States has indicated that it will support this requirement in a fashion similar to that proposed for GARP. The plan also states that at least some of the near-polar orbiting satellites should be equipped with local direct readout of cloud images. The United States is the only country so far that has supported this requirement by equipping its satellites with direct readout sensors. The United States has assisted WMO members in the installation of direct readout stations in their countries, through support under the WMO Voluntary Assistance Program. Support for 10 direct readout stations has been provided to date. Internationally, this has been a very important program since it offers to developing countries the opportunity to obtain almost instantaneous information on the meteorological conditions affecting the climate of the country for a relatively small expenditure of equipment and personnel resources.

Washington-Moscow Data Exchange.—The United States and the U.S.S.R. have continued the exchange of satellite information over the Washington-Moscow data circuit throughout 1970. The Soviet Union has provided television and infrared information from four identical Meteor satellites (Nos. 3, 4, 5, 6), all launched this year. The primary application of data received from Moscow at the World Weather Center, Washington, has been for research purposes. The United States has transmitted to Moscow satellite photographs and cloud analyses derived from data from ESSA 8 and 9, and the Improved-TOS satellites; these data are used routinely in the analyses made at the World Weather Center, Moscow. Representatives from the two countries met in Washington in March to discuss the joint operation of the circuit. Emerging from this meeting were agreements on high-speed data exchange and a change of circuit routing within Europe to improve reception of information.

Environmental Data Service

The Environmental Data Service collects, processes, archives, publishes, and issues environmental data gathered on a global scale. The Service maintains data centers for geodetic, geomagnetic, seismological, meteorological, aeronomic, and oceanographic information, providing a single source of environmental data readily available to specialized and general user groups. It provides administrative support for the corresponding World Data Centers-A, which receive data from cooperative investigations and other international sources. It also sponsors and conducts research and development activities to improve these functions, and coordinates the international exchange of atmospheric and space data. These functions are exercised through the data centers and related research and information activities described below.

The National Climatic Center (NCC).—This center is at Asheville, N.C., and archives meteorological surface and upper air data and NOAA satellite data. Raw and processed data from the National Weather Service and its cooperators, the U.S. Air Force's Air Weather Service, the Naval Weather Service, and foreign meteorological services are archived at the NCC. The NCC provides data retrieval services for a variety of users such as aviation and space activities, research, commerce, industry, and individuals. Data users can purchase, at production cost, copies of data in manuscript, microfilm, photographic, or magnetic tape form, and data summaries prepared to user specifications. Catalogs of satellite data are published periodically by EDS. The NCC also conducts a referral service for satellite data archived elsewhere, and provides information and advice about pertinent meteorological data. Accomplishments at the NCC relating to aeronautics and space activities during 1970 include:

1. Glossy 8 × 10 prints of individual frames of satellite cloud photography are now available from the NCC for interested users. Satellite photographs were previously available only in film strips.
2. The first of four volumes on the Upper Air Climatology of the Southern Hemisphere was produced in cooperation with the Department of Defense and the National Center for Atmospheric Research.
3. In cooperation with the Naval Weather Service Command, the first of two volumes of an Upper Air Climatology of the Northern Hemisphere was published; the second volume is in process.
4. Data for the above six volumes are available from NCC on magnetic tape, microfilm, and microfiche. These data have been supplied to NASA for use in its space vehicle reentry studies.
5. Progress on the design of a Clear Air Turbulence Atlas was achieved through a contract. An extensive

bibliography on the subject was compiled at NCC to supplement the contractor's listing, and is available on microfilm.

6. Climatological summaries were prepared for 41 selected airports in the United States in cooperation with the Federal Aviation Administration. These summaries contain several bivariate tables computed from observations taken when ceilings were below 200 feet or visibilities were less than one-half mile. These summaries were published by the FAA.

7. Cloud analyses transmitted on the national facsimile circuit are being coded and punched into cards for use by NASA in cloud cover studies.

8. The NCC has accepted responsibility for the receipt, processing, publication, and distribution of the High Altitude Meteorological Data received from the Meteorological Rocket Network, the EXAMET Net, and participating foreign countries. The data are published for the World Data Center-A for Meteorology and Nuclear Radiation.

In addition to the above, satellite data provide a particularly important contribution to the global Basic Data Sets which are being assembled by NCC for research in the Global Atmospheric Research Program. It will be the most complete collection of meteorological data possible for one winter month (Nov. 1969) and for one summer month (June 1970). ATS cloud and wind data and the SIRS data included are unique and otherwise unobtainable over large ocean areas.

The Aeronomy and Space Data Center (ASDC) Boulder, Colo.—ASDC has assumed responsibility for part of a new contract program between the NASA Manned Spacecraft Center and the NOAA Research Laboratories Space Disturbances Laboratory. Under this program 24-hour-a-day optical and radio monitoring data of solar conditions are gathered at three sites: Boulder, Colo., Carnarvon, Australia, and the Canary Islands. The solar films and solar radio noise data obtained are sent to the ASDC for processing, scaling, and archiving, after which they are made available to other scientists. The program produces a set of quality-controlled, highly homogeneous data, using the system developed by NASA in 1966 for the detection of hazardous solar particles. The solar patrol films, and reduced solar flare and radio noise data from these earlier observations, made in support of the Apollo and other space missions, have been transferred to this data center, and also are available to users. The Aeronomy and Space Data Center also archives solar-terrestrial data recorded by satellites and space probes. In addition, it publishes data monthly on several solar parameters (protons, X-rays, and solar wind) measured by satellites and space probes, in *Solar Geophysical Data*. This provides the international scientific and technical community with data valuable for understanding many solar-terrestrial relationships. Anal-

yses of satellite and space probe experiments, included in data compilations for special events are published in the World Data Center-A *Upper Atmosphere Geophysics Report* series.

The National Oceanographic Data Center.—Oceanographic observations acquired by aircraft and satellite are still in an early stage of development. The National Oceanographic Data Center (NODC) has been conducting pilot projects for processing, storage, and retrieval of such data. It has acquired and begun digitization of a small number of air expendable bathythermograms to develop a processing system for the large number of observations anticipated. NODC has also undertaken a study to determine optimum techniques for storage and retrieval of sea surface temperature measurements acquired by airborne radiation thermometry.

The Geomagnetic Data Center.—This center furnishes hundreds of copies of observatory data annually to space researchers throughout the world. These data, primarily magnetograms (analog records) and indices derived from them, are furnished on microfilm, magnetic tape, and hard copy. They are used for correlation with data obtained from satellites and for interdisciplinary space studies.

The EDS Laboratory for Environmental Data Research.—This EDS Laboratory is investigating the uses of meteorological satellite data for climatological analysis:

1. Cloud climatology studies, in cooperation with NASA's Goddard Space Flight Center are designed to compute the mean monthly cloud cover over the Pacific Ocean. Frequency distribution of cloud cover amounts have been computed from the 8 years of satellite cloud cover analysis available, and maps of specific cloud amount frequency are ready for publication.

2. Climatological analyses, derived from satellite data, of cloud cover amounts in the Pacific Ocean are being compared to those in the Atlantic and Indian Oceans in an effort to understand oscillations in the cloud cover.

3. The influence of orographic effects on cloud cover was investigated with satellite cloud maps. It was found that the relative humidity at or near the surface is an important factor controlling the amount of orographically produced clouds.

4. Estimates were made of the energy associated with the large scale buoyant lifting of air masses over tropical oceans, using cloud top height data derived from satellite measurements. The estimates based on satellite data were within 10 percent of those based on surface observations.

5. The relationship between the scales of satellite observed patterns and of sea-water temperature dis-

tributions derived from satellite data are currently being studied by EDS, NASA, and the Naval Oceanographic Office.

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

Source for High Energy Photon Calibrations.—With the support of the Goddard Space Flight Center a source of monoenergetic photons is being developed that will be used in calibrating high energy photon detectors for use in satellites, rockets, and balloons. The NBS 180-million electron volt (MeV.) synchrotron will be used to produce a low flux of monochromatic photons in the 10-MeV. to 180-MeV. energy range by in-flight annihilation of positrons. This source will be in operation this year and may be used by many groups through the country.

Studies of the Penetration of High-Energy Radiation Through Matter.—The National Bureau of Standards is engaged in a long-range program for studying the interactions of fast charged particles and photons with matter. A part of this program, slanted towards problems and applications in space technology and science, is supported by a contract with NASA.

Computer programs have been written for calculating the penetration and diffusion of high-energy radiation through extended media. Their reliability has been established through an extensive series of comparisons with experimental data, and these programs are now beginning to pass from the development phase to the production phase. Many applications have been made to problems arising in a variety of space-related fields. Typical examples are: the interpretation of cavity chamber measurements in water media irradiated with high-energy electron beams, in order to establish the relation between the measured ionization in air and the corresponding absorbed dose in water; the determination of the response function of silicon, germanium and sodium iodide detectors, that is, the statistical relation between observed pulse height distributions and the actual photon or electron energy spectra; the calculation of the flux of auroral electrons incident onto the earth's atmosphere from the knowl-

edge of the secondary x-rays observed in balloon experiments at heights of 30–40 km.; and the prediction of three-dimensional auroral ionization and luminosity patterns.

Low Gravity Thermometry.—NBS has developed an instrumentation system to detect the presence of liquid or gaseous phases as well as the temperature of hydrogen in a spacecraft cryogenic propellant tank under near-zero gravity conditions. The measurement system employs a thin-film carbon sensor that provides a relatively high-voltage signal for temperature measurement. Favorable heat-transfer characteristics allow the same sensor surface to discriminate between liquid and saturated vapor.

Apollo-13 Investigation.—Two members of the NBS Cryogenics Division worked as part of a six-man Board of Consultants to help establish the sequence of events leading to the Apollo-13 in-flight explosion. They were asked to assist NASA's investigating team to ensure scientific objectivity, critically review the analyses made by NASA personnel, and contribute their own expertise in the field of cryogenics. The carefully determined data on oxygen properties generated and supplied by the Cryogenics Division enabled the investigators to identify the most probable cause of failure and to establish a basis for redesign.

Comparison of Near- and Far-Field Determination of Antenna Patterns.—To support the deep space program as well as lunar missions, NASA's Jet Propulsion Laboratory required an accurate calibration of standard-gain horns to be used with their 210-foot dish antenna at Goldstone, Calif.

The approach NBS used to calibrate these horns was the measurement of the near-field distribution of radiation in a plane area in front of the horns. The data was then mathematically transformed to arrive at far-field antenna-gain patterns of high accuracy and great detail. The end result was a superior measurement at low cost.

Time and Frequency Signals Useful to NASA Sites.—The NBS standard frequency radio stations provide NASA tracking stations with high-frequency timing signals accurate to within milliseconds. The transmitter in Hawaii (WWVH) has been relocated and equipment and antennas improved, which will significantly improve services in the far Pacific areas. Where a more precise and stable frequency reference is required, the very low frequency transmissions of WWVL in Fort Collins, Colo., are widely used by NASA sites. Where ultraprecision timing applications exist in the United States, NASA's Goddard Space Flight Center is considering using a new TV timing system developed by NBS which is accurate to nanoseconds.

NASA has also contracted with NBS to theoretically predict amplitude and phase for various VLF transmissions under varying propagation conditions. Paths considered are between several VLF stations such as WWVL, and nine NASA tracking stations throughout the world. The VLF signals are used for calibrating the station frequency standards.

Photo Absorption and Ionization Data for NASA.—

During the past year NBS has begun a collaborative program with the Manned Spacecraft Center, NASA, to compile and critically evaluate photo absorption and photo ionization cross-section data for atoms and simple molecules. These data are of critical importance in interpreting satellite, rocket and ground observation of radiation from planetary atmospheres and other hot radiating astrophysical objects.

A New Transition Probability Scale for Iron.—

Astronomers are dependent upon laboratory values of atomic transition probabilities for their determination of the abundances of elements in the sun and stars. Measurements of many neutral iron transition probabilities have been performed at NBS with a wall-stabilized arc and a delayed coincidence lifetime apparatus, leading to a new set of data consistent with all other recent measurements. This set ties together these previously unrelated measurements, and differs from the older, widely used data by factors up to 30. On the basis of these new results, astronomers now believe that there is about 10 times more iron in the sun than previously assumed. The new values for the iron transition probabilities also resolve a long-standing inconsistency between the iron abundance in the corona and the photosphere.

Microwave Spectra of Molecules with Astrophysical Significance.—

Radio astronomers have observed microwaves emitted from water vapor from several sources in the galaxy. This radiation corresponds to a vibrational-rotational transition in the ground electronic state of the water molecule. Detection of the corresponding radiation from water molecules containing a different isotope of oxygen (mass 18 instead of mass 16) would confirm the original assignment as well as provide information on the relative galactic abundance of these two oxygen isotopes and the emission excitation mechanism in the water molecule. Before an astronomical search can be made, it is necessary to have a laboratory measurement of the transition. This measurement has been made by NBS, the result being 5625.147 ± 0.015 MHz. for the appropriate transition frequency in water containing oxygen of mass 18.

Since absorption by the formaldehyde molecule in the galaxy has been detected, speculation exists about the occurrence of similar molecules. The new species thioformaldehyde, H_2CS , has been generated and its

microwave spectrum observed. A prediction of the appropriate frequency of the vibrational-rotational transitions (1046.48 ± 0.02 MHz.) has been made with precision sufficient for an astronomical search.

Thermodynamic Measurements on Gaseous and Liquid Fluorine.—

Fluorine is one of the most reactive oxidizers known and its use with hydrogen provides the highest specific impulse of any stable oxidizer-fuel combination. Accurate thermodynamic-property data on both substances are required for the design of efficient rocket-propulsion systems, but few physical-property measurements have previously been made on compressed fluorine because of its extreme reactivity and toxicity. After solving the compatibility problems associated with handling this substance, accurate vapor pressures, densities and specific heats were measured at temperatures down to the triple point (53.5° K.) and pressures to 21 meganewtons per square meter (equivalent to 3,100 p.s.i.). The volumetric and thermal measurements are being used with ideal gas-spectroscopic measurements to provide the most accurate and extensive thermodynamic-property data in existence for this substance.

Advances in Radiative Transfer.—

The primary means of deriving the physical properties of the atmospheres of stars, including the sun, is by understanding the radiation they emit. In general the radiation is not formed under thermodynamic equilibrium conditions. Some accomplishments at NBS in the theory of radioactive transfer directed towards this goal include: a means of solving the general noncoherent scattering problem; investigation of the transfer of radiation in a stellar atmosphere in which electron scattering is important; and solutions of the radiation field in very extended spherical atmospheres.

Downed-Aircraft Emergency Locator Beacon.—

The FAA has engaged NBS to assist them in determining acceptable performance standards for an emergency locator beacon for downed aircraft. The NBS is determining the minimum radiated power from an emergency locator transmitter (ELT); developing a measurement technique to permit the FAA to evaluate commercial ELT's at their facilities; determining the environmental effects of terrain, metal, weather, etc. on the ELT; and investigating a means of transferring an approved standard ELT to production line testing.

Use of the Moon as an Absolute Flux Calibration Source at Far Infrared and Microwave Wavelengths.—

NBS has carried out calculations of the brightness temperature at the subsolar point on the moon in the spectral region between 5 microns and 10 centimeters wavelength. These calculations used thermal properties and opacities of the lunar soil

which were determined from samples returned from the moon by the Apollo missions. The lunar source will be useful for calibrating observations of the sun, planets and other astronomical objects. This is especially important since the use of an extraterrestrial standard calibrates the atmospheric transmission as well as the instruments employed.

Observations of the Solar Chromosphere.—NBS scientists have made observations of the resonance multiplet and three infrared subordinate lines of singly ionized calcium. These observations were made at Kitt Peak National Observatory and Sacramento Peak Observatory and analysis of the data is underway. Theoretical calculations have been completed of the density and temperature dependence of the intensity ratios of these lines. The observational data will be combined with the calculations to make improved models of the solar chromosphere and to investigate such structures as plages, sunspots, the chromospheric network, and supergranule cells.

Apollo Lunar Ranging Experiment.—During 1970 the McDonald Observatory, in cooperation with the Lunar Ranging Experiment Team, has carried out laser range measurements from the earth to the moon using the Apollo 11 retroreflector package on the moon. The number of successful measurements per month has increased rapidly during the year, with results being obtained for most observing periods in the latter part of the year. NBS has participated in the work of the Lunar Ranging Experiment Team during the year and is working jointly with the Jet Propulsion Laboratory and the University of Maryland in the early analysis of the results. Substantial corrections are already indicated to the eccentricity of the lunar orbit and to the mean distance from the earth to the reflectors.

Institute for Materials Research

Planetary Atmospheres.—Theoretical calculations of radiative absorption cross sections for carbon dioxide and formaldehyde have been made by NBS in collaboration with NASA-Goddard. These cross sections are required to model the equilibrium behavior of a carbon dioxide atmosphere (e.g., Mars and Venus).

Simulated Lunar Samples.—The Bureau of Standards produces a wide range of materials of certified composition that can be used to calibrate analytical instruments and determine the accuracy of techniques of chemical analysis. A series of eight trace elements in glass Standard Reference Materials (SRM's) has recently been produced and certified for trace elements at four concentration levels (500, 50, 1, and 0.02 parts

per million). These SRM's will be of value in establishing the accuracy of methods used in geology and geochemistry and their application to lunar and other "space samples". The standards will be used to calibrate a wide variety of techniques including emission spectroscopy, nuclear methods of analysis, mass spectroscopy, polarography, and spectrophotometry.

Microprobe Standard Reference Materials (SRM's).—These standards were produced and certified to provide a highly homogeneous material at about the micrometer of spatial resolution. They are intended primarily for use in calibration of quantitative electron microprobe analytical techniques that are widely used for the chemical analysis of lunar materials. Twelve different metallic SRM's in the form of coated wires are offered for sale.

Thermodynamic Data of CHNOPS Compounds.—The Chemical Thermodynamics Data Center has completed a handbook of thermodynamic data of the compounds of the elements carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. This work was supported by NASA and is in support of their Exobiology Program.

Thermodynamics of Fluoride Compounds.—NBS has made an investigation of the thermodynamic properties of trifluoride and pentafluoride of chlorine which are of interest as oxidants for rocket propellants. The thermodynamic properties of fluorides and oxyfluorides of molybdenum are also being investigated because of their importance in evaluating the performance of molybdenum as a rocket structural material in a high temperature environment containing fluorine or fluorine containing compounds.

Analysis of Apollo Lunar Samples.—Analysis of lunar soil samples was carried out at NBS by scientists from other institutions. NBS has developed a new electron microprobe multiple detector system that allows the simultaneous investigation of seven elements on a given scan. Investigation of Apollo 11 samples with this instrument was done at the request of NASA.

Institute for Applied Technology

Tape Head Sticking.—NBS has carried out a study for NASA to determine the cause of failure in satellite tape recorders due to tape head sticking. A material was found in the tape backing film which produces a large increase in the coefficient of friction and which may be the cause of recorder failure.

Sterilizable Magnetic Tape.—A program sponsored by NASA, managed by NBS, and carried out at Battelle Memorial Institute produced a prototype mag-

netic tape that is stable when subjected to sterilization by heat, high energy radiation, or chemicals. The tape is needed for spacecraft designed to explore other planets without contaminating them.

Thermal Properties of Transistors.—Reliability of electronic systems used in space and aeronautics depends in large measure on the properties of the semiconductor devices used in their construction. An abrupt change in current-gain of a power transistor was correlated with the onset of current crowding in its operation and the formation of a hot-spot. This parameter is much easier to measure than thermal resistance which has been used to detect such instabilities in the past. This observation is expected to have great applicability in screening devices for defective constructions which might lead to burn-out of the device under operating conditions. It was also found that after a hot spot is formed in many transistors, it cannot always be eliminated by a reduction of the collector-emitter voltage to an operating condition normally free of hot spots. This "thermal hysteresis" effect reduces the maximum safe operating range of some transistors.

Wire Bond Evaluation.—NBS continued work on methods for the evaluation of wire bonds used in connecting semiconductor chips to external leads. Bond failure is a dominant cause of device failure in missile, spacecraft, and aircraft systems in both radiation and nonradiation environments. Techniques to establish uniform and reproducible bonding conditions have been developed for ultrasonic wire bonding machines. These involve direct measurement of the vibration amplitude of the bonding tool tip with a capacitor microphone or a magnetic detector. These observations have demonstrated that the vibration amplitude may be quite different for two or more operating conditions which have the same values of the parameters usually controlled. This appears to be a significant source of bond variability which can be avoided by use of the new techniques.

Microwave Semiconductor Devices.—NBS has undertaken a new project to provide improved measurement methods for microwave diodes. These diodes are critical elements in civilian and military satellite and ground communication links and in radar systems in which the sensitivity and range, and the reliability of the sets, depend substantially on the quality of the diodes. Serious trouble has been encountered in government procurement of these diodes because of the inadequacy of measurement methods currently in use to demonstrate conformance to performance specifications. Work has begun on measurements for properties such as noise figure, conversion loss, and impedance of mixer diodes.

Aircraft Tire Wear.—A program funded by the Air Force Flight Dynamics Laboratory is being conducted by NBS to develop a mathematical model of aircraft tire wear. Other work on aircraft tires includes a study of the internal stress in statically deformed pneumatic tires, computer simulation of skidding, modes of failure and impact performance, wave geometry, and development of nondestructive testing instruments and methods of measuring tread wear.

Wind Speed and Direction Indicators.—NBS has worked to improve instrumentation for measuring wind speed and direction. This work was supported by the Naval Air Systems Command and is important in carrier launches.

Analysis of a Capacity Concept for Runway and Final Approach Path Airspace.—The present measure of such capacity is that embodied in the "Airport Capacity Handbook" and based on a "tolerable average delay level" plus an assumption of highly random arrival times for aircraft. In an FAA-requested study, NBS has developed an alternative "maximum throughput rate" capacity concept, and rigorously established its representability by a simple mathematical formula. Because the formula explicitly combines the various parameters influencing capacity (e.g. traffic mix of aircraft types, runway occupancy time for each type, in-air separation standards), it is useful for studying "what if?" questions concerning capacity, such as the effect of a shift toward more use by large fast planes, as well as in analyzing the relative effectiveness for capacity enlargement of runway improvements versus improvements permitting smaller in-air separations.

Performance of High Temperature Thermocouples.—NBS investigation has shown that significant errors can be introduced when making temperature measurements with noble metal thermocouples in environments found in advanced aircraft propulsion systems. Further investigation is proceeding to determine the ranges of flow velocity and temperature in which such errors are important when noble metal thermocouples are used to monitor and adjust the performance of such systems. Development of means to minimize catalytic errors has begun.

Maritime Administration

The Maritime Administration is continuing its investigations into the commercial applications of existing satellite systems for both communications and navigation.

It is evident from trade and traffic density forecasts that the marine industry will require new or additional radio frequency allocations. An experiment is underway to evaluate UHF communications (L-band) using

the ATS-5 satellite. If this project is successful, a new bank of radio frequencies will become available at a user cost comparable to or lower than VHF systems. Additionally, data transmission for marine traffic control (improved safety) could become a practical reality through a shoreside data-control center.

Satellite navigation systems offer significant potential from both economic and safety standpoints. The Maritime Administration is sponsoring shipboard tests of such systems (synchronous and orbiting) to determine relative reliability and reduce hardware costs.

Office of Telecommunications

The Office of Telecommunications of the Department of Commerce was reorganized in September to undertake a larger role in guiding the development of the Nation's telecommunications. The reorganization was accomplished by the Secretary in response to the President's Reorganization Plan No. 1 of 1970. The Office of Telecommunications is responsible for an extensive program of telecommunication services, economic and policy analyses, and technical and analytic support for the new Office of Telecommunications Policy in the Executive Office of the President. The Institute for Telecommunication Sciences was transferred from ESSA. The reorganized 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 1970 included:

1. Radio propagation studies to improve the accuracy of long range radio-navigation systems used in aeronautical (as well as other) navigation. Results of the study now permit predictions and corrections for the effect of irregular and inhomogeneous terrain on the accuracy of Loran C radio-navigation positioning.

2. Studies were conducted on the effective use of the radio frequency spectrum assigned to space and aeronautic activities. Reports were prepared on "Electro-space Planning and Engineering for the Air Traffic Environment," and "Interference Predictions for VHF/UHF Air Navigation Aids." The "Electro-space" report deals with service limitations imposed upon VHF/UHF/SHF radio communication links by cochannel and adjacent-channel interference, and summarizes

methods that can be used for predicting available desired-to-undesired signal ratios (protection ratios) and determining the required protection ratios. The "navigation aid" report contains service range information relevant to distance measuring equipment (DME), instrument landing system (ILS), tactical air navigation (TACAN), and VHF omnirange (VOR).

3. Forecasts were made of radio propagation conditions for high frequency circuits used in the NASA Ground Communications Network. Operations included the issuance of "Special Disturbance Warnings" to the network and 24-hour to 6-hour forecasts for specific circuits of the networks during the Apollo 13 missions.

4. A method was proposed and developed to use satellite relays to synchronize a network of stations for use in worldwide navigation of air and space vehicles. Field measurement data showed that widely separated oscillators could be maintained within a synchronization of 1 percent of a cycle at 10 GHz. for an indefinite time as far as atmospheric transmission delays are concerned.

5. Laboratory and field measurement programs were conducted on the simulated and observed characteristics of microwave signals passing through the troposphere. The variations in amplitude and time delay of such signals are important in proposed techniques for using satellites to study global atmospheric structure. Other applications include communication between high-flying aircraft, orbiting satellites, and any elevated vehicle communicating with ground stations over paths with low elevation angles. Results to date indicate that signal fading of greater than 40 decibels occurs frequently. Horizontal space diversity can provide significantly improved system reliability.

6. A field measurement and analysis program in Radio Frequency Interference between satellite and ground stations is underway. The principal objective of the study is to determine the possibility and feasibility of alternatives to the present criteria specified for frequency sharing of satellite-ground terminals.

7. The staff participated on U.S. National Committees to the International Consultative Radio Committee (CCIR). Contributions made through the State Department provide, in part, the basis of U.S. positions relative to CCIR planning for the forthcoming World Administrative Radio Conference on Space Telecommunications scheduled for June 1971, in Geneva.



Introduction

In the year following the first moon landing the U.S. Information Agency brought some of the experience of that event to the home ground of millions. Pieces of the moon—lunar rocks returned by the Apollo 11 and 12 astronauts—were exhibited by the U.S. Information Service in virtually all the capital cities of the five continents, and many provincial cities as well.

At Osaka, Japan, an extra large lunar specimen, accompanied by the Apollo 8 spacecraft and a full-scale simulation of Apollo 11's landing site, was the center piece of the American Pavilion and was regarded as the greatest attraction at Expo '70. Over 18 million visitors filed by the lunar exhibit during 6 months, or at the rate of 100,000 a day.

The Agency's own feature film on the first moon landing, "The Infinite Journey," a 90-minute color documentary was shown in 132 countries. Many posts held VIP premieres of the film on the July 21 first anniversary.

The Agency employed all its media to tell the story of the mishap-laden journey of Apollo 13 and its final safe recovery. Later the Agency, and its posts abroad, assisted in the world tours of the Apollo 12 and Apollo 13 crews to many countries abroad. Through photos, films, wireless file, books, posters, and other media, the Agency and its 190 posts continued to explain the American space program to world audiences.

Guidelines

These guidelines were used in treatment of space developments:

(a) The moon landings under Apollo represent an extension of man's need to explore the unknown, the application of man's most advanced tools to unlocking the secrets of earth's nearest neighbor, and the intention to use both space knowledge and technological know-how for man's immediate benefit on earth.

(b) Looking beyond Apollo into the seventies, the American space program promises to be bold, diversified, and wide ranging. Its objectives are that the United States should continue lunar exploration; explore further the near planets and initially survey the outer planets; work to substantially cut costs by developing reusable space vehicles; seek to extend

man's living and working capability in space; expand the practical applications of space technology, and encourage greater international cooperation in space.

(c) The United States encourages the participation of other countries in major aspects of its post-Apollo programs, and welcomes the agreement with the Soviet Union for development of mutually compatible docking arrangements as an instance of significant mutual endeavor in space.

(d) The American space program values automatic machines and uses them, but regards the role of man in space as established and invaluable. Either or both may be required, depending upon the objective.

(e) In fact the automatic instruments left on the moon by the Apollo 12 crew had been there 1 year to the day when the Soviets landed their robot vehicle, Lunokhod, on the moon. At the end of its first year the U.S. robot science station had produced valuable scientific findings on the nature and character of the moon, and showed every expectation of operating for still another year.

(f) No automatic machine, however, can be regarded as the equal of the astronaut, whose superior mobility and carrying capacity, together with his ability to exercise experience and judgment, make him a superior instrument for either close-up or wide-ranging exploration.

Treatment

Radio.—The crisis-ridden Apollo 13 mission was probably the most massive broadcasting effort of the year for the Voice of America. A look at Voice coverage, however, shows broad and detailed treatment of many space events.

Highlights show news carrying full reports on Skylab, the proposed space shuttle, the space ferry, further unmanned missions to Mars and Venus, and other space ventures proposed for the 1970's.

Voice broadcasts reported fully, for instance, on the Soviet's Luna 16 and 17, broadcasting Western reaction, scientific analyses, and congratulatory messages from NASA officials. Russian and most other services carried coverage of the first lunar rock conference at Houston where 200 United States and foreign scientists appraised the initial lunar soil and rock experiments.

The Italian Service interviewed a NASA scientist on medical applications of space research, while an

Estonian-language broadcast featured a discussion with an American astronomer on the subject of the moon structure. Hindi and Tamil shows promoted the moon rock as its exhibit moved through India. An hour-long Hindi broadcast interviewed India's leading meteorologist on weather satellites, analyzed the U.S. space program for the 1970's, and carried the NASA Administrator's statement on the desirability of United States-Soviet space cooperation.

All VOA airshows commemorated the moon-landing anniversary, including a documentary that featured Neil Armstrong's press interview.

When word first came that trouble had developed aboard the Apollo 13 spacecraft, VOA was on top of the story with calm, factual coverage, staying with it around the clock until after recovery. Prerecorded features were canceled for live reports from three Voice correspondents from Houston. In Latin America alone an estimated 108 million listeners heard Voice of America Spanish, Portuguese, and English broadcasts relayed by more than 1,400 stations.

Press and Publications.—The year saw no diminution of the demand from overseas for publishable material on the space program, so output of the Press and Publications Service continued at the high volume level of the year before.

The magazine effort was particularly comprehensive. *America Illustrated*, the Agency's magazine for the Soviet Union and Poland, devoted the whole of its April issue to space—16 in-depth articles on all major aspects of the program. This material was in large part picked up by other Agency magazines.

By the end of this year, editorial and art work had been completed on another special issue of *America Illustrated*, to be produced in February, to coincide with Apollo 14. This material will also be printed at approximately the same time in *Panorama* (Pakistan), *Marzhaye Now* (Iran), *Pregled* (Yugoslavia), *Span* (India), and the two Far Eastern magazines *World Today* and *Horizons*.

The extensive wireless and mailed feature output covered the entire spectrum of the space program, with emphasis on such aspects as additions to the body of scientific knowledge from moon exploration, spinoff values (sample titles: *Space Research Produces Fire Protection Chemical*, *Space Medicine to Help Solve Problems on Earth*), and U.S. efforts toward international cooperation.

In news terms, the dramatic return of the crippled Apollo 13 was thoroughly reported, after which attention was turned to the 1971 mission of Apollo 14.

During the year, as the moon specimens continued their travels, literally millions of copies of a simple two-fold leaflet entitled "A Lunar Sample," were printed

in various languages for distribution to audiences viewing the rocks.

Photo output was varied. There were three picture stories, on special-issue stamps commemorating the moon landing, "An Artist Among the Astronauts," and "True Face of the Earth" on aerial photography which include three pictures from Apollo missions.

A special feature package on Apollo 13: 14 articles, five fact sheets, and an illustration of the mission's target point on the moon was in the hands of press and other media correspondents abroad weeks before lift-off. This was designed to inform foreign correspondents on salient aspects of the mission well in advance of launch. Providing full technical, biographical, and scientific details on the mission, the usefulness of the advance press kits has been widely acknowledged by the foreign press. The advance packet for Apollo 14 was produced and transmitted to the field in the late summer, and is being updated as new material develops.

Motion Pictures and Television.—The Agency gave its usual full coverage to Apollo 12, sending out a pre-flight filmed interview with the Astronaut Training Chief and, following the mission, 784 prints of "Apollo 12: Pinpoint for Science" to 129 countries in 26 languages.

Pre-mission and post-mission filmed reports on Apollo 13 were also distributed, as well as a moon-landing anniversary interview with Astronaut Armstrong. Reports on the 1970 eclipse of the sun, tracing of the weather via satellite, and a half-dozen other subjects appeared in *Science Report*, a half-hour monthly show distributed in, and telecasted regularly in 83 countries. In addition a considerable variety of film footage on space was distributed abroad in answer to requests by commercial film and television producers.

Newsclips sent worldwide to posts included the Saturn 5 roll-out for Apollo 13, the visit to Cape Kennedy of the President of the Congo, and the first press conference of the Apollo 14 crew. A half-hour production on astronaut training, "Moonlanding: Step 2," was sent to 126 countries for a total of 427 prints.

It is interesting that the Agency itself used space for transmission of its programs abroad fully 16 times during the year. This is more than communications satellites had been used previously since the Agency began using them in 1964.

But it was the feature film on the first moon landing that was the Agency's major space film effort of the year. In production for a year, "The Infinite Journey" led the viewer through man's age-long quest for discovery and, through the evolving Apollo program, to the moon. The film is expected to continue to have use through coming years.

Information Centers and Exhibits.—The exhibiting of historic space artifacts and lunar rocks to foreign audiences was of major significance in its relation to the American posture abroad.

In Eastern Europe, where audiences identify deeply with space, the Apollo 10 spacecraft was viewed by a million at the Budapest International Trade Fair, and became “the darling of the Fair” at the Poznan Trade Fair in Poland where close to a half million viewed it. After showings in Yugoslavia and Bulgaria, the spacecraft was the center piece of “Research and Development: U.S.A” at the Bucharest International Fair. The Apollo 10, a lunar rock and various accompanying space artifacts caused near chaos in the Fair’s traffic flow, and drew an estimated 300,000 Rumanians.

Transported on a specially designed flatbed truck, Apollo 10 had been viewed by 2.5 million Europeans close to the end of the year. In Western Europe it was shown in the Scandinavian countries (Norway’s largest newspaper called it “a small piece of human triumph that will adorn Oslo in the days ahead”), Vienna, and West German cities.

In November 1969 NASA made six pieces of moon rock available to USIA for world showing. These, scheduled and exhibited on all continents during the past year, are still greatly in demand. Showings are scheduled well into 1971.

In the first 6 months of 1970 the samples had been scrutinized by 8,370,513 persons, with millions more having seen them on television. Perhaps that many

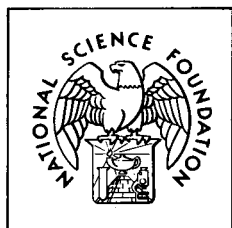
people again viewed the lunar rocks in the second half of the year.

In an eight-city tour of France, a moon rock called on the hometowns of one quarter of the French people, with 30 million more Frenchmen viewing it on television. Through television also, roughly half the population of metropolitan Portugal saw a lunar rock. In Ethiopia the moon rock was said to have marked the beginning of a wider acceptance of science. The Dean of Trinity Cathedral of Addis Ababa declared: “The American people have given us a scientific method for religion—to know how God had created unknown worlds. Thank God for giving us a chance to see this stone from the moon.” In Singapore citizens of every age and race stood in block-long queues under a pitiless tropical sun waiting for a look at the rock. The exhibiting of the rock was in fact unique in its effect and immediate impact. In Moscow viewers nearly burst the walls of a moon rock exhibit that had not even been advertised.

To satisfy the demand for books on space, some 1,000 newly published books on Apollo and other aspects of space were shipped to post libraries. Under the Agency’s book publishing programs, 17 titles on space exploration were produced in Chinese, Burmese, Thai, and Bengali, among other languages.

To inform audiences on the benefits of space exploration 106 sets of a slide lecture on this subject were sent out; so was a space science reader, “Footprints on the Moon: The Apollo Story,” for English lessons.

XIII



National Science Foundation

Introduction

The National Science Foundation was established by Congress in 1950 as an independent agency to promote the progress of science. The Foundation supports scientific research and programs to strengthen research potential in all fields of science, and in 1970, contributed to the support of the aeronautic and space sciences through a number of its programs. Most of the research project support is provided to investigators who are sponsored by colleges and universities. The Foundation also supports and administers a number of national programs and national research centers which in turn provide significant support to investigators in

the aeronautic and space sciences throughout the country. Through these organizational mechanisms the Foundation makes available radio and optical telescopes, scientific balloon services, and the unique facilities of the Antarctic continent.

Astronomy.—There has been a high rate of discovery of interstellar molecules in space just in the past 2 years. The identification of molecules of the OH radical, water, and ammonia have led to the discovery of more complex and unexpected molecules in space including formic acid, methyl alcohol, formaldehyde, carbon monoxide, and cyanoacetylene. All of the discoveries to date have been made at facilities in the

United States and many of them through the use of instruments at the National Radio Astronomy Observatory. The continuing discoveries by radio astronomers of these interstellar molecules should provide new knowledge of the formation of organic molecules in the universe.

The new detectors used for infrared astronomy for both ground-based and flight instruments have enabled astronomers to look at stars and galaxies in a spectral region which was not accessible in the past. The galactic center has proven to be an intense source of infrared waves, and many young stars also give off large amounts of infrared. Some of the sources suggest that stars are surrounded by large quantities of dust.

The Stratoscope Telescope was carried to a 15-mile altitude by a 5.5-million-cubic-foot helium balloon in the late spring of 1970. The 36-inch telescope was operated by ground command and produced pictures of unprecedented sharpness. The resolution of the telescope was five to 10 times better than ground-based installations which must peer through the earth's perturbing atmosphere. Photographs of Uranus showed a slightly flattened disk with distinct limb darkening from which it may be possible to learn more about the nature of the atmosphere. High quality pictures of Jupiter are undergoing further study. The nucleus of one of the Seyfert galaxies also was photographed and found to be about half the expected size. This discovery indicates that the approximately 10 billion stars in each Seyfert-like galaxy must be moving at an unusually high speed to avoid collapse into the center of the nucleus.

The positions of intense radio sources, which could conceivably be utilized as new navigational beacons, are now being measured with high accuracy by very long baseline techniques. These techniques involve the simultaneous observations of an object in space from two or more widely separated instruments and can be extended for use with earth satellites and lunar stations to provide longer baselines. The long baselines are made possible by the use of accurate clocks and recorders at different sites.

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. All facilities are used at maximum capacity with observing time demands backlogged several months. Astronomers use NRAO instruments in very long baseline experiments to study celestial radio sources. Studies of their angular diameters, fine structure, and intensity

variations have led to new theories of the formation of stars and galaxies. In another area of investigation at NRAO, new information concerning the distribution of molecules in the interstellar medium has opened new fields for astrophysical research.

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 dynamics of planetary atmospheres and stellar X-ray sources.

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. Studies of the rich star fields of the southern Milky Way and the Magellanic Clouds which are our nearest galactic neighbors have contributed significantly to our knowledge of the universe. Extensive surveys of stellar objects in the southern skies from this observatory have also enabled us to construct improved models of our own galaxy.

Arecibo Observatory (Puerto Rico).—The Arecibo Observatory was officially designated as a national center on October 1, 1969, and the 1,000-foot diameter telescope is now available to scientists and students throughout the United States. The 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, Mercury, and Venus which are of great importance to space missions. Radar investigations have also yielded new information on the rotational characteristics of Venus and Mercury and, closer to earth, on the structure, dynamics, and chemistry of the ionosphere.

Meteorology Program.—The meteorology program supports a number of research programs which relate to aeronautics and space activities at various universities. These include studies of the large scale dynamics of the atmospheres of the earth and other planets. In the earth's atmosphere, there are several investigations underway to study clear air turbulence, the constituents and energetics of the stratosphere, atmospheric electricity, and remote-sensing techniques for constituents and atmospheric motions. An increasing use of satellite data is evident in such studies. Examples of this work include a study of the physical and statistical aspects of clear air turbulence, a study of the dynamics of the atmospheres of Mars, Venus, and Jupiter by means of both numerical experiments and analytic work, and a study of the distribution of atmospheric ozone and the energetics of the upper atmosphere to determine the radiation heating in the stratosphere.

Studies of atmospheric motions on all scales form the basis of dynamical meteorology and a considerable effort across the Nation in many universities results in analytic studies and numerical simulations of atmospheric dynamics. These range from studies of global dynamics to studies of boundary layer fluctuations at the earth's surface.

Remote sensing of the atmosphere represents one of the great advances in meteorology. Radar investigations, lidar and other optical techniques, and satellite soundings and photographs form the basis of a number of meteorological investigations supported by the National Science Foundation. These techniques yield information on severe storms, atmospheric motions and energetics, the motions of particulates within the atmosphere, radiation balances, and concentration of chemical species.

Solar-Terrestrial Program.—The earth's ionized outer atmosphere is influenced primarily by energetic particles and radiation from the sun and by interaction with the neutral atmosphere below. In 1970 a wide

variety of outer-atmosphere phenomena were studied under the sponsorship of the National Science Foundation.

The sun, as the source of energy, was studied with particular emphasis on the dynamics of the outer regions of the solar atmosphere. The energetic plasma ejected continuously from these regions (the solar wind) was also studied, with model studies of the interaction of the solar wind and the terrestrial magnetic field. Structure in the solar wind and the interplanetary medium was examined through measurements of scattered light in the night sky and effects on cosmic rays reaching the earth.

Energy from the solar wind is injected into the magnetosphere where it is stored temporarily as an increase in magnetic energy in the tail of the magnetosphere. It is subsequently released spasmodically in bursts called "magnetospheric substorms," which are associated with disturbances in virtually all outer atmosphere phenomena in many different regions of the magnetosphere. Research supported in this area is providing a comprehensive view of the morphology of these disturbances and has produced a suggested way in which they might be modified or controlled; that is, through the use of a satellite to inject a low temperature plasma into a critical location. This has major significance in problems related to radio communications blackouts and to augmentation of surveillance radar clutter, both of which are associated with substorms.

In studies of the ionosphere, the dominant trend is the continued development of incoherent scatter radar techniques. There is a large and growing demand to study the ionosphere using the national facility at Arecibo and strong interest in the Millstone Hill facility near Boston.

A highlight of the year was the spectacular eclipse of the sun seen by millions of viewers near the U.S. eastern seaboard and by many millions more on television. Coordination of the many research teams observing the eclipse in the United States and Mexico was provided by the National Science Foundation.

National Center for Atmospheric Research (Colorado).—During 1970 the National Center for Atmospheric Research continued its studies of the sun, the interplanetary medium, and the earth's atmosphere. A major portion of its observing resources are devoted to measurement of solar prominence magnetic fields, which clearly are important to all forms of solar activity. Increasingly sophisticated models were developed and used to investigate the circulation of matter in the solar interior and its effects on the solar atmosphere. Present models of interactions between the solar corona and its magnetic fields reveal a discrepancy between observed and calculated coronal densities during the supersonic expansion of the solar corona

which produces the solar wind. Attempts continue to resolve this discrepancy, which also bears on coronal heating. In solar-terrestrial physics, high altitude tidal winds, and their interactions with the earth's magnetic field were extensively studied.

An improved rocket-borne sampler, using liquid neon rather than liquid hydrogen, which can withstand pre-flight heat for decontamination at 840° F., was built and tested for launching in 1970. The use of constant-level superpressure balloons carrying lightweight electronics packages to track global horizontal air movements has continued. Test flights from New Zealand have demonstrated that above 53,000 feet balloons stay aloft an average of over 6 months and circle the globe many times. In the past year development was started on a concept for obtaining tropospheric wind data by releasing dropsondes from a balloon in the stratosphere.

In a related program, a series of superpressure balloons were launched from Ascension Island to investigate the so-called 26-month equatorial wind oscillation. These balloons are interrogated by the Nimbus 4 weather satellite, which obtains their positions and the atmospheric pressures and temperatures at the balloon float altitudes (67,000 or 77,000 feet).

During February and March of 1970 the Colorado Lee Wave Experiment was carried out in the Boulder area. Simultaneous observations were made at altitudes up to 65,000 feet of lee wave profiles, the growth and decay of clear and rotor cloud turbulence, and the characteristics of downslope windstorms. The study linked mountain-wave turbulence with Kelvin-Helmholtz waves and was a step toward learning to predict and detect atmospheric turbulence—a topic of great concern to commercial aviation.

Engineering.—The Engineering Division supports a number of research programs related to aeronautics and space activities. In general, the support provided is oriented toward earth-based problems such as wind flow over urban areas, wind effects on structures, dispersion of contaminants in the earth's boundary layer, application of aeronautical knowledge to biomechanics problems, aerodynamics of tube and air cushion vehicles, and a broad program of basic fluid mechanics and heat transfer research. Particular emphasis is being given to societal related problems, to technology transfer, and to directing aeronautical researchers into new activities such as biomechanics.

Fundamental areas of research supported include the effects of adverse pressure gradient on turbulent boundary-layers, hypersonic rarified gas dynamics, and variational approaches in fluid mechanics, to name but a few. Research in specific engineering problem areas is supported by grants such as cavitation scale effects

for generalized value shapes, aerodynamic performance of gravity vacuum tube vehicles and dispersion of pollutants from tall chimneys. Support for research on the aerodynamics of insect flight is another interesting area of research where the results will be of interest to life scientists and possibly aid in the control of insect populations.

Experimental studies are underway to investigate plume dispersion from a tall stack under the meteorological conditions which cause fumigation—a condition where relatively high concentrations of pollutants are brought close to ground level. Once this process is better understood, appropriate action can be taken to alleviate the pollution potential.

Mathematics.—The Mathematics Section supports a wide range of research which directly and indirectly supports the space and aeronautics activities. The development of structure and methodology for solutions of integral and differential equations provides a basis for solutions of particular problems in these areas. Studies in celestial mechanics are underway. A program on convergence procedures in orbit calculations is being conducted at one university. In another example, difficulties which arise in the energy and momentum calculations associated with the problem are under investigation. In the area of stellar dynamics investigations are underway on the motion of a star in a galactic potential, on dynamics of large scale astrophysical phenomena, on the interstellar medium, and on bar-shaped galaxies.

U.S. Antarctic Research Program.—Many Antarctic studies relate directly or indirectly to the space program. Informal consultations on mutual problems are frequent between NSF and NASA, and a NASA official presently serves in an advisory capacity to the U.S. Antarctic Research Program.

Space program officials have shown particular interest in the management of the Antarctic program, as its operation at the end of a long logistic line bears some resemblance to the lunar exploration program. There are parallels, as well, between the Antarctic environment and those that may be encountered on other planets. For this reason, soil microbiological studies have been carried out in Antarctica for several years.

Because of the ease with which low-energy phenomena can manifest themselves at high geomagnetic latitudes, the polar regions are especially productive regions from which to perform investigations of the ionosphere and magnetosphere. Correct interpretation of the measurements leads to a better understanding of how the sun affects and controls the earth's environment. The measurements are made from ground level

and from balloons, rockets, and satellites; they are made of events of opportunity as well as on a synoptic basis.

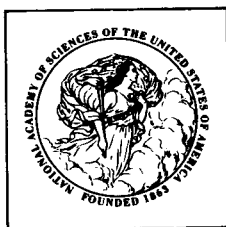
Education Activities.—In fiscal year 1970 approximately \$2.4 million was obligated by the Foundation's three education divisions for activities which were, either in whole or in part, related to the aeronautic and space sciences. Since some of these awards were multidiscipline in nature—e.g., a project which provided training in several different disciplines for a group of high school teachers of science—it is therefore estimated that approximately \$2.16 million was awarded in fiscal year 1970 for education in the aeronautic and space science per se.

The greatest proportion of these funds supported graduate fellowships and traineeships. These funds also

provided for upgrading the subject matter background of teachers of science and mathematics in secondary schools, colleges, and universities, unusual independent study and research experiences for students and the improvement of instructional programs in aeronautic and space science in colleges and universities.

More than 1,450 individuals received training in the aeronautic and space sciences in projects supported by the three education divisions in fiscal year 1970. The majority of these individuals were junior and senior high school teachers of science and mathematics. Of the \$2.16 million obligated by the Foundation for education programs in the aeronautics and space sciences in fiscal year 1970, 76 percent was for graduate education, 8 percent for undergraduate education and 16 percent for pre-college education programs.

XIV



National Academy of Sciences National Academy of Engineering National Research Council

Introduction

The National Academy of Sciences and the National Academy of Engineering are private organizations of scientists and engineers that serve as official advisers to the Federal Government under a congressional act of incorporation. These advisory services are carried out largely by the National Research Council, which was established by the Academy to act as an operating agency.

Highlights of the work of the Academies-Research Council in aeronautics and space during 1970 include the Space Science Board's study on priorities in space science and earth observations for the next decade and its review of the NASA life sciences programs; the Aeronautics and Space Engineering Board's counseling on civil aviation R. & D. policy and on the space shuttle; studies on development and applications of aerospace materials by the National Materials Advisory Board; the Committee on Atmospheric Sciences' Friday Harbor study on physical problems of the atmosphere; administration of NASA fellowships; and a wide range of advisory and review work in aeronautics, space applications, and physical life sciences space programs.

Space Science Board

The Space Science Board is the National Academy of Sciences' principal advisory group on scientific direc-

tion 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). At Board meetings, space research and related topics are discussed with the senior staff of interested Federal agencies. During 1970, 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. The Board, and several individual members, responded to requests from the Senate and House space committees for views on aspects of the space program in the form of testimony and statements on specific topics.

Priorities in Space Science and Earth Observations.—

A Study on Priorities in Space Science and Earth Observations was convened by the Board at Woods Hole, Mass., from July 27 to August 15, 1970, with the participation of more than 90 scientists. Undertaken at the request of the National Aeronautics and Space Administration, the study was asked to determine criteria for relative priorities and to recommend levels of effort and support to be allocated to NASA programs in planetary exploration, lunar exploration, astronomy, fundamental and solar-terrestrial physics, the environmental sciences portion of space applications, and the life sciences, during the period 1971–80, based on likely contributions to basic knowledge and social benefit and on estimated total funding to be available.

The Study developed sets of priorities at three levels of funding. Evaluation of new starts during the coming decade was emphasized. The recommended programs and priorities were presented to NASA management at the conclusion of the study and are contained in the study's report, in press.

Review of NASA Life Sciences Programs.—A special study was conducted in the spring and summer of 1970 in response to a NASA request for a study of its objectives, programs, and procedures in the life sciences. The Study was to develop general guidelines for the organization and conduct of the life sciences activities within NASA. In its report, "Life Sciences in Space" (1970), the study calls for central direction of the NASA life sciences, with functional reorganization along disciplinary lines, and makes specific recommendations concerning the advisory structure, experiment selection, and personnel recruitment. It emphasizes the importance of international cooperation in space biological and medical programs. Exobiology—the search for extraterrestrial life and for deeper understanding of the origin of life—should remain the prime scientific priority in NASA life sciences, and, if manned spaceflight is to continue, a far broader program of space biomedicine and human biology should be undertaken to insure man's safety and efficiency and to qualify him for space. Finally, the study stresses the importance of ground-based research preparatory to and in support of space experiments.

Exploration of Venus.—The capability of relatively small spacecraft to answer fundamental questions about the planet Venus was assessed at a June 1970 study. The report, "Venus: Strategy for Exploration" (1970), concludes that scientific investigation of Venus is one of the most important objectives for planetary exploration in the 1970's and 1980's. It recommends that the Delta-launched, spin-stabilized, planetary Explorer be the prime vehicle for unmanned study of the planet by orbiters, atmospheric probes, and landers. The report recommends a mission strategy and, in the interest of maintaining minimal costs, emphasizes simplicity of operation on early lander missions and suggests that NASA be prepared to accept somewhat higher risk of mission failure if substantial over-all cost savings can be achieved.

Other Special Studies.—Possible contamination of Mars by spacecraft was the topic of two conferences held in July. The first, undertaken by the Board at the request of NASA's Bioscience Programs Office, reviewed and re-evaluated the probability of growth and spread of terrestrial organisms released from spacecraft which might crash land on the Martian surface. The practical importance of the question lies in the fact that significant planetary contamination would confuse the

readings of instruments seeking to detect evidence of life on Mars, and that the greater the probability of growth of terrestrial organisms, the more strict must be the standards for sterilization of the spacecraft. On the basis of information obtained since the last review in 1967, the review group felt confident in recommending a reduction from the current value of the probability of growth from one in a thousand to one in 10,000. The second meeting was held by the Board's Committee on Potential Contamination and Interference from Space Experiments at the request of the Science Adviser to the President. It considered the potential contamination risks incurred with use of radioisotope thermoelectric generators (RTG) as power supply for the unmanned Viking 1975 mission to Mars. Concluding that the advantages of the RTG are considerable and the risk of compromising future experiments small, the Committee saw no objection to use of the RTG on this mission.

The Division of Physical Sciences' Solid State Sciences Panel and a Space Science Board group conducted a joint study for NASA's Office of Advanced Research and Technology on the possibilities of increased solar cell efficiency.

Space Medicine and Biology.—Review of individual NASA research projects and flight experiment proposals was a central activity of the Board's Committee on Space Medicine and its panels during 1970. These evaluations, made at the request of NASA, covered a wide range of disciplines in the life sciences; programs in cardiovascular physiology, calcium dynamics, and microbiology were given particular attention. The Radiobiological Advisory Panel issued its report, "Radiation Protection Guides and Constraints for Space Mission and Vehicle Design Studies Involving Nuclear Systems," in November 1970. Also published was "Space Biology," the report of the special Board study at the University of California, Santa Cruz, in July 1969, concerned with biological studies in the space environment.

International Relations.—The formal international activities of the Space Science Board are centered in the Committee on Space Research (COSPAR). COSPAR, as an Inter-Union organization of ICSU, fosters fundamental research in space science through the use of rockets, satellites, and deep-space probes. Data and significant results are exchanged on a cooperative basis through the World Data Center system. The 13th annual meeting of Cospar took place in Leningrad, U.S.S.R., May 20–24, 1970, immediately following the Inter-Union Commission on Solar-Terrestrial Physics symposium. One major symposium was held during the COSPAR meeting—Remote Sounding of the Atmosphere. Reorganization of the COSPAR work-

ing group structure was augmented by the appointment of permanent chairmen and assignment of membership in the working groups. As in past years, the Board Committee on International Relations organized the U.S. participation in the COSPAR meeting, reviewed U.S. contributed papers, and prepared the annual report to COSPAR on U.S. space research during 1969.

COSPAR accepted the invitation of the U.S. National Academy of Sciences to host the 1971 annual meeting in Seattle, Wash., June 21–July 2. Symposia proposed for 1971 include: Results From the Recent Total Solar Eclipse, High Resolution Astronomical Observations From Space, Movements of the Neutral and Ionized Components of the Atmosphere Above 120 km., and Global Biophysics.

Aeronautics and Space Engineering Board

The Aeronautics and Space Engineering Board (ASEB) of the National Academy of Engineering provides advisory services to the Government in the areas of aeronautics and space engineering by focusing capabilities available within the Nation's engineering community on significant issues involving aerospace policies and programs. It recommends priorities to be assigned to engineering objectives, proposes ways to apply engineering competence to aerospace problems of national importance, and recommends methods of improving education in aerospace engineering and related disciplines.

During October–December 1969, the Board formed the ad hoc Study Advisory Committee on Aeronautics (SACA) to provide expert and broad advice and counsel to NASA and the DOT in their joint study of civil aviation R. & D. policy. The SACA met once in 1969 and four times in 1970 to offer comments on direction of the study, review its progress, and critique drafts of its report. Upon conclusion of each meeting a summary of comments was submitted to the study's director.

Since mid-1969, the ASEB has examined: (1) engineering approaches and concepts considered for the space shuttle, concentrating on sizing of the shuttle booster and orbiter, and (2) the overall program balance and timing for the various phases of development. The Board held a series of meetings at the NASA centers engaged in the space shuttle program and has submitted informal comments on the program's progress and direction to the NASA Administrator. NASA has strongly endorsed the Board's plan to continue following that program and to offer periodic advice on problem areas and critical decision points. This review is expected to continue into 1971.

The Board intends to continue its study and evaluation activities both in aeronautical and space transportation systems throughout 1971. The latter, in particular, may be expected to include increased

consideration of international cooperation in space and space station utilization.

Division of Behavioral Sciences

Committee on Hearing, Bioacoustics, and Biomechanics (CHABA).—CHABA sponsored two aerospace meetings: the Fifth Annual Meeting on Vestibular Functions as Related to Space Travel, in Pensacola, Fla., and a Symposium on Biodynamic Models and Their Applications, in Dayton, Ohio. CHABA is cooperating with the International Civil Aeronautics Organization and the Organization of Cultural and Economic Development in setting international criteria for sonic boom. Another working group is establishing criteria for noise and vibration levels in aircraft. A report was published on the detection of submarines by means of sonar in helicopters. A revision of the Bioastronautics Data Book is nearing completion.

Committee on Vision.—At the request of NASA, a working group has been formed to advise the agency on its program to develop certification requirements for simulation of the aviator's visual environment. The NASA program to develop a device for testing visual functions during spaceflight has been reviewed. The chairman of the Committee's Executive Council debriefed the Apollo 11 commander on visual problems encountered in lunar exploration.

A working group continues to advise the FAA on its program to develop proximity warning indicators (PWI) for general aviation aircraft. Suggestions for research have been reviewed, and information on related programs in the Army, Navy, Air Force, and NASA is being collected. Any recommendations for specifications will be sent to the Aircrew Station Standardization Panel and to the FAA.

At the request of the Air Force and the Army, a working group has been formed to study the levels and effects of microwave radiation in aircraft and in radar installations.

Division of Earth Sciences

Committee on Space Programs for Earth Observations, Advisory to the Department of Interior.—The Advisory Committee has continued to prepare memoranda for the Department of Interior advising on various aspects of remote sensor programs in the discipline areas of geography, cartography, geology, hydrology, and oceanography. Meetings of specialized panels in these fields, as well as of a parent committee, addressed problems and opportunities arising in connection with the Department's Earth Resources Observation Systems (EROS) program. Committee investigations have included such tasks as the development of

sensor technology, the evaluation of in-house and contract research proposals, the application of data to the tasks of the Department of Interior, and design and use of optimum equipment to be used in future earth resources survey aircraft, spacecraft, and processing centers.

Division of Engineering

National Materials Advisory Board (NMAB).—The general purpose of the NMAB is the advancement of materials science and engineering in the national interest. It undertakes to define technical problems, potential approaches, and new opportunities of national concern and relevance to Government, industry, or academia, attempting thereby to stimulate appropriate action.

Aeronautical and space materials and their applications continue to represent an area of problems that challenge the most advanced capabilities of materials technology. These difficulties derive from the extreme environmental conditions imposed on the materials used in aeronautical and space operations and the inherent necessity for minimum structural weight. A large part of the Board's attention and effort is devoted to advising the Government on its programs of aerospace materials research and development.

Beryllium, because of its light weight, strength, stiffness, and other unique properties, is being used to advantage in certain aerospace applications. However, problems relating to brittleness and inherent anisotropy remain. At the Government's request, the Board arranged and held a 3-day conference in March to review a large variety of applications of beryllium in aerospace hardware during the past 5 to 10 years and to discuss problems and opportunities. The Conference Proceedings were published in Report NMAB-272. In addition, an NMAB study is being conducted by the ad hoc Committee on Beryllium to recommend policy options relative to the future Government role in advancing beryllium technology.

A number of other NMAB ad hoc committee studies now under way concern the development and application of aerospace materials. Noteworthy among these are: A study to identify the factors that promote or inhibit the use of advanced materials, to evaluate the influence of these factors, and to recommend measures to encourage prompt utilization; a study of testing methods useful in predicting material performance in structures and components; a study of practices in aircraft design and materials selection, materials behavior, fabrication processes, and inspection techniques, to guide and foster optimal fracture-prevention practice in aircraft; and a study to define problems of producing high-performance castings (metal) and to plan a program for upgrading the technology.

Division of Physical Sciences

Committee on Atmospheric Sciences.—The Committee on Atmospheric Sciences is presently engaged in two studies involving research and technological development and application for observing and measuring the terrestrial atmosphere. A wide variety of physical problems dealing with the atmosphere were discussed and evaluated during a summer study held at Friday Harbor Laboratories of the University of Washington during June 1970. Scientific and technical issues pertaining to requirements necessary for advances in understanding atmospheric dynamics, chemistry, climate, and modifications—both intentional and inadvertent—were identified. The second study, nearing completion, concerns weather modifications and has elements in common with the first. Many of the specific measurements that have been identified as necessary to understand the dynamics of climate also pertain to the determination of ability to modify weather.

Among the principal conclusions of the studies are the following:

—The monitoring and measurements from space platforms should be coupled during the developmental stage with data obtained from ground-based sensing as well as from aircraft.

—The concerns of the public, the Government, and scientists have focused upon a major need to obtain reliable and continuing data on the particulate and gaseous composition of the atmosphere, particularly in light of the effects that man's activities may be having on the global change of climate. Local and regional aspects of man's interference with natural atmospheric processes are also very important. Global aspects are those to which the satellite is most obviously a key element. Measurements of the cloud populations of the globe have been continuing for a number of years. It is now important that measurements crucial to the radiative and heat budgets be made. Such measurements will include secular changes in global albedo and will require monitoring global and regional changes in cloud cover as well as the thermal characteristics of the atmosphere-ocean-land complex.

—The role of man in contributing large quantities of carbon dioxide and sulfur dioxide to the atmosphere may now be sufficiently great to alter the radiative and chemical characteristics of the atmosphere which are important in bringing about long-term changes in the global climate. It seems therefore prudent and wise to plan for an integrated system of monitoring from the earth's surface as well as from space which will confirm the existence, location, and time-variation of constituents, both gaseous and particulate, of natural or man-devised origin.

—The relative importance of various atmospheric constituents in effecting climatic change must also be tested through the use of existing numerical atmospheric models and models specifically developed to study long-term climatic changes. Computer developments that will permit testing of experimental models should be utilized to the fullest extent possible.

U.S. Committee for the Global Atmospheric Research Program.

—The Global Atmospheric Research Program (GARP), a major international program established to improve our knowledge of the dynamics of the general circulation of the global atmosphere, has the ultimate goal to develop the physical and mathematical basis for extended predictions of the planetary circulation. The U.S. Committee for the GARP (USC-GARP) has worked closely with Federal agencies in developing the scientific objectives and is continuing to establish observational and technological requirements through its working groups that are considering specific scientific problems and planned field programs to deal with them. The USC-GARP is also serving as the focal point for coordination and communication between the scientific community and the Government, and will continue to assist in developing international planning for the scientific activities.

During the International Planning Conference on GARP, held in Brussels in March 1970, 25 nations agreed to move toward the implementation of the proposed observational experiments, in particular a tropical experiment to be conducted in the Atlantic during 1974, and a first global experiment to be undertaken a few years later. Space-based observation systems are crucial to both experiments for the identified remote measurements, data collection, platform tracking, and communications. GARP requirements have already been incorporated into the U.S. operational meteorological satellite system planned for that period, and several other nations, notably France, Germany, Japan, the United Kingdom, and the U.S.S.R. have indicated their intention to contribute space platforms. The USC-GARP will continue to participate in both national and international planning and coordination of these particular activities.

Office of Scientific Personnel

The NASA International University Fellowships in Space Science and the NASA Postdoctoral and Senior

Postdoctoral Resident Research Associateship Programs, which are administered for NASA by the Office of Scientific Personnel, continue to have a strong attraction for scientists and engineers. The NASA International University Fellowships Program, jointly financed by NASA and participating space agencies of other countries, was completely subscribed, with 52 full-year fellowships, both in 1969 and 1970. A total of 282 fellowships have been awarded from the beginning of the program in 1961 to December 1970.

The number of applications for the Resident Research Associateship Program continues to exceed by a wide margin the number of appointments which are available. On August 30, 1970, there were 192 associates on tenure.

The associateship program, initiated in 1959, provides an opportunity for investigators of unusual ability to conduct research in NASA centers. In the fellowship program young scientists from other countries study and participate in space research at leading universities in the United States.

Committee on SST-Sonic Boom

The Committee on SST-Sonic Boom, through its subcommittee structure, met as necessary during the year to determine what additional sonic boom research is needed to better understand the impact of the boom on people, animals, and structures. Deliberations were based on a review of ongoing sonic boom research, within the guidelines of Presidential directives.

One of the areas of sonic boom generation and propagation research in which little work has been done and which the Committee currently considers important is the careful field measurement and subsequent analysis of shockwave phenomena produced by an aircraft in the Mach 1.0-1.2 range. During the year, a team from NASA's Langley Research Center planned such a field test centered on the 1,527-foot Bren Tower located on Jackass Flats at the AEC Nevada Proving Ground. The tower serves as the focal point for instrumentation to measure air mass and shockwave characteristics. The data obtained from this test will be of particular value as a check on sonic boom theory now in process of formulation and refinement in this speed regime. These theoretical efforts are under way partially as the result of earlier Committee interest and support of such work. The Committee cooperated with NASA on the Bren Tower project and continued its policy of close collaboration with other organizations sponsoring sonic boom research work in other areas.



Introduction

The Smithsonian Institution has been concerned with aeronautics and space sciences for nearly a century, since its second Secretary conducted his pioneering research in the dynamics of manned flight.

Today, the Smithsonian Institution continues its contributing role in this Nation's aeronautics and space programs. The Institution's research programs in these disciplines are coordinated through the Office of the Assistant Secretary for Science. Aeronautics- and space-related activities are conducted by the Smithsonian Astrophysical Observatory (SAO), the Office of Environmental Sciences, the National Museum of Natural History, the Center for Short-Lived Phenomena (CSLP), and the National Air and Space Museum.

Recognizing the new tools and methodologies that are emerging with the development of satellites and space technology, the Smithsonian Institution is exploring the possibilities of their applications to biological and ecological problems requiring wide-range and long term surveillance. Observations of climatic changes on earth as reflections of a variety of cyclical fluctuations help to establish a baseline for the study of the world ecosystem.

The responses of animals to the environment can also be monitored and a test for a system for tracking migrating animals is currently underway. The Institution was cosponsor with NASA for a Symposium on Animal Orientation and Navigation which took place at Wallops Island, Va., on September 9-13, 1970.

The support of the public for the U.S. activities in space is largely dependent on the extent to which the man on the street understands its purposes. The exhibits in the National Air and Space Museum are designed to educate its visitors and to stimulate their interest. The great number of people visiting the museum daily attest to our success in this respect.

Smithsonian Astrophysical Observatory

The Smithsonian Astrophysical Observatory (SAO) has attempted to follow the tradition of its founder through a dynamic program of astrophysics and space sciences contributing to both the specific goals of the national space program and the broader goals of pure discovery.

During the past year, SAO researchers have made significant advances in the understanding of the nature and evolution of the solar system through the analyses of lunar and meteoritical samples; of the energetic processes in the universe through the observation of high-energy sources of radio, infrared, and gamma ray emissions; and of earth itself through an extensive program of geoastronomy that has helped establish basic models for the earth's size, shape, atmosphere, and gravitational field. Throughout all this research SAO has fostered international cooperation and whenever possible has as actively contributed to those worldwide efforts complementing national goals.

Earth Physics.—In ranging experiments utilizing satellites equipped with retroreflectors, the current laser systems developed by SAO have proven about 20 times more accurate than the Baker-Nunn camera used at the satellite tracking stations. Continued development of these systems may produce precision further improved by a factor of 10. Eventually, the laser should permit the measuring of the distances between ground stations to an accuracy of 1 inch. Obviously, such a capability would offer many new scientific possibilities, such as the direct measurement of continental drift, the solid-earth tides, the rotation of the poles, the spreading of the seabeds, ocean-level profiles, and large-scale crustal shifts.

Spacecraft-tracking data obtained by this network of cameras and lasers have contributed much to earth physics, specifically in SAO's research on atmospheric density variations, the gravitational field, and the geometry of the earth.

For example, much of what is known about the earth's atmosphere above 200 km. is based on SAO analysis of satellite orbital data gathered over the past decade. By a long-term study of the correlation between satellite drag and solar activity, SAO scientists last year generated the bulk of the data for an "International Reference Atmosphere." This tabulates the mean temperature and density variations of the atmosphere at any position for any period of the day and for varying solar and geophysical circumstances.

Similarly, the "Smithsonian Standard Earth" provides the most accurate representation yet produced of the earth's size, shape, and gravitational field. The 1970 edition was improved both by the addition of new

laser data and by the contribution of data from a score of international sources, including the U.S.S.R.

International Scientific Cooperation.—Since its inception, the SAO spacecraft-tracking activity has fostered a high level of international cooperation, both through the operation of stations in foreign countries and through the active participation of foreign scientists in SAO research programs.

In addition, SAO has organized cooperative tracking programs for earth-science purposes, drawing on the resources of other agencies both at home and abroad. Such a joint campaign is now being implemented with overall coordination by the Centre National D'Etudes Spatiales of France and with SAO serving as one of the four major "subcenters." This program, known as the International Satellite Geodesy Experiment or ISAGEX, will be conducted from January to June 1971 and will emphasize laser tracking. Some 20 countries will participate. The observational data from this ambitious joint venture should permit significant advances in earth physics.

Analysis of Meteoritical and Lunar Samples.—On January 9, 1970, near Lost City, Okla., the field manager of SAO's Prairie Network recovered a 22-pound fragment of a meteorite photographed falling to earth 6 nights earlier. Within the next 4 months, three more fragments of the same fall were recovered in this area. This marked only the second time in history—and the first time, intentionally—that a meteorite photographed entering the earth's atmosphere had been recovered.

The rapid recovery of the Lost City Meteorite allowed almost immediate analysis of its short-lived radioisotopes created by cosmic-ray bombardment in space. More important, the photographic record of the fall provided information on the meteorite's origin (from the asteroid belt beyond the orbit of Mars) and its loss of mass in flight. Because the meteorite proved to be a bronzite chondrite, a type accounting for 35 percent of all falls, Lost City provides a standard reference model for many objects recovered in the past. Moreover, the photographic data can be used to calibrate information gathered on thousands of bright meteors photographed by the Prairie Network in the past 5 years.

Because of SAO's extensive experience with the analysis of recovered meteoritical material, three separate research groups were selected by NASA as principal investigators of lunar material returned by the Apollo astronauts.

One group, engaged in the mineralogical and petrological studies of samples through X-ray diffraction and electron-microprobe techniques, found an unexpected amount of gabbroic anorthosite in Apollo 11 samples. This anorthosite material matched the chemi-

cal composition of materials in the lunar highlands as revealed by earlier Surveyor landings, thus suggesting that the anorthosites might be mountain fragments tossed into the Mare Tranquillitatis (Apollo 11 landing site) by cratering impacts. The unusual anorthosite content of the lunar highlands has led to the suggestion that this material may have formed in the early evolution of the moon when it floated to the top of the molten matrix as a sort of geological scum, thereby forming the first part of the moon's crust. This theory has led, in turn, to a search of earth itself for similar outcroppings of anorthosite as examples of this planet's own primordial crust. A new view of the earth's evolution may result from this research on the lunar samples.

Another group has been conducting radioisotopic analyses of Apollo 11 and 12 samples to find traces of argon-37 and tritium, radioactive isotopes created by cosmic-ray exposure. This research reveals information concerning both radiation levels on the moon and exposure ages of the samples themselves. In related research, a third group is using a small, tabletop laser to free the radioactive gases in the lunar samples for mass-spectrometer analysis.

Energetic Processes in the Universe.—The past several years have witnessed an explosion of new astronomical discoveries, many of which may have consequences for mankind beyond our imagination. For example, at the edge of the known universe, powerful quasars are observed receding at nearly the velocity of light. The regular, rapid flashes of pulsars indicate the presence of matter so compressed it might be comparable to squeezing all the world's automobiles into a thimble. Intense sources of infrared radiation are detected at the core of several galaxies, including our own Milky Way. A host of molecules, many representing organic chemicals basic to the chain of life on earth, have been discovered in interstellar space, and a uniform microwave background seems to engulf the entire sky, indicating to some astronomers that they might be receiving the left-over radiation from the primordial explosion that created the universe.

To understand these and other problems associated with the creation and evolution of the universe, SAO scientists are conducting intensive research programs utilizing new instrumentation capable of observing longwave radio radiation, infrared and ultraviolet light, and very shortwave gamma rays.

SAO prepared and operated aboard the OAO-A2 an experiment called Telescope. It consisted of four astronomical telescopes mated with special television cameras designed to photograph star fields in four different wavelengths of ultraviolet light.

During more than 16 months of operation that ended in late April 1970, the Telescope experiment observed 3,000 star fields, taking 8,700 photographs that covered about 10 percent of the sky, including about 20 percent

of the region near the Milky Way containing the majority of ultraviolet objects.

The photographs provide data for more than 25,000 stars in four ultraviolet regions of the spectrum. The experiment also observed the Moon, Comet Tago-Sato-Kosaka, and the planets Mars and Jupiter in ultraviolet light.

Smithsonian scientists are now compiling and analyzing the data in preparation for making a detailed comparison of the actual observations with theoretical stellar models developed at SAO. Complete analysis is expected to take several years, culminating in a catalog of ultraviolet star brightnesses and an interpretation of the material that will enable astronomers to refine their theories of the evolution of young or "hot" stars.

Observing the universe at radio wavelengths with both an 85-foot antenna operated jointly with Harvard University and a 140-foot antenna maintained by the National Radio Astronomy Observatory at Green Bank, W. Va., Smithsonian astronomers have discovered two new important constituents of interstellar gas—formic acid and methyl alcohol.

The search for these and other molecules in space is aided by the accurate determination in the laboratory of a particular molecule's radio wavelength frequency. These same laboratory experiments have also provided a possible explanation for the process by which infrared energy is converted to the microwave radiation observed from the water and hydroxyl molecules in space.

One of the most challenging fields of research at SAO involves gamma-ray astronomy. Theoretical studies indicate that some celestial objects should be emitting gamma rays. This ultra-high energy radiation may provide the key to understanding many phenomena, including magnetic fields, the density of matter, high-energy particles in intergalactic space, radio sources, and the pulsars. Indeed, gamma-ray studies may even provide answers to basic questions concerning the creation of matter and antimatter in the universe.

The search for gamma-ray sources is being conducted at SAO's Mount Hopkins Observatory with a 10-meter optical reflector and with balloon-borne detectors launched from Texas and India. The observations at Mount Hopkins represent one of the most sensitive ground-based searches ever conducted. One of the major suspected sources now under investigation is the pulsar at the center of the Crab Nebula.

Man in Space.—During the past year, SAO scientists also contributed to the growing body of information concerning the effects of the outer space environment on man.

Several theories have been suggested to explain the mysterious light flashes reported by Apollo astronauts. One investigator has theorized that the flashes may be Cherenkov light created inside their eyeballs. He sug-

gests that when the charged particles, known as cosmic rays, penetrate the spacecraft walls and the helmets of the astronauts, they pass into the vitreous humor of the eyeball and produce extremely brief bursts of light. In short, the astronauts' eyeballs may be acting as small Cherenkov radiation counters. The theory was tested on the Apollo 13 flight, when the astronauts made careful observations of the flashes in a darkened cabin both with their eyes open and with them covered by a light-tight mask. On a future flight, they will attempt similar observations when in lunar orbit to see if the moon serves as a barrier against such radiation.

The Office of Environmental Sciences

Satellite tracking of animals, together with the monitoring of physiological factors simultaneously with conditions of the environment provides unique opportunities for investigating a vast array of important biological questions—such as the migratory movements and navigational guidance mechanisms of animals, patterns of dispersal, and concentration associated with feeding and/or reproduction, the entrainment of physiological cycles by environmental parameters, and patterns of the vector transmission of disease by migratory or nomadic animals.

As an initial step in this direction, a wild free-roaming elk was tracked and monitored on the National Elk Refuge during the month of April 1970, demonstrating the practicability of tracking animals on the surface of the earth by satellite. The experiment so far has been a qualified success, and the study will be continued with an improved instrument collar through an entire migratory cycle to correlate behavioral activities with tracking and simultaneous monitoring of physiological and environmental parameters.

National Museum of Natural History

The past year has been unique in the association of the National Museum of Natural History (NMNH) with the space program. After many years of collection and research on randomly acquired extraterrestrial rocks—meteorites—scientists at NMNH have been privileged to examine the lunar rocks purposefully collected by the Apollo missions. Thus the preceding man-years of thought, training, and experimentation were put to the ultimate challenge of elucidating the history and evolution of the moon from these samples.

Samples of the Apollo 11 collections were received at the Museum in mid-September 1969, and since then virtually everyone in the Department of Mineral Sciences has been actively involved in a coordinated research effort on them, and on samples from the Apollo 12 mission. NMNH has been able to plan and execute

a truly comprehensive investigation of the lunar materials—their chemical and mineralogical composition, and the interpretation of these data to provide a tentative account of their petrologic history and evolution. Although the samples received were small (totaling less than an ounce), it was possible to extract from them a remarkable variety of rock and mineral fragments. Among these was a unique object, a small metallic spheroid 4 millimeters in diameter. It evidently formed as a droplet of nickel-iron from a metallic meteorite which crashed on the moon. The surface of this spheroid is spotted with small craters, the product of impacts of lunar particles traveling at supersonic velocities. In its shape and surface features it mimics the moon itself.

Center for Short-Lived Phenomena

The Smithsonian Center for Short-lived Phenomena (CSLP) 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 1970, the CSLP participated in a number of activities related to the space sciences.

The Analysis of Extraterrestrial Materials.—The CSLP participated in the investigation of 13 major fireball events occurring in seven countries and six States during the year. These investigations included contact with event areas by telephone and cable, collecting eyewitness reports of magnitude, direction, duration, color, sound phenomena, and impact locations where they occurred. The reports were telephoned and cabled to interested scientists throughout the world who made on-the-spot investigations of the majority of the reports.

As a result of these investigations, the CSLP was responsible for the recovery and delivery to laboratories of four meteorite fragments from falls in Venezuela (January 18), Ethiopia (May 11), Sudan (Au-

gust 15), and Swaziland (October 6). All four samples were subjected to extensive study, including radioisotopic analysis, in Smithsonian laboratories.

Man in Space.—Under contract to NASA, the CSLP continued its role in the attempts to determine the validity of the transient lunar phenomena—brightenings, colorations, etc.—supposedly observed in the moon's surface by ground-based observers.

During the Apollo 13 flight, the CSLP coordinated communications between 216 astronomical observers in 34 countries and the NASA Manned Spacecraft Center for the rapid relay of reports of transient lunar phenomena to the astronauts. The Apollo astronauts were unable to confirm any observations made from ground stations.

National Air and Space Museum

Under the terms of the space artifacts agreement with NASA, the National Air and Space Museum continued to receive rocket engines, manned spacecraft, scientific satellites, spacesuits, etc. All such material in exhibitable condition is placed on display at the Smithsonian or loaned to NASA centers, museums and other appropriate organizations in the United States and abroad. Overseas loans are coordinated with the U.S. Information Agency and the Department of Commerce. During 1970 major overseas exhibits of spacecraft were displayed at Expo 70 in Japan, and in western and eastern Europe. They were viewed by millions of visitors.

At the Smithsonian Institution in Washington, several newly displayed aircraft include an RAF Hurricane and the "Polar Star" of Antarctic fame. Charles Lindbergh's Tingmissartoq was displayed at Expo 70.

Other new exhibits at the museum were the communications satellite Early Bird, and Astronaut Armstrong's Apollo 11 lunar visor. An outstanding and complete library of oral history of space flight was received from a private donor.



Federal Communications Commission

Introduction

The major responsibilities of the Federal Communications Commission in aeronautics and space include the following:

1. Specific responsibilities in the communications satellite field such as authorizing Comsat's participation in the ownership and operation of satellites for use in the global communications satellite system and authorizing the construction and operation of U.S. non-Government earth stations.

2. Participation in national and international groups and organizations concerned with satellite communications for general use, as well as specialized uses by the aviation, marine, and amateur radio services.

3. Administration of domestic rules and regulations applicable to non-Government radiocommunications.

4. Participation in national and international development of frequency allocations and solutions to technical, operational, and policy problems regarding aeronautical communications, space satellites, and radio astronomy, as well as the coordination of international notification of specific frequency assignments and use.

Communication Satellites

International satellite communications have continued to grow at a rapid rate, so that at the end of the year the Intelsat system was using 2,126 circuits, an increase of 710 circuits over the number in operation at year-end 1969. Membership in the International Telecommunications Satellite Consortium (Intelsat) increased by an additional seven countries, as of December 31, 1970. The Global Satellite System now has 43 earth stations with 51 antennas in operation in 30 different countries.

Two additional satellites in the Intelsat III series were successfully launched and placed in service over the Atlantic Ocean. The configuration of the space portion of the Global System now consists of the two Intelsat III satellites serving the Atlantic region, one Intelsat III satellite serving the Pacific region, and one Intelsat III satellite serving the Indian Ocean region. An Intelsat II series satellite is providing service between the mainland and Hawaii. A sixth satellite,

also of the Intelsat II series, is available for service in the Atlantic region on a contingency basis.

The first commercial satellite, Early Bird, launched April 24, 1965, designed with a useful lifetime expectation of 18 months, has now lost its stationkeeping capability after five years of operation and is drifting westward. It could be used in emergency for communications between the U.S. earth stations on the west coast and the Hawaii earth station.

The Intelsat III F-2 satellite launched December 18, 1968, for service over the Atlantic experienced difficulties requiring its replacement, and the Intelsat III F-8 satellite, launched July 23, 1970, never achieved proper orbit due to an apparent malfunction of the satellite apogee motor.

The first satellite of the Intelsat IV series now under construction is scheduled for launch and placement over the Atlantic Ocean in early 1971.

The earth station in Alaska became operational in July 1970 with 80 circuits authorized for service to the U.S. mainland. The Guam earth station also became fully operational, bringing the total number of U.S. earth stations now operating in the Intelsat system to eight. Construction has been authorized and is now underway for a new replacement antenna at the Andover, Maine, earth station.

International Radio Consultative Committee

A Plenary meeting of all the study groups of the International Radio Consultative Committee (CCIR), including Study Group IV (Space Systems), was convened in February 1970 at New Delhi. The CCIR, encompassing 14 study groups, serves as an adviser to the International Telecommunication Union (ITU) on technical matters involving the use of radio. Five FCC members attended the plenary, one of them as vice chairman of the U.S. delegation and another as a major working group leader for Study Group IV. The plenary approved documents prepared by Study Group IV at the final CCIR meeting of September 1969 in Geneva with only minor changes. At the plenary continuation of an International Working Party (IWP) of Study Group IV on Efficient Use of the Geo-Station-

ary Orbit and an IWP of Study Group V on Propagation for Space Telecommunications was approved. An FCC representative serves on both IWP's. The IWP of Study Group IV met in London during the week of October 19 and the IWP of Study Group V met in Nice during the week of November 30 with the FCC member attending both meetings.

At the plenary a special joint study group meeting preceding the Space Conference, 1971, was set for February 1971. FCC members have been heavily involved in the preparation of over 100 technical documents for this special meeting, including documents on feasibility of satellite broadcasting on several frequency bands, criteria for sharing of frequencies between Comsat and terrestrial radio systems at frequencies above 1 GHz, discussion and proposals for the escalation of power flux densities from satellites with angle of arrival in bands shared with radio relay systems, and other similar documents.

The Commission will provide participation by about four of its members to the special joint study group meeting in February 1971. The intensive preparation for this meeting is responsive to the needs of the World Administrative Radio Conference (WARC) on Space in June 1971.

Radio Astronomy and Space Services

The Commission has been in continuing consultation with the Office of Telecommunications Policy and the Department of State in the preparatory work for the forthcoming WARC on matters pertaining to radio-astronomy and the space services. The ITU Administrative Council adopted a resolution in 1968 calling for such a conference and set forth a tentative agenda for comments. The date on which it will convene has now been set for June 7, 1971, and will run for 6 weeks. In response to the resolution, the FCC initiated an inquiry (docket No. 18294) in August 1968 for the purpose of developing proposals to that conference which would be responsive to the needs of its licensees. This preparatory work, conducted in consultation with the Office of Telecommunications Management and its successor, the Office of Telecommunications Policy (OTP), evolved through a series of seven notices of inquiry into a document entitled "Draft Proposals of the United States of America for the World Administrative Radio Conference for Space Telecommunications (Geneva, 1971)." The latter document was also transmitted abroad in August 1970, by the Department of State, to elicit the comments and reactions of other member countries of the ITU. The formal proposals of the United States to the Conference will be based on these draft proposals, as modified to take into account the national and international comments.

Aeronautical Services

Commission staff representatives have continued working nationally with other Government agencies and the aviation industry, and internationally with the International Civil Aviation Organization (ICAO) and the CCIR, toward development of system parameters and the application of space radio communication techniques to help satisfy the communication and navigation requirements of domestic and international civil aviation. During 1970 various tests and study programs previously established, as well as new programs, have been pursued. New authorizations or renewals have been granted where required.

The air transport industry, under the authorization of the Commission, continued tests which were begun in 1966 to assess the relative merits of emission techniques and normal power versus substantially higher power abroad aircraft as elements between a communication aeronautical station and aircraft via satellites. The Commission staff continued study of the results of those tests as well as the results of studies such as the previously contracted industry report of the program in order to determine the most suitable techniques to be used in aeronautical satellite systems. Such information assisted the Commission in developing preliminary views transmitted internationally for coordination prior to the forthcoming WARC.

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

The Commission continued to authorize various scheduled airlines to participate in tests using NASA's Applications Technology Satellites (ATS). Tests using ATS are presently continuing over both the Atlantic and the Pacific between ground terminals and aircraft. Continued analysis of the results is in progress with particular emphasis on the potential effect of satellite systems on the existing aeronautical radio communications systems. Further test programs, particularly in regard to UHF usage and technology are being prepared. Actions within the Commission are being taken to provide for the capability of collision-avoidance systems. The possibility of simplified and inexpensive equipment to provide pilot warning, in addition to the more complex and expensive collision-avoidance systems is being studied.

Commission staff representatives have participated in the preparation of guidance material for the use of U.S. representatives to international conferences including those of the CCIR and the ICAO. Members of

the staff again served on the U.S. delegation to the CCIR interim meeting at Geneva this year which treated, inter alia, aeronautical satellites. The staff is preparing documentation for the forthcoming WARC. This is particularly important because presently the ITU rules provide only a portion of the frequency requirements to satisfy the aeronautical requirements foreseen for the near future. Staff emphasis will be on the required changes to satisfy aeronautical requirements through the time period present to 1980.

Maritime Mobile Service

The ITU World Administration (Maritime) Radio Conference held in Geneva in September–November 1967 adopted recommendation No. MAR 3 relating to the utilization of space communication techniques in the maritime mobile service. The recommendation invited administrations, IMCO, and the CCIR, respectively, to undertake a study of maritime operational requirements for a safety and navigation radio communications system via satellite and the technical aspects of such systems. In 1970, the Commission, working with the Intergovernmental Maritime Consultative Organization (IMCO) Subcommittee on Radiocommunications, CCIR, the Radio Technical Commission for Marine Services (RTCM), industry, and other Government agencies, is continuing to study the potential value of adapting satellite relay techniques to the communications requirements of the marine mobile service.

The RTCM, an organization established by the FCC in which Government and industry, cooperate in studies of existing and proposed systems of maritime communications, previously established a special committee SC-57, Maritime Mobile Satellite Communications, to investigate the possibilities of utilizing satellites for marine communications and navigation. A test program was developed which was subsequently adopted by the Maritime Administration as a basis for tests conducted during early 1968 in which VHF communications were relayed via NASA's ATS-1 and ATS-3 satellites between U.S. ground terminals and the merchant ship S.S. *Santa Lucia* en route from Port Newark, N.J., through the Panama Canal to Valparaiso, Chile, and return. These tests together with those performed during 1967 through 1968 by the U.S. Coast Guard from the cutters USCGC *Klamath*, *Staten Island*, *Glacier*, and *Casco* have demonstrated the feasibility of communicating with ships at sea via satellite. This was a basic and vital first step.

The Commission is continually analyzing the results of these and other test programs and study reports to determine their validity and potential for satisfaction of maritime communications requirements and to establish the parameters for the additional test and study

programs that may be required. Additionally, working with the RTCM, the staff is developing a program plan for the evolutionary development and implementation of marine communication systems using space techniques. In 1970 it was determined that further information was required before a program plan can be finalized.

A Government-industry program has resulted in the establishment and documentation of a comprehensive statement of operational requirements which is being used as guidance in the development of the evolutionary program plan. Updating from newly received information was accomplished.

A detailed study generated by the RTCM SC-57 in 1970 and funded by governmental agencies, has been performed for the purpose of determining the required scope of a satellite system to satisfy maritime mobile requirements, on a worldwide basis, in the present to 1980 time frame. This study, as well as the test programs previously mentioned are being analyzed to determine specific existing and foreseen problems in order that feasible solutions can be promulgated.

Present efforts are directed, in particular, to the problem of feasibility of the sharing of systems or subsystems between aviation and marine services; feasibility of sharing of frequency bands for commonality (particularly for search and rescue); problems of terrestrial and space systems sharing frequencies; and preparation of documentation in advance of the forthcoming ITU Space WARC. Preconference coordination with other administrations is in progress.

The Commission, in reviewing responses to the seven notices of inquiry in docket No. 18294, is developing the U.S. position concerning maritime communication needs using satellite techniques. The ITU radio regulations (pars. 273A and 352B, EARC for Space, Geneva, 1963) presently contain authority for the aeronautical mobile service to use space communication techniques whereas no provisions exist for the maritime mobile service. The major efforts involved presently are directed specifically toward the analysis of all information now available in order to establish a viable U.S. position for the 1971 WARC.

Amateur Radio Service

The Radio Amateur Satellite Corp. (Amsat) satellite, Australis-Oscar (AO-5), carrying telemetry beacons, was launched January 23 and functioned 23 days on 144 MHz and 46 days on 29 MHz before the batteries were depleted. The command system for the 29-MHz beacon functioned reliably; the passive attitude-stabilization system proved to be excellent for the low polar orbit. Reception of the 29-MHz beacon indicated more experiments would be highly desirable at this order of frequency. The method of thermal control

and the simplified multiple-parameter telemetry system proved to be practical and useful.

The same group is seeking NASA approval of a satellite proposal calling for the launch of a small communication relay satellite, Amsat-Oscar B(AO-B), operating in the 144- and 432-MHz amateur bands as a secondary payload on an unspecified NASA launch late in 1971. It would be used in the conduct of an experimental multiple-access communications program involving small, low-powered ground terminals operated by the amateur service.

Broadcasting Policy Coordination

The Commission furnished a member of the U.S. delegation to the UNESCO meeting of governmental experts on international arrangements in the space communication field which was held in Paris in December 1969. This meeting examined the problems involved in the use of space communication for the free flow of information, the rapid spread of education and greater cultural exchange. The meeting advised on a possible convention to insure legal protection of satellite television transmission against uses not authorized by the

originating body; defined the studies which might be prepared by UNESCO on space communication; assessed the requirements of education, science, and culture in the allocation of frequencies for space communication; and discussed a draft declaration on the guiding principles which might govern the use of space communication for the furtherance of UNESCO's aims.

The Commission was represented on the U.S. delegation to the third session of the working group on direct broadcast satellites of the U.N. Committee on the Peaceful Uses of Outer Space at New York in May 1970. This group further studied satellite broadcasting with particular regard to international cooperation and the legal questions raised by broadcasting via satellite.

The Commission also participated in the work of Panel 1, Ad Hoc Intragovernmental Communication Satellite Policy Coordinating Committee, under the direction of the Office of Telecommunications Management (now Office of Telecommunications Policy). The Panel studied national policies relating to the use of satellites for international broadcasting, including general consideration of the technical, economic, legal, political, and other aspects of such broadcasting. Panel 1 issued its report on July 15, 1970.

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 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					
1964.....	69	8	4	0	Total.....	669	114	42	11

¹ 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	Australia	Japan	Red China
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	1
Total.....	513	465	6	2	1	1	1

¹ 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—1970

Launch date (Gmt) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Jan. 14 Defense 2A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	253 78 89.8 109.9	Decayed Feb. 1, 1970.
Jan. 15 Intelsat III (F-6) 3A Thrust-augmented Thor-Delta	Objective: To provide equivalent of 1,200 2-way voice circuits or 4-Color TV channels to carry communications traffic between the United States, Latin America, Europe, and the Middle East. Spacecraft: Cylindrical 56-in. diameter and 78 in. high; spin stabilized; 5-year lifetime electrical power system provides 130 watts generated by 10,720 solar cells; rechargeable 20-cell nickel-cadmium battery; weight 334 lbs.	22, 259 22, 243 1, 437.2 0.9	Launched by NASA for Comsat Corp., the manager of Intelsat. Stationed in synchronous orbit at 24° west longitude. Replaced Intelsat III F-2 over Atlantic. Spacecraft operating normally; began full-time commercial services Feb. 1, 1970.
Jan. 23 ITOS I (Tiros M) 8A Thrust-augmented Thor-Delta (2 stage)	Objective: To flight qualify the prototype spacecraft, thereby obtaining the engineering data required for the evaluation of a single momentum wheel stabilization system for an earth-oriented, stabilized platform. To evaluate the use of the stabilized platform for operational methodology by performing cloud-cover observations in both direct readout and stored modes of operation. Spacecraft: Rectangular, box-shaped spacecraft with a deployable 3-panel solar array. 3-axis stabilized, earth-oriented satellite carries 2 Advanced Vidicon Camera System (AVCS) and 2 Automatic Picture Transmission (APT) camera subsystems which provide daytime coverage, and 2 Scanning Radiometer (SR) Subsystems (infrared) which furnish nighttime coverage. Solar panels measure 3 ft. by 5 ft. each and total 48 sq. ft. Spacecraft measures 14 ft. with panels deployed. Thermal control system. 4 antennas. 10,000-n-on-p solar cells produce 250 watts average power. Weight: 675 lbs.	925 887 115.0 101.9	Second generation operational meteorological satellite placed in a circular, near-polar, sun-synchronous orbit. First launch of Delta with 6 strap-ons. Provides first daily global day-night cloud cover data; also furnishes both remote and local readout. All systems functioning normally.
Jan. 23 Oscar 5 (Australis) 8B Thrust-augmented Thor-Delta	Objective: To transmit low-power signals on 2 amateur bands to be used by radio amateurs world-wide or training in the art of tracking and for experiments useful to NASA in radio propagation. Spacecraft: Carries 20 lbs. of batteries and transmits at 29.45 mhz in 10-m band and 144.05 mhz in the 2-meter band; weight: 39 lbs.	921 891 115.0 101.9	Built at the University of Melbourne in Australia and launched by NASA as secondary payload for the Radio Amateur Satellite Corporation. Spacecraft is functioning normally.
Feb. 4 SERT-II 9A Thrust-augmented Thor-Agena	Objective: To accumulate 6 months (4382 hours) of satisfactory operation on an electric ion thruster system in space. Spacecraft: Cylindrical 21-in. long and 59-in. diameter is supported by same size Spacecraft Support Unit (SSU) which is attached to 21.5 ft. long and 5 ft. diameter Agena D second stage. Two 5 ft. by 19 ft. solar arrays attach-to Agena D stage measure 187.5 sq. ft. total and contain total of 33,300 solar cells for power total of 1471 watts. Spacecraft contains 21 kw ion thrusters each powered by 29 lbs. of mercury propellant. Thermal control system. Weight in orbit is approximately 3,330 lbs. of which 1100 lbs. is spacecraft and SSU weight.	627 620 105.1 99.1	First orbital test of electron-bombardment ion engines. Spacecraft's solar arrays are largest ever flown on NASA satellite. No. 1 engine shut down July 23 after successful operation for 3782 hours. No. 2 engine shut down Oct. 17 after 2,011 hours of operation.

Successful U.S. Launches—1970—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Feb. 11 Defense 12A Thor-Burner II	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	542 480 101.3 98.6	Still in orbit.
Mar. 4 Defense 16A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	141.0 139.7 88.4 88.4	Decayed Mar. 26, 1970
Mar. 4 Defense 16B Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	315 273 94.0 88.1	Still in orbit.
Mar. 20 NATO I 21A Thor-Delta	Objective: The NATO I 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 with the U.S. terminal located at Norfolk, Va. (SACLANT). Spacecraft: Weight 285 lbs.	22,548 21,258 1,440 2.8	Still in orbit.
Apr. 8 Nimbus-IV 25A Thrust-augmented Thor-Agena	Objective: To acquire a sufficient number of global samples of atmospheric radiation measurements for the purpose of comparing vertical temperature, water vapor, and ozone profiles, and of providing a basis for comparing the merits of the several instrument approaches. Comparative data are to be obtained from the successful operation of at least three of the five spectrometric experiments: The Satellite Infrared Spectrometer (SIRS), the Infrared Interferometer Spectrometer (IRIS), the Filter Wedge Spectrometer (FWS), the Selective Chopper Radiometer (SCR), or the Backscatter Ultraviolet (BUV) Spectrometer, or from successful operation of either the FWS or SCR, plus either the SIRS or IRIS. Spacecraft: 120-in. high and 132-in. wide spacecraft. Torus ring base structure 56-in. diameter with pyramidal frame structure and two 3-ft. by 5-ft. solar paddles. Active three-axis stabilization. Solar cells provide 465 watts of power and eight nickel-cadmium batteries average 255 watts. Weight: 1,488 lbs.	684 679 107.1 99.8	Spacecraft and sensors operating successfully except for FWS, which failed June 7, 1970. Primary objectives achieved and flight a success.
Apr. 8 TOPO-1 25B Thor-Agena	Objective: This Army tactical satellite survey system is a SECOR type satellite and is used through triangulation for ground tactical positioning. Spacecraft: Weight 48 lbs.	667 667 107 99	Still in orbit.
Apr. 8 Vela 11 27A Titan III C	Objective: To orbit nuclear detection sensors capable of monitoring X-ray, gamma ray, neutron, optical, electromagnetic pulse, and air fluorescence emissions. Spacecraft: weight 770 lbs.	68,478.4 68,810.3 6,695 37.7	Still in orbit.
Apr. 8 Vela 12 27B Titan III C	Objective: Same as Vela 11. Located in similar orbit; satellites separated by 180.° Spacecraft: weight 770 lbs.	69,281.8 69,041.2 6,699 32.9	Still in orbit.

Successful U.S. Launches—1970—Continued

Launch date (Gmt) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Apr. 11 Apollo 13 (CSM 104) 29A 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. Three 31-cell Bacon-type hydrogen-oxygen fuel cells plus batteries in command module and six batteries in LM. Total weight at initial earth orbit insertion: 296,463 lbs.; at translunar injection: 110,210 lbs.; command and service modules: 61,453 lbs. CSM: 34 ft. long, 12.8 ft. diam.	Circumlunar	Aborted after 56 hours. GET due to loss of pressure in liquid oxygen in Service Module and failure of fuel cells 1 & 3. Pre-flight damage to wiring insulation in tank caused electrical short circuits which initiated combustion in oxygen tank No. 2. Astronauts were James H. Lovell, Jr., Fred Haise, Jr., and John L. Swigert, Jr. Splashdown in Pacific Ocean after total flight time of 142 hrs. 54 min. 44 sec., April 17, 1970.
Apr. 11 Saturn IVB (AS 508) 29B 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 diam. Total weight at impact, about 28,665 lbs.	Lunar strike	Crashed on moon April 15, 1970 about 88 miles from Apollo 12 landing site with a force equal to 11 tons of TNT, setting up signals for 4 hours.
Apr. 11 Lunar Excursion Module (LM 7) 29C 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 34,067 lbs.	Circumlunar	After explosion in service module, the lunar module was used as a lifeboat by the astronauts for the flight around the moon and back toward earth; jettisoned just prior to reentry. Decayed in earth's atmosphere April 17, 1970.
Apr. 15 Defense 31A Titan III B-Agena	Objective: Development of spaceflight technique and technology. Spacecraft: Not announced.	240 85 89.7 110.9	Decayed May 6, 1970.
Apr. 23 Intelsat III (F-7) 32A Thrust-augmented Thor-Delta	Objective: To provide equivalent of 1,200 two-way voice circuits or four color TV channels to carry communications traffic between the United States, Europe, North Africa, and the Middle East. Spacecraft: Cylindrical 56-in. diameter and 78-in. high; spin stabilized; 5 year lifetime electrical power system provides 130 watts generated by 10,720 solar cells; rechargeable 20-cell nickel-cadmium battery; weight: 334 lbs.	21,902 21,891 1,408.1 0.3	Launched by NASA for Comsat Corp., the manage of Intelsat. Launch vehicle underperformed and onboard hydrazine thrusters pushed satellite into desired synchronous orbit 19° west longitude over Atlantic. Remaining fuel expected to maintain satellite in proper orbit for five years. Began commercial service May 8, 1970.
May 20 Defense 40A Thor-Agena	Objective: Development of spacecraft techniques and technology. Spacecraft: Not announced.	147 111 88.6 83.0	Decayed June 17, 1970.
May 20 Defense 40B Thor-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	313 304 94.5 83.1	Still in orbit.
Jun. 19 Defense 46A Atlas-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	22,270 22,240 1,426.5 0.1	Still in orbit.

Successful U.S. Launches—1970—Continued

Launch date (Gmt) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Jun. 25 Defense 48A Titan III B-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	255 73.9 89.8 108.8	Decayed July 6, 1970.
Jul. 23 Defense 54A Titan III B-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	251 73.9 90.1 59.9	Decayed Aug. 19, 1970.
Jul. 23 Intelsat III(F-8) 55A Thrust-augmented Thor-Delta	Objective: To provide equivalent of 1,200 two-way voice circuits of four color TV channels to carry communications traffic between the United States, Hawaii, and the Western Pacific. Spacecraft: Cylindrical 56-in. diameter and 78-in. high; spin stabilized; five year lifetime electrical power system provides 130 watts generated by 10,720 solar cells; rechargeable 20-cell nickel-cadmium battery; weight: 334 lbs.	22,553 175 642.7 28.0	Launched successfully into transfer orbit by NASA for Comsat Corp., the manager of Intelsat. Comsat-controlled apogee motor began scheduled 27 second burn at 27 hours GET to place satellite into planned synchronous orbit at 128° east longitude over Western Pacific, but motor cut off after burning 14.5 seconds and contact lost. Last of Intelsat III series.
Aug. 18 Defense 61A Titan III B-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	246 94 89.9 110.9	Decayed Sept. 3, 1970.
Aug. 19 SKYNET II 62A Thor-Delta	Objective: The Skynet II is the second and final military communications satellite launched for the United Kingdom. The satellite was to be placed in geostationary orbit over the Indian Ocean where it was to support communications of British forces. Spacecraft: Weight 285 lbs.		Orbit undetermined. Status unknown, contact lost during apogee boost motor firing.
Aug. 26 Defense 66A Thor-Agena	Objective: Development of spaceflight technique and technology. Spacecraft: Not announced.	313 301 94.4 74.9	Still in orbit.
Aug. 27 Defense 67A Scout	Objective: To provide a navigation satellite. Spacecraft: Not announced.	757 595 106.9 90.0	Still in orbit.
Sept. 1 Defense 69A Atlas-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	24,750 19,830 1,441.9 10.3	Still in orbit.
Sept. 3 Defense 70A Thor-Burner II	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	542 475 101.2 98.7	Still in orbit.
Oct. 23 Defense 90A Titan III B-Agena	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	248 81 89.8 111.0	Decayed Nov. 11, 1970.
Nov. 6 Defense 93A Titan III C	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	22,299 16,186 1,197.1 7.8	Still in orbit.

Successful U.S. Launches—1970—Continued

Launch date (Gmt) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Nov. 9 Orbiting Frog Otolith (OFO) 94A Scout	Objective: To obtain information on the functioning and adaptability in weightlessness of the portion of the inner ear which controls balance. Also to obtain data on the acceleration of .001 g or less at the otolith during weightlessness, and on water environment temperature. Spacecraft: Truncated cone with spherical top affixed to octagonal platform; 47-in. long and 30-in. diameter. Two 9-cell battery packs deliver 28 volts; five antennas; four booms extend 78-in. from side of spacecraft; yoyo despin assembly. 91 lb. Frog Otolith Experiment Package (FOEP) contains two bullfrogs and encased in pressure-tight 18-in. diameter and 18-in. long container. Total weight: 292 lbs.	328.0 186.4 92.8 37.4	6 day flight met all research objectives and considered a success. Frogs adapted to zero gravity of space after three days in orbit. Demonstrated that sense organ of man rather than central nervous system makes the adjustments.
Nov. 9 Radiation/ Meteoroid (R/M) 94B Scout	Objective: Radiation—to demonstrate the feasibility and accuracy of an advanced dosimeter concept in a real time mode of the space environment; Meteoroid—to verify, in flight, the proper operation of instrumentation (including sensor materials) to be used on long duration flight experiments for future study of the meteoroid population of the solar system. Spacecraft: Cylindrical 30-in. diameter and 28-in. high attached to Scout 4th stage (FW-4); spin stabilized; total length (including FW-4) 67-in.; 7 sq. ft. of solar cells provide 25 watts of power; 2 nickel-cadmium batteries; R/M weight: 46 lbs.	328.0 186.4 92.8 37.4	Spacecraft launched as secondary payload, operating satisfactorily.
Nov. 18 Defense 98 A Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	140.4 110.0 88.5 82.9	Decayed Dec. 11, 1970.
Nov. 18 Defense 98B Thor-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	317.5 302.0 94.5 83.1	Still in orbit.
Dec. 11 NOAA-I 106A Long-Tank, Thrust-Augmented, Thor-Delta	Objective: To place spacecraft in a sun-synchronous orbit having a local equator crossing time between 3:00 pm and 3:20 pm, and conduct in-orbit engineering evaluation so that daytime and nighttime cloudcover observations can be obtained regularly and dependably in both direct readout and stored modes of operation. Spacecraft: Rectangular, box-shaped spacecraft with a deployable 3-panel solar array. Three-axis stabilized, earth-oriented satellite carries 2 Advanced Vidicon Camera Subsystems (AVCS) and 2 Automatic Picture Transmission (APT) Camera Subsystems which provide daytime coverage, and 2 Scanning Radiometer (SR) Subsystems (infrared) which furnish nighttime coverage. Solar panels measure 3 ft. by 5 ft. each and total 48 sq. ft. Spacecraft measures 14 ft. with panels deployed. Thermal control system. 4 antennas. 10,000 n-on-p solar cells produce 250 watts average power. Weight: 675 lbs.	914.8 884.0 114.8 101.95	First operational spacecraft of Improved TIROS Operational System (ITOS) series. Spacecraft is functioning normally.

Successful U.S. Launches—1970—Continued

Launch date (Gmt) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Dec. 11 CEP 106B Long-Tank, Thrust- Augmented, Thor- Delta	Objective: To obtain information on electron density, temperature, and ion current in the ionosphere during a 2-orbit lifetime. Spacecraft: 5 lb. experiment which carries its own small analog computer; permanently attached to second stage of Delta launch vehicle.	916.6 885.7 114.9 101.9	Spacecraft launched as secondary payload. Obtained useful information during 2-orbit lifetime which may aid in reducing ground data processing.
Dec. 12 Explorer XLII (SAS-A) 107A Scout	Objective: To develop a catalog of celestial x-ray sources by systematic scanning of the celestial sphere in the energy range from 2-20 KEV. Spacecraft: Cylindrical 22-in. diameter and 20-in. high; 4 solar paddles (10-in. by 53-in.) with solar cells on both sides, hinged to outer shell and measure about 13 ft. tip-to-tip. One nickel-cadmium battery provides 27 watts average power; thermal control system; carries advanced x-ray instruments; spin stabilized; weight: 315 lbs.	355.4 329.9 95.7 3.04	First launch of an American spacecraft by a crew of another country (Italy). Launched as part of San Marco project from mobile seaborne equatorial facility off coast of Kenya. All spacecraft systems operating normally.

APPENDIX A-4

Aeronautical Events of 1970

Jan. 21.....	The Boeing 747 (the first jumbo jet, type certificated on Dec. 30, 1969) made its first flight in commercial airline operations.
Feb. 18.....	The rocket-powered HL-10 lifting body research vehicle achieved a new speed record for lifting body flight vehicles of Mach 1.86 (1,224 mph).
Apr. 10.....	A notice of proposed rulemaking banning flights by civil aircraft in the United States at speeds producing sonic booms capable of reaching the ground (except in designated flight test areas) was issued by FAA. (Final rule-making action was expected early in 1971.)
May 21.....	Landmark legislation (Public Law 91-258, of which title I is the Airport and Airway Development Act of 1970 and title II is the Airport and Airway Revenue Act of 1970) was signed into law by President Nixon, solving the longstanding problem of adequate funding for airport and airway development by establishing an Airport and Airway Trust Fund based on aviation-user taxes.
June 2.....	The M2-F3 lifting body research vehicle made its first unpowered glide flight.
June 6.....	The C-5A was introduced to the first operational squadron at Charleston AFB.
June 22.....	The President issued a policy statement on international air transportation.
July 1.....	Neil Armstrong, former NASA test pilot and Apollo 11 astronaut was appointed NASA's Deputy Associate Administrator for Aeronautics.
Aug. 29.....	The Douglas DC-10 "airbus" made its first flight. The DC-10 is a large-capacity jet designed for medium- and long-haul operations.
Sept. 11.....	President Nixon announced a 5-point program to deal with the problem of air piracy. The program included the placing of specially trained, armed U.S. Government personnel on flights of U.S. commercial airliners.
Oct. 20.....	A full-scale hypersonic research engine was tested for the first time in the 8-foot, high-temperature structures tunnel at Langley at a Mach No. of 7.4 reaching temperatures of 2,000° F.
Oct. 24.....	The X-24 lifting-body research vehicle, having first flown earlier this year, made its first supersonic flight, reaching 760 m.p.h.
Nov. 4.....	The Anglo-French Concorde 001 flew at the speed of mach 2 at 50,000 ft.
Nov. 14.....	The joint Army-Navy-Marine Corps Heavy Lift Helicopter request for proposals was issued to industry. This aircraft will have a payload of 22.5 tons, double the existing free world capability.
Nov. 16.....	The Lockheed L-1011 "airbus" completed its maiden flight. The L-1011 is also a large-capacity jet designed for medium- and long-haul operations.
Nov. 24.....	In a joint Navy-NASA flight program, a modified T-2-C aircraft made its first flight with a thick supercritical wing.
Dec. 21.....	The F-14A Tomcat, Navy air superiority fighter, successfully flew for the first time at Calverton, N.Y.

APPENDIX B

U.S. Applications Satellites 1958-1970

GEODESY

Date	Name	Launch vehicle	Remarks
Oct. 31, 1962	Anna 1B	Thor-Able Star	Used 3 independent measuring techniques: Doppler frequency shift, flashing lights, and radio triangulation.
Jan. 11, 1964	Secor I	Thor-Agena D	Uses radio triangulation and trilateration.
Oct. 10, 1964	Beacon-Explorer XXII	Scout	Conducted reflecting-light geodetic measurements.
Mar. 9, 1965	Secor III	Thor-Agena D	
Mar. 11, 1965	Secor II	Thor-Able Star	
Apr. 3, 1965	Secor IV	Atlas-Agena D	
Apr. 29, 1965	Beacon-Explorer XXVII	Scout	
Aug. 10, 1965	Secor V	Scout	
Nov. 6, 1965	GEOS-I Explorer XXIX	Thor-Delta	
June 9, 1966	Secor VI	Atlas-Agena D	
June 23, 1966	Pagesos I	Thor-Agena D	Spacecraft is a 100-foot-diameter balloon used as a photographic target to make geodetic measurements.
Aug. 19, 1966	Secor VII	Atlas-Agena D	
Oct. 5, 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	

COMMUNICATIONS

Date	Name	Launch vehicle	Remarks
Dec. 18, 1958	Score	Atlas B	First Comsat, carried taped messages.
Aug. 12, 1960	Echo I	Thor-Delta	100-foot balloon served as first passive Comsat, relayed voice and TV signals.
Oct. 4, 1960	Courier 1B	Thor-Able Star	First active-repeater Comsat.
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.
June 16, 1966	Oscar IV		
	IDCSP 1-7	Titan IIIC	Initial defense communication satellites program (IDCSP)-Active-repeater spacecraft in near-synchronous orbit, random spaced.

APPENDIX B—Continued

U.S. Applications Satellites 1958—1970—Continued

COMMUNICATIONS—Continued

Date	Name	Launch vehicle	Remarks
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 OV 4-IR	Titan IIIC	Transmitter and receiver for low-power satellite-to-satellite F layer experiments.
Dec. 7, 1966	ATS I	Atlas-Agena D	Multipurpose, including VHF exchange of signals with aircraft.
Jan. 11, 1967	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 LES V	Titan IIIC	Tactical military communications tests with aircraft, ships, and mobile land stations from near synchronous orbit.
	DATS DODGE		Electronically despun antenna experiment.
Sept. 27, 1967	Intelsat II-F4	Thor-Delta(TAT)	Multipurpose, gravity stabilized. 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.
Feb. 6, 1969	Intelsat III(F-3)	Thor-Delta (TAT)	Stationed over Pacific to carry commercial traffic between the United States, Far East, and Australia.
Feb. 9, 1969	Tacsat I	Titan IIIC	Demonstrated feasibility of using a spaceborne repeater to satisfy selected communications needs of DOD mobile forces.
May 22, 1969	Intelsat III(F-4)	Thor-Delta(TAT)	Stationed over Pacific to replace F-3 which was moved westward to the Indian Ocean. Completes global coverage.
July 26, 1969	Intelsat III(F-5)	Thor-Delta(TAT)	Spacecraft failed to achieve the proper orbit. Not usable.
August 12, 1969	ATS V	Atlas Centaur	Multipurpose; for millimeter and L band communications; entered flat spin.
Nov. 22, 1969	Skyнет 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	Skyнет 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.

NAVIGATION

Date	Name	Launch vehicle	Remarks
Apr. 13, 1960	Transit 1B	Thor-Able Star	First navigation satellite. Used Doppler frequency shift for position determination.
June 22, 1960	Transit 2A	Thor-Able Star	
Feb. 21, 1961	Transit 3B	Thor-Able Star	
June 29, 1961	Transit 4A	Thor-Able Star	Used the first spacecraft nuclear SNAP-3 as a secondary power supply.
Nov. 15, 1961	Tranist 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.

U.S. Applications Satellites 1958—1970—Continued

NAVIGATION—Continued

Date	Name	Launch vehicle	Remarks
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	

WEATHER OBSERVATION

Date	Name	Launch vehicle	Remarks
Apr. 1, 1960	Tiros I	Thor-Able	First weather satellite providing cloud-cover photography.
Nov. 23, 1960	Tiros II	Thor-Delta	
July 12, 1961	Tiros III	Thor-Delta	
Feb. 8, 1962	Tiros IV	Thor-Delta	
June 19, 1962	Tiros V	Thor-Delta	
Sept. 18, 1962	Tiros VI	Thor-Delta	
June 19, 1963	Tiros VII	Thor-Delta	
Dec. 21, 1963	Tiros VIII	Thor-Delta	
Aug. 28, 1964	Nimbus I	Thor-Agena B	Carried advanced videcon camera system, APT, and a high resolution infrared radiometer for night pictures.
Jan. 22, 1965	Tiros IX	Thor-Delta	
July 2, 1965	Tiros X	Thor-Delta	First weather satellite in a sun-synchronous orbit.
Feb. 3, 1966	ESSA 1	Thor-Delta	
Feb. 28, 1966	ESSA 2	Thor-Delta	Complemented ESSA I with 2 wide-angle APT cameras.
May 15, 1966	Nimbus II	Thor-Agena B	
Oct. 2, 1966	ESSA 3	Thor-Delta	
Dec. 6, 1966	ATS-1	Atlas-Agena D	Provided continuous black-and-white cloud-cover pictures from a synchronous orbit, using a Suomi camera system.
Jan. 26, 1967	ESSA 4	Thor-Delta	
Apr. 20, 1967	ESSA 5	Thor-Delta	Provided continuous color cloud-cover pictures from a synchronous orbit, using 3 Suomi camera systems.
Nov. 5, 1967	ATS-3	Atlas-Agena	
Nov. 10, 1967	ESSA 6	Thor-Delta	
Aug. 16, 1968	ESSA 7	Thor-Delta	Provided first vertical temperature profile on a global basis of the atmosphere from the spacecraft to the Earth's surface.
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	Second generation operational meteorological satellite.
Apr. 8, 1970	Nimbus IV	Thor-Agena	Fifth in a series of 7 advanced research and development weather satellites.
Dec. 11, 1970	NOAA-1 (ITOS-A)	Thor-Delta	Second generation operational meteorological satellite

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. 36 mins.	Longest-duration manned flight.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	25 hrs. 51 mins.	Rendezvous within 1 foot of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	10 hrs. 41 mins.	First docking of 2 orbiting 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. 40 mins.	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	260 hrs. 8 mins.	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgi Beregovoy	94 hrs. 51 mins.	Maneuvered near unmanned Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	147 hrs.	First manned orbit(s) of moon; first manned departure from earth's sphere of influence; highest speed ever attained in manned flight.
Soyuz 4	Jan. 14, 1969	Vladimir Shatalov	71 hrs. 22 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 Yevgeniy Khrunov	72 hrs. 40 mins.	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	241 hrs. 1 min.	Successfully simulated in earth orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	192 hrs. 3 mins.	Successfully demonstrated complete system, including lunar module descent to 47,000 ft. from the lunar surface.
Apollo 11	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	195 hrs. 19 mins.	First manned landing on lunar surface and safe return to earth. First return of rock and soil samples to earth, and manned deployment of experiments on lunar surface.

APPENDIX C—Continued

History of U.S. and Soviet Manned Space Flights—Continued

Spacecraft	Launch date	Crew	Flight time	Highlights
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy Kubasov	118 hrs. 21 mins.	Soyuz 6, 7 and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and earth and celestial observations.
Soyuz 7	Oct. 12, 1969	Anatoliy Filipchenko Vladislav Volkov Viktor Gorbatko	118 hrs. 43 mins.	
Soyuz 8	Oct. 13, 1969	Vladimir Shatalov Aleksey Yeliseyev	118 hrs. 51 mins.	
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	244 hrs. 36 mins.	Second manned lunar landing. Continued manned exploration and retrieved parts of Surveyor III spacecraft which landed in Ocean of Storms on Apr. 19, 1967.
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	Jun. 1, 1970	Andrian G. Nikolayev Vitaliy I. Sevastianov	424 hrs. 59 mins.	Longest manned space flight lasting 17 days 16 hrs. 59 mins.

APPENDIX D-1

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant ⁴	Thrust (in thousands of pounds)	Max. dia. (feet)	Height spacecraft (feet)	Payload (pounds)		First launch
						300 NM orbit	Escape	
Scout.....	1. Algol (IIB)..... 2. Castor II..... 3. Antares II..... 4. Altair III or FW4.	Solid..... Solid..... Solid..... Solid.....	100.9 60.7 20.9 5.9	3.3	64.4	320	50	¹ 1965 (60)
Thrust-augmented Thorad-Delta.	1. Thor (SLV-2J) plus three TX 354-5... 2. Delta (DSV-3)... 3. FW-4D/TE 364...	LOX/RP..... Solid..... IRFNA/UDMH... Solid.....	170 ² 52 7.8 5.9/10.0	11	92	2,000	525	1968 (60)
Thrust-augmented Thorad-Agena.	1. Thor (SLV-2H) plus three TX 354-5... 2. Agena.....	LOX/RP..... Solid..... IRFNA/UDMH... LOX/RP.....	170 ² 52 16 400	11	90	2,900	1966 (60)
Atlas-Burner II.....	1. Atlas booster and sustainer (SLV-3A). 2. Burner II.....	LOX/RP..... Solid.....	400 10	10	84	4,950	700	1968
Atlas-Agena.....	1. Atlas booster and sustainer (SLV-3A). 2. Agena.....	LOX/RP..... IRFNA/UDMH... N ₂ O ₄ /Aerozine...	⁶ 465 16 440	10	100	7,500	1,430	1968 (60)
Titan IIIB-Agena...	1. LR-87..... 2. LR-91..... 3. Agena.....	IRFNA/UDMH... N ₂ O ₄ /Aerozine... N ₂ O ₄ /Aerozine... IRFNA/UDMH...	100 100 16	10	113	8,000	1,550	1966
Titan IIC.....	1. Two 5-segment 120" diameter. 2. LR-87..... 3. LR-91..... 4. Transtage.....	Solid..... N ₂ O ₄ /Aerozine... N ₂ O ₄ /Aerozine... N ₂ O ₄ /Aerozine...	2,400 ⁵ 527 100 16	10x30	107	25,000	5,500	1965
Titan-Centaur.....	1. Two 5-segment 120" diameter. 2. LR-87..... 3. LR-91..... 4. Centaur (Two RL-10).	Solid..... N ₂ O ₄ /Aerozine... N ₂ O ₄ /Aerozine... LOX/LH.....	2,400 440 110 30	10x30	209.5	⁷ 32,000	11,000	1974 (est.)
Atlas-Centaur.....	1. Atlas booster and sustainer. 2. Centaur (Two RL-10).	LOX/RP..... LOX/LH.....	400 30	10	103	9,100	2,700	1967 (62)

See footnotes at end of table.

U.S. Space Launch Vehicles—Continued

Vehicle	Stages	Propellant ⁴	Thrust (in thou- sands of pounds)	Max. dia. (feet)	Height space- craft (feet)	Payload (pounds)		First launch
						300 NM orbit	Escape	
Up-rated Saturn IB..	1. S-IB (Eight H-1).	LOX/RP.....	1,600	21.6	142	40,000@	1966
	2. S-IVB (One J-2).	LOX/LH.....	200			105 NM		
Saturn V.....	1. S-IC (Five F-1)...	LOX/RP.....	7,570	33	³ 281	285,000@	100,000	1967
	2. S-II (Five J-2)...	LOX/LH.....	1,150			105 NM		
	3. S-IVB (One J-2).	LOX/LH.....	230					

¹ The date of first launch applies to this latest modification with a date in parentheses for the initial version.

² Each motor.

³ 363 feet, including Apollo modules and Launch Escape System.

⁴ Propellant abbreviations used are as follows: Liquid Oxygen and a modified Kerosene—LOX/RP; Solid propellant combining in a single mixture both fuel and oxidizer—Solid;

Inhibited Red Fuming Nitric Acid and Unsymmetrical Dimethylhydrazine—IRFNA/UDMH; Nitrogen Tetroxide and 50% UDMH and 50% Hydrazine (N₂H₄)—N₂O₄/Aerozine; Liquid Oxygen and Liquid Hydrogen—LOX/LH.

⁵ Vacuum thrust; stage 1 is ignited at altitude.

⁶ Thrust at sea level.

⁷ Structural weight limitation currently 12,000 lbs.

Appendix D-2

**U.S. Successful Launches to Earth Orbit or Beyond
By Launch Vehicle, 1958-70**

Launch vehicle	Subtotals	Launch vehicle	Subtotals
Thor-Able.....	3	Titan IIIB Agena.....	29
Thor-Able Star.....	14	Titan IIIC.....	14
Thor-Delta.....	76		
Thor-Agena.....	155	TITAN total.....	57
Thor-Altair.....	5	SCOUT total.....	43
Thor-Burner II.....	10		
THOR total.....	263	Saturn I.....	6
		Saturn IB.....	3
Atlas.....	16	SATURN I total.....	9
Atlas-Agena.....	90	SATURN V total.....	8
Atlas-Centaur.....	17	REDSTONE total.....	3
ATLAS total.....	123	JUPITER total.....	4
		VANGUARD total.....	3
Titan II.....	11	Grand total.....	513
Titan IIIA.....	3		

APPENDIX E

Nuclear Power Systems for Space Application

Designation	Application	Status
SNAP-3	Navigation satellites (DOD)	Units launched in June and November 1961. Unit still operating at reduced power levels.
SNAP-9A	Navigation satellites (DOD)	Units launched in September and December 1963. Units still operating at reduced power level. Third satellite failed to orbit in April 1964.
SNAP-19	Nimbus B weather satellite (NASA)	First Nimbus B launch aborted; Pu-238 fuel recovered from offshore waters. Replacement unit launched in April 1969 and has operated continuously at gradually reducing power levels since that time.
SNAP-27	Apollo lunar surface experiment package (NASA)	First SNAP-27 placed on lunar surface by Apollo 12 astronaut in November 1969. System is supplying total power for ALSEP.
SNAP-10A	Unmanned missions	Tested in orbit in 1965.
Transit ¹	Navigation satellites (DOD)	Development program underway.
Pioneer ¹	Jupiter flyby mission (NASA)	Modified SNAP-19 generator system will be used.
Viking ¹	Mars unmanned lander mission (NASA)	Modified SNAP-19 generator system will be used.

¹ Planned missions.

Space Activities of the U.S. Government

10-YEAR SUMMARY AND 1972 BUDGET RECOMMENDATIONS, JANUARY 1971—NEW OBLIGATIONAL AUTHORITY

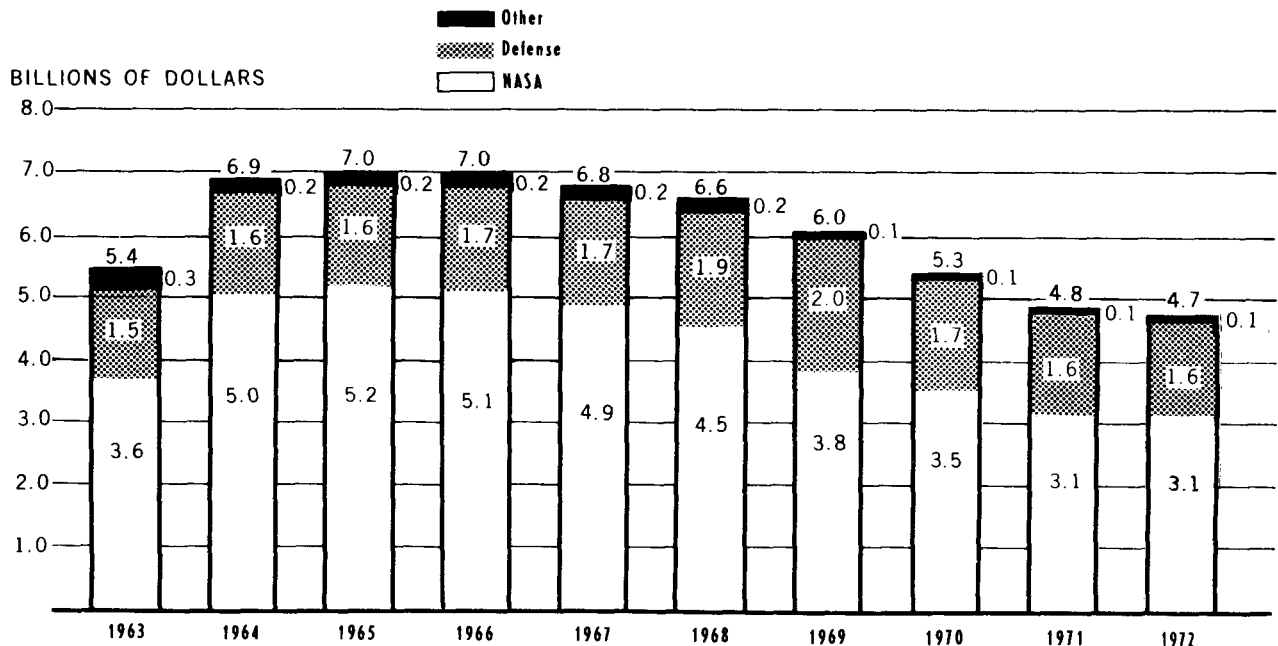
[In millions of dollars (may not add due to rounding)]

	NASA		Department of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total space
	Total	Space ¹							
1959.....	305.4	235.4	489.5	34.3					759.2
1960.....	523.6	461.5	560.9	43.3				.1	1,065.8
1961.....	964.0	926.0	813.9	67.7				.6	1,808.2
1962.....	1,824.9	1,796.8	1,298.2	147.8	50.7			1.3	3,294.8
1963.....	3,673.0	3,626.0	1,549.9	213.9	43.2			1.5	5,434.5
1964.....	5,099.7	5,046.3	1,599.3	210.0	2.8			3.0	6,861.4
1965.....	5,249.7	5,167.6	1,573.9	228.6	12.2			3.2	6,985.5
1966.....	5,174.9	5,094.5	1,688.8	186.8	26.5	4.1		3.2	7,003.9
1967.....	4,967.6	4,862.2	1,663.6	183.6	29.3	3.0		2.8	6,744.5
1968.....	4,588.8	4,452.5	1,921.8	145.1	28.1	2.0	0.5	3.2	6,553.2
1969.....	3,990.9	3,822.0	2,013.0	118.0	20.0	2.0	0.7	1.9	5,977.6
1970.....	3,745.8	3,547.0	1,678.4	102.8	8.0	2.0	0.8	2.4	5,341.4
1972 budget									
1971.....	3,297.0	3,101.4	1,553.1	94.5	25.0	3.0	1.1	2.2	4,780.3
1972.....	3,270.0	3,055.4	1,552.6	56.2	32.0	7.0	1.5	2.0	4,706.7

¹ Excludes amounts for aviation technology.

Source: Office of Management and Budget.

U. S. SPACE BUDGET - NEW OBLIGATIONAL AUTHORITY



REQUEST
JAN. 1971

NASC STAFF

Space Activities Budget, January 1971

[In millions of dollars]

	New obligational authority			Expenditures		
	1970 actual	1971 estimate	1972 estimate	1970 actual	1971 estimate	1972 estimate
Federal space programs:						
NASA ¹	3,547.0	3,101.4	3,055.4	3,565.2	3,185.2	2,957.6
Defense.....	1,678.4	1,553.1	1,552.6	1,756.1	1,577.0	1,574.8
AEC.....	102.8	94.5	56.2	102.6	96.5	62.3
Commerce.....	8.0	25.0	32.0	24.0	23.0	29.0
Interior.....	2.0	3.0	7.0	2.0	3.0	6.0
NSF.....	2.4	2.2	2.0	2.3	2.1	2.0
Agriculture.....	0.8	1.1	1.5	1.0	1.1	1.5
Total.....	5,341.4	4,780.3	4,706.7	5,453.2	4,887.9	4,633.2
NASA:						
Manned space flight.....	2,262.5	1,770.2	1,637.6	2,209.2	1,887.3	1,662.2
Space science and applications.....	637.1	693.2	889.8	569.4	631.1	727.2
Space technology.....	288.4	278.2	208.0	328.1	286.1	234.6
Aviation technology.....	198.8	195.6	214.6	187.9	183.7	194.8
Supporting activities.....	364.9	373.1	333.4	460.2	392.6	345.6
Less receipts.....	-5.9	-13.3	-13.4	-5.9	-13.3	-13.4
Total NASA.....	3,745.8	3,297.0	3,270.0	3,748.9	3,367.5	3,151.0

¹ Excludes amounts for aviation technology.

Source: Office of Management and Budget.

Aeronautics Budget

[In millions of dollars]

	New obligational authority		
	1970	1971 estimate	1972 estimate
Federal aeronautics programs:			
NASA ¹	198.8	195.6	214.6
Department of Defense ²	1,640.9	1,642.8	1,975.4
Department of Transportation.....	41.8	70.0	81.5
Total.....	1,881.5	1,908.4	2,271.5

¹ R. & D., R. & P.M., C. of F.

² R.D.T. & E. aircraft and related equipment.

Source: Office of Management and Budget.