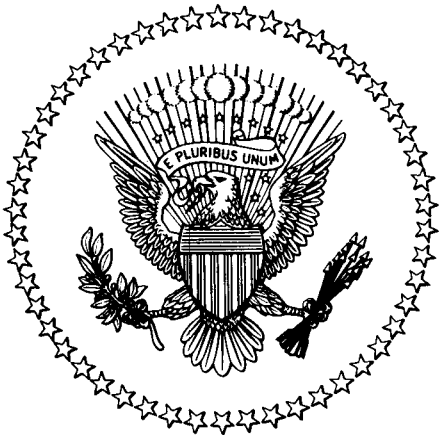

Aeronautics and Space Report of the President

1972 Activities

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Aeronautics and Space Report of the President

1972 Activities

Executive Office of the President
National Aeronautics and Space Council
Washington, D.C. 20502

PRESIDENT'S MESSAGE OF TRANSMITTAL

To the Congress of the United States:

I am pleased to transmit a report of our national progress in aeronautics and space activities during 1972.

The Apollo program was successfully concluded with the flights of Apollo 16 and 17. These missions were designed to obtain maximum scientific return and provided almost half the lunar exploration time in the Apollo program. Though it is far too early to attempt a definitive assessment of the value of this program, it is clear that one result will be a quantum jump in both our scientific knowledge and our technological expertise.

Our unmanned satellites include a variety of vehicles ranging from meteorological, navigational and communication satellites to a new experimental spacecraft providing information on our resources and environment. Increasing practical applications for satellite technology confirm the immediate value of our efforts in space, while observatory satellites and others carrying specialized scientific instruments provide accurate and dependable data never before available to scientists on earth.

The conclusion of the Apollo program marks only another step in this Nation's push into space. In the current year, we expect to launch Skylab, which will permit extended experimentation in a manned vehicle. After Skylab, a joint mission by this Nation and the Soviet Union will rendezvous and dock two spacecraft, helping to link our two space efforts in a mutually productive manner. The space shuttle presently under development will make the launching of satellites and laboratories less expensive and more productive. The shuttle will be augmented by the sortie laboratory which the Western European countries intend to develop as part of our joint cooperation in space.

The past year has also seen advances in aeronautical research and development. It should be emphasized that work in this field is particularly vital if America is to maintain its leadership in the development and production of civil and military aircraft and engines.

Our efforts in aeronautics and space will continue through programs balanced at levels which will allow us to meet demands in these and other important domestic and foreign areas.

THE WHITE HOUSE,
March 1973

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I United States Aeronautics and Space Activities in 1972

Introduction

Considerable progress was made in both space and aeronautics activities in 1972. The achievements of the United States space program confirm our desire and our determination to continue space exploration and the application of space technology to the benefit of mankind. In aeronautics, while maintaining our leadership in civilian and military aviation, steps have been taken to minimize the undesirable environmental effects of aircraft operations through the introduction and application of advanced technology.

Completion of the successful Apollo 17 mission brings to conclusion the Apollo lunar program. Its conclusion realized the accomplishment of one of the six specific objectives for the United States space program which was enunciated in March 1970—the continued exploration of the moon. From the samples brought back for study and the instrumentation which continues to make vital measurements on the lunar surface, the fundamental history and nature of the moon are being revealed. The lunar samples and knowledge gained from the Apollo program will be studied for many years by scientists from all over the world.

The United States space program is balanced between exploration, science and applications, and is designed to accomplish the specific objectives outlined at the beginning of this decade. Pioneer 10 continues its epic journey which will take it near the planet Jupiter and from there it will become the first man-made object to escape the solar system. Mariner 9 has completed its mission of photographically mapping the entire surface of Mars and its results have dramatically revised our understanding of that planet. Work is presently underway which will greatly extend man's capability to live and work in space and also to substantially reduce the cost of space operations. Efforts are also being taken to apply the advanced technologies of the space program for the benefit of mankind.

During 1972, the United States continued its desire to share the new knowledge and benefits derived from space. Further, the United States recognizes that much more can be accomplished in space activities if the costs are shared by other countries. Cooperative programs with the European nations and with the USSR have been actively pursued. These beginnings hold promise for increased international cooperation in the future.

Though perhaps not as spectacular as space, the aeronautics program includes efforts to help maintain strength in commercial aircraft sales and superiority in military aviation. At the same time, programs emphasizing research and development activities that will lead to more comfortable, safe, and convenient air travel for all have been pursued. Progress has been made in the development of technology for efficient, quiet, and clean aircraft engines to reduce undesirable impact of airplanes on the environment.

This chapter reviews the activity in the United States space and aeronautics programs in 1972, summarizes the progress made, and emphasizes the need for continuing a balanced program.

Space

Lunar and Planetary Exploration.—During 1972 both manned and unmanned spacecraft explored space and returned data which will yield for many years to come significant information on the origin and composition of the universe.

The past year saw the completion of the planned lunar exploration with the flight of Apollo 17. This mission explored a combination of lunar mountain highlands and valley lowlands. The data returned will supply scientists with new information on the early crust of the moon, large meteorite impacts on the lunar surface, young volcanic rock, and other important geological discoveries.

In an earlier mission of the Apollo series, Apollo 16, in April 1972, achieved several new records. The landing site, the first in the lunar highlands, permitted collection of lunar rock and soil samples believed by some scientists to be from the oldest region on the moon.

The Apollo 16 and 17 science program included experiments to determine the nature of the lunar interior and to help unlock secrets about the structure and evolution of the universe. The lunar science packages included a seismometer whose emplacement completed a four-sided network (together with Apollo 12 and 15 instruments) from which many answers to questions regarding the moon's interior are being derived.

Another high point in planetary exploration was achieved by the Mariner 9 spacecraft as it mapped the entire surface of Mars, stimulating additional interest and revising many prior concepts of the planet. The major findings obtained from the Mariner 9 spacecraft are: Mars is a geologically active planet with volcanic mountains taller than those on earth; an equatorial crevasse three to four times deeper than the Grand Canyon marks the surface of the planet; free-flowing water might have existed during its geologic history; and its dust storms and clouds are primarily responsible for the Martian appearance to astronomers. Mariner also made the first close-up photographs of the red planet's tiny moons—Phobos and Deimos.

The Pioneer 10 spacecraft continued its flight to Jupiter and in the process was the first spacecraft to probe the cosmic debris forming the Asteroid Belt. Pioneer will observe Jupiter at close range in December 1973 and then swing by the planet to become the first man-made object to escape our solar system. Its complement of scientific instruments continues to collect data on interplanetary magnetic fields and meteoroids as well as solar and galactic radiation. Valuable scientific data on the solar environment was obtained during the several severe solar storms which occurred in early August 1972.

A second Pioneer spacecraft is scheduled for launch during April 1973. The primary objectives of this mission include exploration of the interplanetary medium beyond the orbit of Mars and examination of the environmental and atmospheric characteristics of the planet Jupiter. A valuable dividend from the two Pioneer missions will be the information and technology derived to improve the operational capability for long-duration flights to the outer planets.

Another Mariner spacecraft is scheduled to be launched during October/November 1973 and has as its primary objective the first exploration of the planet Mercury. On its way to Mercury the spacecraft will fly close by Venus and the high resolution TV cameras on board will take pictures of both planets.

The Mariner 9 findings have laid the groundwork for America's next venture to Mars—the Viking launch to search for evidence of life on the planet. Two Viking spacecraft are planned to soft land on the Martian surface in 1976. While scientific emphasis will be placed on obtaining data relative to the search for life, additional science results will aid in understanding the evolution of Mars and the solar system. The two separate Viking spacecraft are scheduled for launch in 1975.

During 1972 a Mariner Jupiter/Saturn project was defined. This project involves two launches in 1977 of spacecraft which will fly by Jupiter some one and one-half years after launch and will reach Saturn some three and one-half to four years after launch. In addition to obtaining information on these planets, the spacecraft trajectories will be designed to provide data from flybys of Saturn's rings and of the various massive satellites of both these planets.

Physics and Astronomy.—The physics and astronomy program was conducted on a broad front during 1972. Basic scientific data on the sun, planets, stars, and interstellar matter were acquired from orbiting operational spacecraft.

Orbiting Astronomical Observatory–3 (OAO–3) was launched in August 1972. This satellite, named Copernicus in honor of the 500th Anniversary of the birth of the well-known Polish astronomer, has as its primary objective the acquisition of high resolution ultraviolet spectra of stars necessary to investigate the composition and physical state of matter in interstellar space. In combination with OAO–2, launched in 1968, basic scientific data on planets, stars, nebulae, and galaxies are being obtained. Among data acquired for the first time are ultraviolet observations of Uranus and observations of a super-nova. The Orbiting Solar Observatory–7 (OSO–7), launched in 1971, has continued to observe a number of significant events and phenomena of the sun. Nuclear reactions in solar flares were confirmed for the first time by OSO–7 observations.

Two Explorer class satellites were launched in 1972: an Interplanetary Monitoring Platform, designated Explorer 47, to make long term observations of the earth-sun relationships; and a Small Astronomy Satellite–B (SAS–B) designated Explorer 48, to measure the spatial and energy distribution of primary galactic and extra-galactic gamma radiation. In addition, SAS–A, launched in 1970 as Explorer 42, continued to provide data on spatial X-ray sources. Data acquired by this satellite led to discovery of binary star systems and lent possible support to the theories of "Black Holes" being massive stars that have collapsed to the point where gravitational forces prevent the escape of visible light.

An Atmospheric Explorer program is underway, with the first launch scheduled for late 1973. This program will investigate the earth's lower thermosphere where most of the chemical and energy conversion processes occur. High Energy Astronomy Observatories (HEAO) are being planned to perform an extensive study of celestial X-ray, Gamma-ray, and Cosmic-ray phenomena.

Space Applications.—Major advances in space applications were made during 1972. Earth resources, weather and communications satellites were orbited and are providing data to aid in solving some of the problems of man on earth. Near term follow-on efforts will employ both manned and unmanned spacecraft to continue to provide the benefits available from space applications.

Launch of the first Earth Resources Technology Satellite (ERTS) took place in July 1972. This spacecraft is providing data to help us learn to cope with the earth's environmental problems, as well as the critical needs caused by the increasing demands placed on our natural resources. ERTS is a modified version of the Nimbus experimental weather satellite. Among the many potential uses, ERTS data have been used to demonstrate that coastal circulation patterns are revealed by sediment distribution shown in the photographs; ERTS photos were used to show that dumping of acid wastes outside of designated areas off New York harbor can be detected. The first in a new series of operational environmental satellites, NOAA2, was also placed in earth orbit during the year. The NOAA2 satellite is commanded and controlled by the National Oceanic and Atmospheric Administration's National Environmental Satellite Service. This satellite, the first to obtain vertical temperature measurements of the atmosphere on a near-global basis, represents a major step in acquiring the data necessary for accurate long range weather forecasting.

The first satellites of the Defense Satellite Communications Systems (DSCS) Phase II became operational during the year. These satellites provide communications in support of critical command, control, intelligence, and warning needs to satisfy unique requirements of the President, Department of State, and other special users.

The final prelaunch phases of the Skylab program are now progressing satisfactorily. These consist of system checkout and detailed mission planning aimed at the flight of the nation's first manned orbiting laboratory in the spring of 1973. The Skylab experimental space station will include experiments in earth resources, solar astronomy, and space applications involving the efforts of approximately 250 foreign professionals in addition to the over 350 American investigators currently on board.

International Cooperation.—On May 14, the President signed a space cooperation agreement with the USSR which features plans for a joint docking mission of U.S. and Soviet-manned spacecraft in 1975. The agreement also endorsed at the highest level a variety of ongoing cooperative programs in such areas as space meteorology, space biology and medicine, space science, and the use of space for studies of the natural environment. These activities are proceeding in a very satisfactory manner. The initial study and design activity required to implement the docking of a U.S. Apollo and a Soviet Soyuz spacecraft is proceeding satisfactorily. Joint working groups have been formed and have met periodically throughout the year in both Houston and Moscow. Initial design of a common docking adapter has been completed and detailed designs are in progress.

Significant progress was also made in defining European participation in the post-Apollo program. Discussions with members of the European Space Conference concerning their development of a Sortie Laboratory as part of the post-Apollo program have been proceeding. The Sortie Laboratory is envisioned to be a low-cost payload carrier to increase the capability of the space shuttle to perform manned and man-tended research in space science and applications.

On October 9, the President announced a policy for launch assistance to other countries and international organizations. The availability of these launch services makes it possible for other nations to have access to the advantages of space.

The Definitive Agreements for the International Telecommunications Satellite Organization, INTEL SAT, have been negotiated and will enter into force in February 1973. They will replace Interim Arrangements negotiated in 1964 by 11 countries including the United States, and in which 83 countries now participate as members. The United States has actively encouraged acceptance of the new agreements which are intended to provide the basis for the global commercial telecommunications system using satellite technology.

Launch Vehicle Development.—Design and development of the space shuttle transportation system was initiated in 1972. It will consist of a reusable rocket booster for launch from earth and an airplane-like, manned reusable orbiter for flight into orbit to conduct space missions and return. The shuttle will be capable of delivering and retrieving from orbit unmanned and manned spacecraft, including communications, weather, navigation, and earth resources satellites. The shuttle will have a significant effect on the economies of space operation. It will afford two principal types of cost savings; reduced launch costs and reduced payload costs. The former are attributable to the reuse capability of the orbiter and booster. The latter are attributable to the ability to retrieve and refurbish satellites and the relaxation of weight and volume constraints that have heretofore increased satellite development and production costs.

Aeronautics

Issues of aeronautical policy were the focus of the Civil Aviation Research and Development (CARD) study, which was completed in 1971. A CARD Review

Group was formed early this year, with participation by NASA, DOT, and the NASC staff. In addition to providing continued CARD-type policy guidance, the Review Group is preparing a CARD Implementation Plan to assure appropriate visibility, coordination, and effectiveness of government programs for civil aviation R&D.

A third model (L–1011) of wide-bodied jet transport joined the civil aircraft fleet this year. While production was terminated for one early generation jet transport (DC–8), worldwide sales continued with other civil jet transports. In one case (the B–727), sales have far exceeded early forecasts. For the first time in aviation history, over 1000 jet transports of one basic model have been sold.

Research programs for Advanced Transport Technology (ATT) and Advanced Supersonic Technology (AST) continued with active industry participation. The ATT program is developing technologies applicable to the next generation long haul subsonic air transports. Exploratory flight research of the supercritical wing is one outstanding example of progress. Supersonic flight technology applicable to large aircraft is being developed under the AST program in the absence of a national supersonic aircraft developmental effort.

Paralleling the introduction of quiet, clean, wide-bodied jet aircraft to the world's airlines, research continues on the further reduction of jet transport noise and harmful exhaust emissions. The joint NASA/DOT Noise Abatement Office serves as a focal point for investigating solutions to aircraft noise problems. The introduction of advanced technology and identification of effective means of quieting current aircraft of older design will permit additional reductions in future fleet noise levels. FAA and NASA research and flight tests continue in order to determine development options for noise reduction. In addition, NASA continued ground tests of experimental quiet engines to advance technology development for future aircraft applications.

Both NASA and DOD engine technology programs are investigating combustion phenomena in order to determine ways of reducing exhaust emissions to desired levels. The Climatic Impact Assessment Program continued towards the goal of assessing, by mid-1974, the effect of high altitude subsonic and supersonic aircraft upon the world's climate.

As the year ended, the Air Force awarded contracts for design refinement and final cost effectiveness analysis of an advanced medium STOL transport (AMST) intended to replace the C–130 tactical transport. A development program for AMST would provide some technological advances applicable to future civil Short Take-Off and Landing (STOL) and other aircraft which would incorporate powered lift technology. Exploratory tests of powered lift technology were initiated by NASA this year with a small airplane.

Further significant developments occurred in military aeronautical programs during 1972. The AX close-support airplane competitive fly-off was successfully completed in December. The F–15 advanced tactical fighter made its first flight this year and is undergoing scheduled development tests. The B–1 bomber fabrication continued in support of a first flight milestone in early 1974. Lightweight fighter prototype aircraft are also under fabrication and scheduled to enter a competitive fly-off phase in 1974.

Navy evaluation of the F–14A carrier-based advanced tactical fighter continued during 1972, and the first two squadrons were commissioned. First flight of the S–3A, a jet-powered replacement for the aging S–2 carrier-based anti-submarine warfare airplane, took place in January; carrier suitability and avionic system tests are now underway.

The Army prototype advanced attack helicopter program was redirected in 1972, as a result of a special task force evaluation, towards a lower cost, more survivable, and somewhat smaller design. Industry proposals for a revised but highly effective weapon system are due in 1973. Other Army programs for the heavy lift helicopter (HLH) and the utility tactical transport aircraft system (UTTAS) continue on schedule.

Summary

Reviewing this year's space and aeronautical activities, it is clear that 1972 was a year of significant, advanced accomplishments in lunar exploration, exploration of the planets and the universe, and in aeronautical concepts. In addition, a balanced program has been initiated to continue exploration in space, space science studies, application of space for benefits on earth, and the development of new technology for space and aeronautics.

The activities summarized above are reported in more detail in the following chapters of this report. Each of the sixteen agencies involved has provided the report carried under its seal.

II National Aeronautics and Space Council

Introduction

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

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

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

Studies and Reports

Typical of the activities of the Executive Secretary and Council staff are the reviews conducted at the request of the President or his staff. During 1972 studies relating to the problems of the aerospace manufacturing and air transport industries were continued. In addition to adverse effects on these industries caused by the Nation's transition from a wartime to a peacetime economy, the influence of growing foreign competition is becoming more evident. The magnitude of these problems, their impact on the national economy and security were examined and policy options developed for Executive and Council consideration.

The dominant position which the United States has held for many years in the area of international sales of commercial and military aircraft is being challenged by a coalition of foreign competitors supported by their respective governments. Paradoxically, agreements between United States and foreign companies for joint aerospace ventures also exist and others are under serious discussion. The Council staff continually reviews these challenges to our aeronautical leadership, identifies key policy options, and provides support to concerned Executive and Council organizations. A staff report was prepared which suggested government initiatives in the area of Foreign Military Sales.

Last year the Council staff supported a joint DOT/NASA study to examine the options for national policy with respect to civil aviation research and development (CARD). During 1972 the Council staff supported a joint DOT/NASA review group in the preparation of an implementation plan on CARD recommendations. The plan, which details selected member agency programs responsive to the broad CARD guidance, will provide a medium for an annual technical and policy accounting of these programs.

Council staff members provided interagency coordination which led to start-up in November of development programs for prototype military STOL aircraft and civil STOL research aircraft. Council staff work has also contributed to progress in government research to find ways to quiet older noisy civil aircraft, to establish requirements for environmentally acceptable future aircraft, and has assisted in the understanding of the necessary balance between noise regulations and technology, and other demands on critical resources.

The Executive Secretary and Council staff assisted in the formulation of European participation in the Post-Apollo Program. Members of the European Space Conference were encouraged to develop such a Sortie Laboratory, a manned scientific laboratory for use in conjunction with the Space Shuttle.

Building on last year's Interagency Ad Hoc Study Group report on earth resources survey efforts, the Executive Secretary consulted with members of interested government agencies and the Office of Manage-

ment and Budget to aid in structuring the newly established Interagency Coordinating Committee for Earth Resource Survey Programs (ICCERSP). This committee is intended to insure that the individual agency activities results in an integrated and productive program.

Other Activities

The Council is represented by the Executive Secretary as Chairman of one interagency subcommittee of the National Security Council and by staff on others which discuss and advise on international cooperation in aeronautics and space. The Executive Secretary participated as a member of the U.S. delegation which went to Japan to review Japanese progress in space (and aeronautics) activities in relation to the manufacture under license and launching of Thor Delta launch vehicles and to propose joint aircraft development ventures with U.S. industry.

Staff members participate in many interagency panels and committee meetings such as the NASA/DOD Aviation and Astronautics Coordinating Board (AACB) and its panels, the NASA/DOT Short Haul Working Group, the NASA/USAF National Aeronautical Facilities requirements review, the Space Transportation Systems Committee and the Interagency Coordinating Committee for Earth Resource Survey Programs. The Council staff also reviews and approves proposals for use of radioisotopes in space and aids in preparation of the President's Annual Report on Aeronautics and Space to the Congress.

III National Aeronautics and Space Administration

Introduction

The past year witnessed the President's go-ahead decision for development of the reusable Space Shuttle, the conclusion of the Nation's successful lunar landing program, and preparations for the 1973 Skylab missions. Highlighting unmanned spacecraft programs were the launch of a Pioneer two-year flight to Jupiter and the orbiting of the first Earth Resources Technology Satellite.

Aircraft noise abatement was assigned a high priority during 1972, and noteworthy progress was made in the development of a quiet, short-takeoff-and landing transport aircraft. NASA also began flight tests of its Supercritical Wing test aircraft.

In a year marked by considerable activity in international affairs, this country and the U.S.S.R. moved to fulfill the NASA/Soviet Academy of Sciences agreement of January 1971 on space science and applications and to conduct a joint experimental flight during 1975 to test compatible rendezvous and docking systems.

During 1972 NASA also launched an Intelsat commercial communications satellite for the Communications Satellite Corporation and an ITOS–D operational meteorological satellite for the National Oceanic and Atmospheric Administration of the Department of Commerce. Further, an Orbiting Astronomical Observatory (named *Copernicus* in honor of the Polish astronomer) was placed in orbit to investigate stellar phenomena, and galactic and intergalactic media.

Manned Space Flight

Apollo 16.—The fifth Apollo manned lunar missio was launched on April 16, 1972, carrying the crew John W. Young, Commander; Thomas K. Mattingly II, Command Module Pilot; and Charles M. Duke, Jr., Lunar Module Pilot. The landing in the Descartes area was 230 meters NW of the planned target point. At the beginning of EVA–1, the crew deployed and activated the Apollo Lunar Surface Experiments Package (ALSEP) and other experiments. During ALSEP deployment, the heat flow experiment cable was inadvertently pulled loose at its central station connector and that experiment was abandoned. Approximately 42 pounds of samples were collected during the 7-hr. 11-min. EVA and total distance travelled by the LRV was 4.2 km.

The second traverse of 11.4 km took place during EVA–2 and took the crew half way up 500-meter high Stone Mountain, 4.1-km south of the LM. The lunar roving vehicle provided excellent mobility and stability, achieving eleven to fourteen kilometers per hour (kph) over rocky, cratered surfaces and easily climbing 15- to 20-degree slopes at about 7 to 8 kph.

About 71 pounds of samples were collected during this 7-hr. 23-min. EVA. EVA–3 lasted 5 hrs. 40 min. The LRV traverse was 4.5 km to North Ray Crater, the largest yet explored on an Apollo mission. Rocks were sampled, one about house-size, another with permanent shadowed area in the lee of the sun line and interesting "drill-like holes" normal to its surface. Approximately 100 pounds of samples were collected during the 11.4-km traverse and the film cassette from the far ultraviolet camera was retrieved after recording 11 planned celestial targets.

The Apollo 16 Far Ultraviolet Camera/Spectrograph Experiment, the first lunar astronomical observatory, allowed scientists for the first time to examine the whole Earth atmosphere and geocorona from outside the Earth's environment. The hydrogen in the geocorona is believed to be derived from the break up of water vapor in the Earth's upper atmosphere.

The 71-hour stay in the Descartes area featured excellent experiment, LRV, TV, and crew systems operation; revised theories of Cayley formation; provided less evidence of volcanism than expected and the highest recordings of local magnetic field of any Apollo landing site. 1809 frames of 70 mm film and 4½ magazines of 16 mm film were exposed during the 20-hour 14-minute total EVA time. One hundred eleven documented samples totaled approximately 213 pounds. LM ascent from the lunar surface, rendezvous, and docking were normal.

During transearth coast final detailed objectives were completed and an 18-min. TV press conference was conducted. CM separation, entry, and descent were normal, with water landing 0.3 NM from the planned target point and 3.4 NM from the recovery ship on April 28, 1972.

Total time for the Apollo 16 mission was 266 hours.

Apollo 17.—The final lunar mission, scheduled for launch at 9:53 p.m. EST on December 6, was delayed for 2 hours 40 minutes by a tank pressurizing problem; actual liftoff came at 12:33 a.m. on December 7, but from then on the flight went with smoothness and precision. The last was also the best.

Apollo 17 was planned to accomplish selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Taurus-Littrow region of the Moon; emplace and activate surface experiments; and conduct in-flight experiments and photographic tasks. Flight crew members were Commander, Captain Eugene A. Cernan (USN); Command Module Pilot, Commander Ronald E. Evans (USN); Lunar Module Pilot, Dr. Harrison H. Schmitt (PhD).

The countdown proceeded smoothly until T–30 seconds when an automatic cutoff occurred. After a recycle and hold at T–22 minutes an additional hold was called at T–8 minutes.

The hold was caused by a failure of a function in the terminal count sequence card which monitors S–IVB LOX tank pressurization. A workaround to jump the failed function was analyzed and checked-out on the breadboard at MSFC and a decision was made to proceed with the countdown which then proceeded smoothly.

Earth parking orbit, translunar injection, translunar coast, lunar orbit insertion, and S–IVB stage impact were all nominal. The S–IVB impacted the lunar surface at 4°12′ South and 12°18′ West and was recorded by the Apollo 12, 14, 15 and 16 ALSEP's.

The lunar landing occurred on December 11, 1972, at the Taurus-Littrow site. Total EVA time was 22 hours, five minutes and six seconds, total distance traveled in the lunar rover was 35 Km (22 nm) and 115 Kg (250 lbs) of lunar samples were returned.

Ascent, rendezvous, docking, LM impact, transearth injection, coast, reentry, landing and astronaut recovery were all nominal. Total mission time was 301 hours and 51 minutes.

The Apollo 17 site, Taurus-Littrow, was the first selected largely in response to new knowledge acquired on earlier missions. Similarly, the science instruments placed on the lunar surface and those used on the traverses and in orbit were designed predominantly to obtain data useful in solving problems whose very existence could not be predicted prior to the first several Apollo flights.

The sample objectives at Taurus-Littrow were clearly defined: (1) try to find some of the youngest lunar material in order to determine whether lunar volcanism ceased three billion years ago as pre-Apollo 17 data indicate; (2) look for signs of volcanic activity possibly indicative of the presence of volatiles; and (3) obtain highland rocks, hopefully igneous, which might indicate what occurred on the Moon between four and four and one-half billion years ago, a time for which our record is limited. Although sample analysis has only just started, the commentary and descriptions of Geologist-astronaut Schmitt and Astronaut Cernan indicate that there is good probability that all sample objectives were met. In particular, the orange rocks and soil found at a probable volcanic crater on EVA–2 appear to have been caused by volatile-rich volcanism of a relatively recent age (i.e., possibly billions of years after the last mare outpourings three billion years ago). Highlands breccias were abundant at South Massif and highlands igneous rocks, all possibly older than four billion years, were sampled at the North Massif. Overall, the variety of rocks and soil, and thus the scientific value, is greater than that found on any prior mission.

The Apollo Lunar Surface Experiments Package was successfully deployed on EVA–1. The Heat Flow Experiment already indicates that the high value

found at Apollo 15 is not anomalous. The Mass Spectrometer and Meteoroid Detector are in good shape and undergoing pre-operation conditioning on the lunar surface. The Tidal Gravimeter is currently inoperative and, unless a workaround procedure is found, will constitute the only failure of the mission.

The valley of Taurus-Littrow was an ideal spot to operate three new geophysical experiments designed to detect layering. The Seismic Profiling, utilizing eight explosive charges and the LM Ascent-stage impact, and the Traverse Gravimeter, obtained data indicating that layered igneous rocks, similar to those sampled on the traverses, probably extend to depths of at least a kilometer. The Surface Electrical Properties experiment will complement the data from these other traverse experiments.

All orbital experiments performed successfully. The ultraviolet spectrometer detected a hydrogen atmosphere two orders of magnitude less abundant than predicted. The infrared spectrometer detected many thermal hot spots and showed the first convincing evidence for the existence of lunar cold spots. The preliminary lunar radar sounder telemeter data indicate layering in upper surface of the Moon but verification must await data reduction of the optical recorder film recovered during CMP Ronald Evans' EVA during Transearth Coast. It also provided several orbits of altitude profile data which will be integrated with laser altimetry. Lastly, the camera systems operated as planned and obtained significant new photographic coverage with which to conduct photogeologic studies and with which we can construct accurate topographic products. Apollo 17, building upon the foundation of all earlier U.S. lunar missions, can be called the most scientifically rewarding Apollo mission.

Continued Exploration of the Moon.—With the successful completion of Apollo 17, nine teams of astronauts have made the epic journey to the Moon and 12 Americans have walked the lunar surface. These men have returned some 360 kg (800 lbs.) of lunar sample for analysis and have established a network of geophysical stations on the Moon.

While the flight portion of Apollo was completed with Apollo 17, we have only begun to reap the full benefits of the program. The geophysical stations are expected to operate for several years, laser ranging to the lunar reflectors will continue for at least a decade, and detailed analysis of the lunar samples and photography will continue through the seventies.

We do not need to wait, however, to see that we already know more about the Moon than we might reasonably expect from the sampling of six rather isolated points on its frontside surface. In fact, lunar scientists speak in terms of Moon-wide chemistry, structure, and processes. They are able to do this largely because of the extensive and sophisticated remote sensing conducted from lunar orbit on Apollo. The remotely-sensed data, when correlated with geophysical station and sample information, enables the broad extrapolation of landing site results to those vast unsampled regions of both the near and far sides of the Moon.

The lunar program has also shown that the Moon is a unique and extremely advantageous platform from which to study the Earth and outer space as demonstrated by the laser ranging, far ultraviolet astronomy and cosmic ray experiments and the solar wind studies. The Laser Ranging Retroreflector Network was deployed during Apollo Missions 11, 14, and 15, and from it the McDonald Observatory in Texas now routinely obtains ranging accuracies to the Moon of a few centimeters. These accuracies make it possible to study the motions not only of the Moon, but also of Earth.

The study of the Moon's rocks and soil, all older than 3 billion years, is providing data pertaining to that period of time where the Earth's history has been obliterated.

Lunar highlands rocks returned to Earth via Apollo have been found to be rich in calcium and aluminum. Called anorthosites, these rocks are believed to be part of the early lunar crust. Anorthosites are rare on Earth but enigmatic and potentially very significant to the unraveling of early Earth history. The fact that they occur only in very ancient Earth rocks, those over 1½ billion years old, has suggested to some scientists that they may be related to the Earth's primordial crust. But there is no generally accepted way to produce anorthosites by melting rocks now thought to exist in the Earth's interior.

ASTP.—The Apollo/Soyuz Test Project is a joint U.S.-U.S.S.R. Earth orbital mission to test a compatible rendezvous and docking system.

In June 1972, the Apollo Program Director was appointed Apollo/Soyuz Test Project Director in the Office of Manned Space Flight, Washington, D.C. Joint Working Groups with members from each country have been established to address the major technical subjects involved in the project. These Joint Groups continued to define program details in a meeting at Houston in July and at a meeting in Moscow in October of this year. Follow-on meetings were held in November and December 1972. The Apollo spacecraft for the test mission will be a modified version of the Command and Service Module flown during early lunar landing missions, and will incorporate a Docking Module and Docking System. The basic spacecraft was manufactured and checked out for the Apollo Program and has been in storage. Modifications will be required as a result of unique mission requirements, including additional propellants for the reaction control systems, heaters for thermal control,

and controls and displays for the Docking Module, a cylindrical structure, about 5 feet in diameter and 10 feet in length. Equipped with the necessary stored gases, displays, and controls, it will serve as an airlock for the internal transfer of crewmen between the two spacecraft.

On its forward end there will be the new peripheral, universal docking device being designed by the U.S. and the U.S.S.R. Radio communications, docking displays, and antennas will also be mounted on the Module. The Soyuz spacecraft to be used by the U.S.S.R. has been the primary manned vehicle for the Soviet space program since it was introduced in 1967, and consists of an Orbital Module, a Descent Module, and an Instrument Module, to include the compatible rendezvous and docking equipment.

The mission is scheduled to begin no earlier than July 15, 1975, with the launch of a Soyuz-type spacecraft which will be inserted into a circular rendezvous orbit with a nominal altitude of 230 km and an inclination of 51.6 degrees. The first Apollo launch opportunity will occur about 7.5 hours after the Soyuz lift-off.

After separation from the second Saturn stage (S–IVB), Apollo will turn around, dock and extract the Docking Module internally mounted in the adapter area in essentially the same fashion as the Lunar Module is extracted on current lunar missions. The Apollo Command and Service Module will then have the docking module attached in place of the Lunar Module. The Apollo spacecraft will perform the maneuvers necessary for rendezvous and then dock with the Soyuz using the universal mechanism on the Docking Module. For about 2 days, astronauts and cosmonauts will exchange visits between vehicles. Additional tests of the docking mechanism are planned and, after final separation, the two spacecraft will conduct independent activities before re-entry.

Skylab Program.—Delivery of the Skylab modules to KSC for the initial missions was completed in October. In step with the hardware program has been the training of our astronauts and the refinement of mission planning. Changes in operational concepts and procedures have resulted from special tests and simulations conducted with astronaut crews in preparation for launching this country's first experimental space station.

Additionally, the unique Skylab Student Project has completed its selection of experiments from among the thousands submitted, and these are now being integrated into the experiment program.

Finally, Skylab has been given extensive international support for many experiments in earth resources, solar astronomy and space applications involving the efforts of about 250 foreign professionals and more than 350 American investigators.

The final prelaunch phases of the Skylab Program are now in progress, consisting of equipment checkout, launch preparations, astronaut training, and mission planning. Attention is now focused on activities at the Kennedy Spaceflight Center. These include extensive checkout and launch preparation operations, changeout of some items that could not be accomplished prior to delivery, stowage of consumables, systems tests, stacking of the modules on the launch vehicles, and movement to the launch pad. This will be followed by count-down demonstration tests and a final flight readiness review. At present, KSC activities are on schedule for the launch of the Skylab Workshop on April 30, 1973, followed by the first crew launch on May 1, 1973.

With the selection of the flight crews in January 1972, an active training program of approximately 2200 hours was begun. Included in the training program, and first used in February 1972 is the Skylab Simulator, designed to provide training in the operation of the major Skylab systems including Electrical Power, Environmental Control, Communications, and Solar Experiments. An Apollo Command Module simulator, modified for Skylab, has been in use since May. A number of other simulators are also being used for training and mission planning.

The first rehearsal, conducted in January, simulated the flight control activities that take place in the Mission Control Center at MSC. The second, held in May, included flight planning, as well as flight control elements. Flight control specialists, program personnel, and many scientist experimenters took part.

In September the astronauts simulated flight operations which covered launch and rendezvous of the CSM with the Skylab, activation of the Skylab, some typical in-orbital days, deactivation of the Skylab, and return to Earth.

The "Skylab Medical Experiments Altitude Test" was conducted in an altitude chamber for 56 days, from July 26 to September 20, 1972, at the Manned Spacecraft Center, to obtain baseline medical data for a typical Skylab mission under the expected Skylab environmental conditions (5 psia, 70 percent oxygen and 30 percent nitrogen), except for zero gravity. The test results showed no significant physiological changes due to test duration or conditions.

In 1972 the breadth of the scientific and technological investigations associated with Skylab has been significantly increased. This came about through: selection of the Earth Resources Experiments investigations; the addition of new experiments; the efforts of existing Principal Investigators to bring additional talent into their areas of investigation; and through general efforts to achieve a maximum of scientific product from the Skylab data. Overall, the 70 special purpose instruments aboard the Skylab will gather

data for about 290 distinct investigations. Over 600 senior scientists are now formally associated with the program.

During the year the Solar Astronomy Principal Investigators have established agreements for joint investigations with over 40 astronomers and physicists in the USA and abroad to assure a thorough problem-oriented attack on solar physics. Concurrent ground-based observations in accessible wavelength regions, and X-ray and gamma-ray spectroscopy from sounding rockets and balloons will provide needed supporting data to the space-born observation programs and will multiply the solar physics return from both activities.

The Earth Resources Experiment Package (EREP) hardware has been completed and installed in Skylab flight vehicles. The six high-performance sensors in this experiment facility will be used to gather information to be utilized by scientists world-wide. Their investigations, using the Earth resources data acquired from space, will include studies of the atmosphere, the oceans, geology, environmental quality and agriculture.

More than half of the 300 proposals received from potential EREP investigators have been selected for inclusion in the Skylab Program. A third of these represent participation by scientists of foreign nations, making this a truly international undertaking.

The preflight phases of the Skylab Student Project were nearly completed during 1972. Early in the year approximately 3,400 proposals were received from all areas of the country. From these, 301 regional winners were selected and given suitable recognition, and a further selection resulted in the 25 national winners representing 18 different states. Of the 25, 11 required new hardware; the remaining 14 will be able to carry out their experiments using data from existing hardware.

Space Shuttle.—In the Space Shuttle Program significant progress was made during 1972. After two years of intensive study, undertaken by NASA with the assistance of major aerospace companies, it was determined conclusively that development of a low-cost transportation system based on a reusable vehicle was both economically and technically feasible. Accordingly, the President decided in January 1972 that NASA should proceed with development of the Space Shuttle.

The configuration selected offers maximum economic advantages with minimum technical risk. The reusability concept makes it possible to reduce transportation and payload costs projected for the 1980's.

Configuration.—The Space Shuttle is a two-stage vehicle, consisting of an orbiter with an externally attached hydrogen/oxygen tank and two solid-fuel rocket boosters. This combination is launched vertically, with the twin boosters and orbiter main engines firing in parallel. At an altitude of 40 km (25 miles) the boosters are detached and descend by parachute, so that they may be recovered, refurbished and reused. The orbiter vehicle continues its flight, using its own propulsion systems and jettisons the external tank after entering Earth orbit. Upon completion of its mission the orbiter returns to Earth and lands like a conventional airplane.

Missions.—This configuration provides the flexibility necessary to place a wide variety of payloads, into Earth orbit for scientific, commercial and military space operations. Integrated space operations may include: the placement of unmanned satellites into low Earth orbit; the delivery of satellites and propulsion stages into high Earth orbit for scientific exploration or deep space probes; the conduct of man-tended experiments in low Earth orbit by means of a "sortie laboratory". In the case of unmanned payloads, the Space Shuttle will deliver, deploy and revisit satellites to service, update, repair, and retrieve them.

Shuttle Economics.—In comparing the costs of conducting space operations utilizing a Space Shuttle in lieu of expendable launch vehicles, significant savings have been identified. These savings result from reusing the Shuttle, providing accessibility in space to payloads and spacecraft, and the capability to retrieve and reuse payloads. Of the savings expected to be realized, 62 percent would result from retrieval and reuse of payloads and 38 percent from lower launch costs and increased vehicle reliability.

Management Concepts.—Another major decision made in 1972 was the selection of the management concept for the Space Shuttle Program. This concept calls for a small program staff at NASA Headquarters in Washington, while day-to-day management of the program is delegated to a "lead center" (the Manned Spacecraft Center, Houston, Tex.). Systems integration will be the responsibility of the orbiter prime contractor, who will be supervised in this task by personnel from MSC. The Marshall Space Flight Center, Huntsville, Ala., will be responsible for development and testing of the Shuttle main engine, the external tank and the solid rocket booster. Launch and landing operations (including vehicle refurbishment) will be conducted at the Kennedy Space Center and at Vandenberg Air Force Base depending upon mission requirements. Close cooperation will be maintained with the United States Air Force.

Environmental Impact.—In 1971 a draft environmental impact statement was prepared and distributed to the Council of Environmental Quality, the Office of Management and Budget, the Environmental Protection Agency, and the Departments of Transportation, Defense, and State. Based on comments received from these agencies, the potential environmental im-

pact of the Space Shuttle was analyzed in 1972. It was agreed that the potential for adverse effects on the environment would be small, of limited duration and confined to narrow geographic areas.

Technology Development.—The Space Shuttle represents, in effect, a "second generation" space transportation system and will take maximum advantage of advanced technologies, some of which were developed during earlier manned space flight programs but were not applied since those programs had matured to a point where it would have been uneconomical to make major changes.

Contractor Selection.—In July 1972 the Space Division of North American Rockwell was selected as the prime contractor for orbiter development and systems integration. A letter contract was signed on August 9 and negotiations for contract finalization were begun. The Rocketdyne Division of North American Rockwell, which had been selected as the prime contractor for development of the Space Shuttle main engine, was awarded a definitive contract on August 11, 1972. This contract provides for the delivery of propulsion-test and flight-rated engines. Seven of these are to be used during the development phase, with the balance destined for operational flights.

Program requirements for the external tank and solid rocket booster were definitized and work was begun on the preparation of procurement packages for these major Shuttle components. Major emphasis will be placed on low-cost manufacturing and tooling techniques to reduce unit costs to acceptable levels. The external tank will be fabricated and assembled in the government-owned plant in New Orleans, La.

Program Baseline.—The approved program baseline calls for the delivery of two orbiter vehicles during the development phase of the program; plans call for three additional vehicles to be delivered during the operational phase. The Shuttle main engines, the external tank and solid rocket boosters will be furnished to the orbiter contractor by the government, with the Space Division of North American Rockwell responsible for integration of all Space Shuttle systems elements. First horizontal flight is planned in the mid 1970's and the first manned orbital flight in the late 1970's.

Mission Planning.—Work continued to define payload requirements and to plan missions which will make maximum use of Shuttle capabilities. Discussions were begun with potential users and an organizational framework was established, which would insure close cooperation with user organizations.

Shuttle Operations.—On April 4, 1972, Dr. James C. Fletcher, the NASA Administrator, announced that the Shuttle would operate from the Kennedy Space Center in Florida and Vandenberg Air Force Base in California. It was determined, after a thorough review of 150 potential launch sites, that those two existing facilities offered major advantages with respect to cost, safety, operational requirements and environmental impact.

In early 1972 the Sortie Laboratory was suggested as a potential activity for European study and development. Active study of the Sortie Lab was undertaken by ESRO and a decision whether or not to proceed is under consideration.

Space Tug.—Conceptual studies of the Space Transportation System include a propulsive stage that is carried into low Earth orbit by the Space Shuttle. The primary function of this reusable upper stage, termed Space Tug, would be to extend the operating regime beyond the Space Shuttle to include orbital plane changes, operations to and from higher energy orbits extending to geosynchronous positions, and Earth escape missions. The Tug could be used for orbit placement, retrieval, stage/payload reuse and in-on-orbit refurbishment, for civil and military programs.

In early 1972, Tug definitions studies under sponsorship of the European Space Conference (ESC) were conducted by the European Launcher Development Organization (ELDO) in coordination with NASA. NASA later initiated a major planning activity to define and assess options that would provide an interim Tug capability at about the same time the Shuttle is initially operational. This effort is being well coordinated with associated Air Force work in this area and joint funded Tug study activities will be implemented in fiscal year 1973.

Life Sciences.—Advances to date on "early warning" disease detection systems, and medical diagnosis to remote areas by otherwise unavailable specialists show great promise for application to the general public.

Development of a new concept in space suits for Space Shuttle application is rapidly moving along. The space suit is lightweight—less than 12 pounds; utilizes new soft fabric joint technology in shoulders, elbows, and knees; incorporates a soft, stowable visor-helmet; and provides short term comfort of five hours at the operating pressure. Suits will not require custom fitting, and can be reused.

Cooperation with the U.S.S.R. in the medical area is also continuing.

Remote Medical Diagnosis.—NASA and HEW have begun a joint effort which ultimately will extend to remote areas the health care facilities and expertise heretofore only available in large metropolitan medical centers. The concept to be employed is based on techniques used in tracking the health status of astronauts

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during space flight. The system will make maximum use of advanced computers and modern communications to transmit patient medical data from a remote site to urban control centers, where physicians will diagnose ailments and prescribe treatment to be executed by trained medical assistants at the remote location.

Advanced Program Studies.—These studies focused on the missions, systems, and interface studies needed to support the effective utilization of the space transportation system based on the Space Shuttle.

Studies of the hardware and operating interfaces between the Space Shuttle, the Space Tug and a representative group of potential future space payloads produced a conceptual definition of appropriate interface equipment. Also investigated were the launch site service interfaces for the Space Tug, and the dynamics, control and capture of tumbling spacecraft.

During 1972 the Materials Science and Manufacturing in Space (MS/MS) program, sponsored by OMSF, conducted two small "demonstration" experiments on the Apollo 16 and 17 lunar missions, added a group of ten new experiments to the Skylab mission, and considerably expanded its activities aimed at preparing payloads for the Space Shuttle. The new Skylab experiments will use a small, multipurpose furnace system added to the payload in 1972. Proposals were solicited in January, and eight United States and two foreign scientists were selected to participate.

A Mission and Payload Integration Office (MPIO) has been established in OMSF. This new office is responsible for the planning, direction and coordination of payload activities between the various elements of the Space Shuttle, Tug, and Sortie Lab within OMSF and the payload sponsor in NASA and other government agencies. The primary objective of the MPIO is to assure the compatibility of the Shuttle, Tug, and Sortie Lab with the payloads to be flown on these vehicles. Payload/mission trade studies have been initiated and will be continued.

The MPIO has also been assigned the responsibility for periodic updating of the NASA Mission Model. The Mission Model displays, in abbreviated format, planned and potential space missions scheduled to be flown in the period extending from 1973 through 1990.

Studies of sonic boom and effects of exhaust effluents as related to Shuttle flights have been conducted and will be continued into the coming year. Cryogenic technology, structures, thermal control, propulsion and space power devices are typical of the tasks under development. Lightning warning and control in the launch area, development of short pulse lasers, control components and solar cell energy wheel systems are other areas of promising developments.

Initial study activity leading to agreement with the Soviets for the Apollo/Soyuz Test Project was coordinated within the Advanced Development Office. With emphasis now shifting to the study of a Space Tug, system developments applicable to this type vehicle are being planned.

Space Science

Mariner Mars.—Mariner 9 was launched successfully on May 30, 1971, and was placed in orbit about Mars on November 13, 1971. The spacecraft remained operational until October 27, 1972, approximately one year after orbital insertion. Despite a severe dust storm during the first 1½ months of its orbital lifetime, it mapped 100 percent of Mars to an optical resolution of about 1 km by taking nearly 7,400 pictures of the planet and its satellites. It also mapped large portions of the planet in the infrared and ultraviolet spectra providing information on the atmospheric temperature and composition including definite identification of water vapor features, and on the surface characteristics including many elevation measurements. In addition, it provided a Mars gravity contour map, more precise information on the ephemerides of Mars, and conducted a relativity experiment as part of the celestial mechanics experiment. Finally, the S-band occultation experiment provided temperature and elevation profiles for major areas of the planet.

Mariner 9 has been more than 100 percent successful in meeting all of the objectives of both the basic 90-day mission and the 9-month extended mission. The results of Mariner 9 have completely rewritten the book of knowledge on Mars and have completely changed the previous image of the planet.

Mars has now been identified as a live, dynamic, evolutionary planet with dust storms, changing cloud formations and volcanoes instead of a barren, dead, Moon-like planet.

Mariner Venus/Mercury '73.—During 1972 development continued on the Mariner spacecraft scheduled to be launched from Cape Kennedy during the October/November 1973 opportunity, which has as its primary objective the first exploration of the planet Mercury.

On its way to the closest planet to the Sun, the spacecraft will fly within 5,3000 kilometers (3,300 miles) of Venus, where it will receive an increase in speed and the necessary trajectory deflection to reach Mercury.

The high-resolution TV cameras aboard the spacecraft will take the first TV pictures of both planets. A total of 5,500 pictures of Venus, and 2,000 pictures of Mercury are scheduled to be taken. The average resolution of these pictures is expected to be two kilometers (1¼ miles), but selected targets will be photographed at a 100-meter (110-yard) resolution.

Other science instruments aboard the spacecraft

will investigate the composition, color and circulation patterns of Venus' clouds. These same instruments will also investigate the surface of Mercury, measure any atmosphere present, and explore its environment both on the approach and departure legs of the encounter trajectory.

Final assembly of the Launch Vehicle (Atlas Centaur D–1A) has been started, and will be completed by January 1973.

The assembly of the Flight Spacecraft will begin in January 1973 and is scheduled for completion during April 1973. System and environmental testing will be completed by August 1973.

Pioneer.—Two interplanetary Pioneer spacecraft have been designed for exploratory missions to fly to Jupiter. Pioneer 10 was launched on March 2, 1972, while Pioneer G will be launched in the April 1973 time period. Once it successfully achieves its trajectory it will be designated as Pioneer 11. These spacecraft each carry 11 separate scientific instruments to explore the interplanetary medium beyond the orbit of Mars, to determine the size, density and velocity of meteoroids and asteroids in the asteroid belt and to examine, during a close flyby, the environmental and atmospheric characteristics of the planet Jupiter.

The information and technology derived will improve the operational capability for long-duration flights to the outer planets—Saturn, Uranus, or Neptune.

Following the March 2 launch of Pioneer 10, the scientific instruments were turned on and checked out and 10 of the complement of 11 began to collect data on the interplanetary medium (magnetic fields, meteoroids, solar and galactic radiation.) The eleventh instrument is designed for the Jupiter encounter phase and therefore remains inactive for the greater part of the interplanetary cruise phase. With the exception of some anomalies, all subsystems and experiments have continued to function satisfactorily. During early August 1972, when several severe solar storms occurred, scientific data on the solar environment was collected simultaneously from both Pioneer 10 and Pioneer 9 (launched Nov. 8, 1968) at their different heliocentric distances.

Acceptance testing of the flight article Pioneer G was conducted throughout the latter part of the year following the integration of the experiments and spacecraft subsystems in June 1972.

Helios.—This program, first conceived in 1966 as a cooperative endeavor between the United States and the Federal Republic of Germany, is planned for one mission in 1974 and a second in two years to investigate the properties and processes in interplanetary space in the direction of and close to the Sun (within approximately 0.25 of the distance from the Sun to the Earth). The United States will provide three scientific experiments to complement the seven German experiments; will launch the spacecraft; provide tracking and data acquisition facilities and personnel; and will provide technical assistance to the German personnel in testing the spacecraft and in the review of the spacecraft design and the spacecraft test program. The Federal Republic of Germany will design, develop and fabricate the spacecraft (as well as the seven experiments), and will operate it during each 130-day mission.

During the year a substantial test phase was completed with two developmental models (the spacecraft and thermal models) of the spacecraft. The engineering models of both the U.S. and German scientific instruments were delivered for integration with the spacecraft and subsequent testing. The spacecraft design review, conducted in Germany by a NASA team, essentially completed the design phase for the spacecraft and the scientific instruments.

Viking.—The exploration of Mars will enter a new phase in 1976 when two Viking landers are scheduled to reach its surface and begin their detailed scientific investigations.

Scientific emphasis will be placed on obtaining data relevant to the search for life on Mars. Additional science results will help us understand the evolution of Mars and the solar system. Two separate Viking spacecraft are scheduled to be launched in August–September 1975, to reach and orbit Mars in June–August 1976. Each spacecraft will first inspect the preselected landing sites, then separate into two parts: an Orbiter which will continue to conduct visual, thermal, and water-vapor mapping of the planetary surface; and a Lander which will analyze the atmosphere as it descends and then will conduct varied surface experiments.

Progress during the year included completion of the preliminary design reviews for the Orbiter, Lander, and Launch and Flight Operations systems.

Most of the instrument and subsystem development tests were completed, leading to the beginning of prototype hardware fabrication. Three of the science instruments—for biology, meteorology and organic analysis of the soil—were simplified to keep within cost, weight, and schedule constraints. As a result of the science findings from the Mariner 9 mission, a new science experiment for inorganic analysis of the soil was added to the payload to increase the geological results from Viking.

Outer Planets Missions.—The Outer Planets Mission, Mariner Jupiter/Saturn (MJS77), is planned to take advantage of a favorable planetary alignment that occurs in the latter half of the 1970's, by using the gravity-assist "swingby" technique to explore these two planets.

The MJS77 mission will involve two launches in 1977 of spacecraft which will fly by Jupiter some 1½ years after launch and, after being accelerated by Jupiter's gravity and orbital velocity, will fly on to reach Saturn some 3½ to 4 years after launch.

Mission and spacecraft design studies have been underway to maximize the science return for the mission. The design calls for two identical spacecraft based primarily on Mariner/Viking Orbiter designs, making maximum use of leftover Viking hardware where possible. An Announcement of Flight Opportunity (AFO) was issued to the scientific community to solicit experiments for the mission. The proposals in response to the AFO have been evaluated and the science payload selected. Detailed design of the mission and refinement of the spacecraft system have continued.

Orbiting Observatories.—Two OAO satellites are now orbiting the Earth and are currently obtaining scientific data on planets, stars, nebulae and galaxies. OAO–2, launched December 7, 1968, has this past year extended the ultraviolet spectral coverage of both galactic and extra-galactic objects that has advanced our understanding of the true nature of these objects. The first ultraviolet observations of Uranus have been obtained, and complete light curves of eclipsing variable stars have been produced, permitting more detailed analysis of the outer atmospheres of these stars than has been possible before. The first observations of a super-nova are being interpreted as an expanding gas cloud.

In its 4 years of operation OAO–2 has obtained over 13,000 observations of celestial objects with the University of Wisconsin experiment, and over 3,500 observations with the Smithsonian Astrophysical Observatory experiment. OAO–3 (*Copernicus*), whose primary objective is to obtain high resolution ultraviolet spectra of stars necessary to investigate the composition and physical state of matter in interstellar space and stellar sources, was launched August 21.

In its first few months of operation, OAO–3 has observed a number of "bright" stars, both reddened and unreddened, which may give important information on mass loss from extended stellar atmospheres and on the nature of interstellar clouds.

The X-ray experiment on OAO–3 has observed a number of X-ray sources and was able to correlate in soft X-rays a recent giant radio wave outburst from the X-ray source Cyg XR–3.

The Orbiting Solar Observatory–7 (OSO–7), launched in September 1971, has continued to observe a number of significant events and phenomena of the Sun. Techniques for forecasting the appearance of active regions on the Sun have been improved. This will aid in the study of the Sun's effects on the Earth's environment. Nuclear reactions in solar flares were confirmed for the first time by OSO–7 observations of gamma ray emission lines from nuclear reacting products. Development of the last spacecraft of the OSO Series, OSO–I, continued during 1972.

High Energy Astronomy Observatory (HEAO).—Studies continued on the HEAO missions to investigate celestial X-ray, gamma-ray, and cosmic-ray phenomena.

Explorer and International Satellites.—An Interplanetary Monitoring Platform (IMP) designated Explorer 47 was launched on September 22, 1972. The IMP series was established to make long-term observations of Earth-Sun relationships, particularly the outer magnetosphere, the magnetosheath and the interplanetary medium. Earlier IMP's have mapped in broad detail the interplanetary region, the Earth's magnetosphere, solar and galactic cosmic rays, and other complex solar-terrestrial relationships.

A cooperative mission with Germany, AEROS, was launched in December to measure the main aeronomic parameters of the upper atmosphere and the solar ultraviolet radiation in the wavelength band of main absorption.

SAS–B, Explorer 48, the second in the Small Astronomy Satellite series, was launched in November 1972 by an Italian team from the San Marco facility off the coast of Kenya, Africa. SAS–B is designed to measure the spatial and energy distribution of primary galactic and extra-galactic gamma radiation.

SAS–A, Explorer 42, since launch in December 1970 has provided a continuing stream of highly significant scientific information. In addition to cataloging to date some 160 X-ray sources and discovery of X-ray pulsars which appear to differ in some respects from the more commonly known radio pulsars, other unique information includes the discovery of binary star systems identified solely on X-ray data and possible data to support the theories of "Black Holes" which are massive stars that have collapsed to the point where gravitational forces prevent the escape of any electromagnetic radiation including visible light.

Atmosphere Explorer.—The three-mission Atmosphere Explorer (AE–C, D, E) program represents NASA's primary effort in investigating the largely unexplored region of the lower thermosphere, the region where the bulk of solar energy is absorbed and most of the chemical and energy conversion processes occur which govern the structure and properties of the upper atmosphere.

This year was devoted to the completion of the spacecraft and experiment final designs, fabrication of spacecraft and experiment hardware, procurement of the data handling system, and the initiation of the

integration and test phase of the AE–C mission which is scheduled for launch in late 1973.

Sounding Rockets, Balloons, and Aircraft.—The NASA Airborne Science Program uses aircraft to make scientific measurements not possible from the Earth. The program is currently using a 30-cm diameter telescope installed in a Lear Jet which is capable of operating at altitudes near 15 kms (50,000 feet). One of the far-reaching results of this program has been the detection of enormous amounts of radiation emitted by gas and dust clouds in our galaxy at these long wavelengths.

In 1972 the manufacture and assembly of the 91-cm (36-inch) infrared telescope was completed. Installation of the telescope into a C–141 aircraft was started. Initial observations are scheduled for 1973.

The NASA Sounding Rocket and Balloon Program launched 84 rockets from sites including: Wallops Station; White Sands Missile Range; Ft. Churchill, Canada; Sweden; Alaska; Hawaii; and Norway. About 50 research teams from universities, private industry, NASA centers, other U.S. Federal Government agencies and foreign governments were supported. A rocket launched from WSMR gathered X-ray data of sufficient precision to confirm that the binary star HZ Herculis is a source of X-ray emissions. A rocket flight gave information indicating that approximately four per cent of all hydrogen atoms are in molecular form, along the path toward the star Delta Scorpii. This is only the second positive detection of interstellar molecular hydrogen.

There were 55 balloons launched from sites including: Palestine, Tex.; Ft. Churchill, Canada, and Australia. The balloons ranged from 0.008 million cubic feet to 46 MCF (the largest balloon ever flown successfully); the most common size was 11 MCF. A balloon launched in September 1972 carried an infrared experiment which directly observed a 3° K temperature for the cosmic background, strongly supporting the "Big Bang" theory of the origin of the universe.

Physics and Astronomy Shuttle Sortie Payloads.—Possibilities for operating national physics and astronomy research facilities on the Space Shuttle by providing the capability for conducting unique experiments or observations of specific phenomena are being investigated. These facilities could encompass both laboratories and observatories configured as Shuttle payloads and operated by scientists on the Shuttle. Each payload could be flown several times per year and have an operational lifetime compatible with traditional ground-based facilities.

Launch Vehicle and Propulsion Program.—The Scout launch vehicle successfully orbited five satellites this year. The Meteoroid Technology Satellite (MTS–A) was launched from the Wallops Station launch site in Virginia; three missions, the Transit Improved Navigation Satellite, European Space Research Organization/ESRO–4, and the German cooperative Satellite/AEROS were flown from the Western Test Range in California; and the Small Astronomy Satellite (SAS–B) was launched from the San Marco Range off the east coast of Africa under a cooperative reimbursable launch services contract with the Italian Centro Ricerche Aerospaziali. The five missions extended the Scout launch record to 28 consecutive successes—a new record for U.S. launch vehicles. The Scout Program has now sustained a 100 percent reliability record since September 1967.

In January, the HEOS II mission was successfully launched for the European Space Research Organization (ESRO) on a Delta vehicle.

This was followed by another successful launch for ESRO when the TD–1 satellite was launched in early March. In July one of the most significant milestones in the history of the Delta Program was achieved with the launch of the ERTS–1 satellite. The launch vehicle/Delta 89 flew with the following first-flight items: first flight using nine solids (strap-on solids to the Thor booster); first flight of the spring separation system; first flight of the Delta inertial guidance system (DIGS); and first flight of the AJ–10–138 second stage propulsion system on Delta.

The vehicle performed flawlessly and placed the satellite into a nearly perfect orbit. A little over a month later, Explorer 47 (IMP–H) was launched using for the first time the extended Thor booster and the TE–364–4 motor third stage on a Delta mission. In November, ANIK I was successfully launched for the TELESAT Canada Corporation. This was the first mission requiring the new eight-foot diameter fairing (called "straight eight" Delta). The "year of firsts" for Delta was completed with the successful launch of Nimbus V in December.

The Atlas-Centaur launch vehicle successfully completed the launch of four missions during this period, including two INTELSAT IV launches for the Communications Satellite Corporation, an Orbiting Astronomical Observatory (OAO–C) called *Copernicus,* and the Pioneer G launch to Jupiter. The launching of Pioneer G marked the first flight of the TE–364–4 solid rocket motor and resulted in the highest velocity ever achieved by a man-made satellite and the first man-made object to escape the gravitational pull of the Sun.

Applications Programs

On December 3, 1971, NASA announced the establishment of the Office of Applications within the Headquarters organization. At that time the personnel, programs, and functions of the Earth Observations Programs Division and the Communications Programs

Division were transferred to the new office from the Office of Space Science and Applications. That office was renamed the Office of Space Science. The Deputy Associate Administrator for the Office of Manned Space Flight was appointed to head the new Office of Applications.

In March 1972, the Applications Program Integration Board was established. This board is comprised of the Deputy Administrator, all Associate Administrators, and the Directors of field installations. The purpose of the board is to provide a mechanism for negotiating support with the cognizant Associate Administrators and Field Installation Directors for specific elements of the NASA Applications Program, and for establishing a consistent approach to institutional support. As a further effort to develop field installation support and to increase the depth of program staffing, the Applications office employed the Lead Center concept. This involves the assignment of program development effort by major discipline areas to selected field installations, as an extension of the cognizant Headquarters office.

A very important part of the development of the Office of Applications is the addition of a User Affairs Division. This Division is intended to increase the responsiveness of applications programs to those whose technological requirements might be satisfied by NASA capabilities. It will also assist these potential users in identifying their program areas wherein NASA can make valuable contributions. The Lead Center organizations will add depth also to this critical two-way flow of information.

Earth Resources Technology Satellites.—Perhaps the most important single applications program event during 1972 occurred on July 23, when the first Earth Resources Technology Satellite (ERTS 1) was successfully launched from the Western Test Range on a Delta launch vehicle. The accurate polar orbit achieved allows the satellite to cross over the equator at about 10 a.m. each day, phased with regard to the rotation of the Earth to cause the satellite to cross the same area of Earth every 18 days for repetitive coverage. The objective of this mission is to obtain multispectral earth resources imagery for 330 selected investigations in areas such as agriculture, forestry, geology, geography, oceanography, ecology, and environmental quality.

Earth Observations Aircraft Program.—In 1972, as in past years, the Earth Observations Aircraft Program (EOAP) served as a major source of remote sensing data for the Earth Resources Survey investigative program and continuing support was provided to in-house and interagency surveys and to sensor development efforts. The major portion of the 1972 aircraft program effort resulted from the requirements generated by ERTS and Skylab investigations for supporting data in the new EOAP role as an integral part of prototype space-borne remote-sensing systems.

Accomplishments included the completion in March of the ERTS simulation undertaken with the new high altitude aircraft. These two aircraft were later used to acquire data for several agricultural investigations during the early 1972 growing season. Because of delays in the launch of ERTS 1, an essential segment of data would have been missed, had it not been for the use of the aircraft. Since the launch of ERTS 1, all EOAP aircraft have been engaged in a supporting role.

To date some 150 overflights of ERTS 1 test sites have been accomplished. With the assistance of the USAF, NASA remote-sensing aircraft also acquired photomosaic data needed for Skylab astronaut simulator training and for the development of on-board data files needed for site recognition in operating the EREP S191 Infrared Spectrometer sensor.

During 1972, NASA aircraft contributed to several disaster surveys in cooperation with NOAA and the State of California. Disaster survey flights included two forest fires in California, a dike break and subsequent flooding in California and the flood damage associated with Hurricane Agnes.

Nimbus.—Another major event during 1972 was the launch into polar orbit of Nimbus 5 (E) on December 12, on a Delta launch vehicle from the Western Test Range. This mission carries six major experiments to improve remote sounding of the atmosphere from orbital altitudes and to extend this capability to cloud-covered areas and to higher altitudes. These kinds of data are needed for research which could lead to improved long term weather for forecasting and increased understanding of atmospheric processes.

This mission also carries a surface composition mapping radiometer (SCMR) to determine the composition of the surface by measurement of the modification of the thermal emission of igneous rock. Contracting for the experiments for the next mission, Nimbus F, was completed during early 1972 and the development effort more than half completed by the end of the year. Nimbus F is planned for a mid-1974 launch.

Improved TIROS Operational System.—On October 15, 1972, the NASA-developed ITOS–D mission was launched by NASA into a polar orbit on a Delta launch vehicle from the Western Test Range. The cost for this mission (the spacecraft and launch services) is fully reimbursed by the National Oceanic and Atmospheric Administration (NOAA) and the post-launch designation of the mission is NOAA 2. In addition to the cloud cover imaging sensors carried by the previous TIROS missions, NOAA 2 carries a vertical temperature profile radiometer. This sensor,

which provides the first operational temperature profile sounding capability, stems from development work done in support of the Nimbus missions. The spacecraft was checked out by NASA and turned over to the National Environmental Satellite Service (NESS) on November 8 for operational service. Follow-on missions are planned at the rate of about one per year for the next 3 years.

Applications Technology Satellites.—The Applications Technology Satellite (ATS) F is a multi-user communications experiments satellite. It is a heavy and complex spacecraft involving a large deployable parabolic antenna, an accurate three-axis, Earth-oriented stabilization system and a sophisticated communications transponder. The ATS–F mission also carries several multidisciplinary experiments that benefit from the synchronous orbital altitude of the ATS mission. During 1972 a major review was undertaken to reestablish a proper schedule phasing between the various elements of the project.

The Department of Health, Education, and Welfare (HEW), and the Corporation for Public Broadcasting (CPB) will make use of ATS–F in coordination with the Rocky Mountain Federation area, the State of Alaska, and the Appalachian Regional Commission. This effort involves the demonstration of education and health care by satellite. Experiment coordination and working group meetings have been held and operations planning is on schedule. The users have educational and broadcasting groups under contract to generate the programs that will be used. In addition, separate contracts have been let to develop an evaluation subproject to help evaluate the results of these experiments. One year after launch ATS–F will be repositioned over the Indian Ocean to allow the government of India to conduct a one-year instructional television experiment. The receiving hardware being developed by India appears to be on schedule for a mid-1975 start, and television tapes are being prepared.

During 1972 the ATS 1, 3, and 5 missions continued to perform valuable services well beyond their design lifetimes. In addition to the well known synchronous altitude imagery of the Earth which has located and tracked many hurricanes, these missions have provided experience to many users in communications.

Synchronous Meteorological Satellites.—The objective of the Synchronous Meteorological Satellite (SMS) project is to develop a geostationary satellite system which will meet the National Operational Meteorological Satellite System (NOMSS) requirements as specified by NOAA. Meteorological satellite imagery to date has found its main strength in the integrative effect of orbital altitudes. Such large-scale imagery can afford to be intermittent in coverage as provided by the ITOS missions. However, short-term, local-area forecasting can be helped immeasurably by near-continuous observation of short-duration phenomena such as severe weather features. These phenomena are frequently of such a size and have a brief lifetime in comparison to large-scale systems that they pass through the relatively coarse mesh of the conventional, land-based observational network. This short-term weather forecasting and satellite observational requirement will be met with the capability of the SMS spacecraft, which will carry the large and sophisticated Visible and Infrared Spin Scan Radiometer (VISSR) sensor.

This sensor can take full-Earth disk pictures every half-hour, day or night. Additionally, the SMS system provides for the collection of environmentally significant data from up to 10,000 sensing platforms in remotely located sites. Both raw and processed environmental data can be distributed to small regional forecasting or warning stations by using the data relay capabilities of SMS. SMS experienced a deep and thorough management review during 1972. This review determined that advanced design features had been incorporated into the spacecraft design which had not been adequately assessed in the program definition estimates. As a result the launch of SMS–A has been delayed about ten months to late 1973, with SMS–B scheduled for early 1974. During 1972 the SMS spacecraft design and verification was completed and the thermal/structural model fabricated and tested. Also, the VISSR engineering and prototype models were completed.

Global Atmospheric Research Programs.—The Global Atmospheric Research Program (GARP) is the research arm of the international World Weather Program as contrasted to the operational branch, the World Weather Watch. Research in GARP is aimed at providing scientific knowledge needed to improve the range and accuracy of weather forecasts, to determine the feasibility of large-scale weather modification, and to assess the long-term effects of pollutants on the atmosphere. In pursuing these objectives, the program will center on the following tasks: (1) the design and testing by computational methods of a series of theoretical models of the atmosphere to permit a more precise description of the significant physical processes and their interactions; and (2) observational and experimental studies of the atmosphere to provide the data from various sources that are required for the design of such theoretical models and the testing of their validity. An interagency and international effort is necessary to execute these tasks.

The National Oceanic and Atmospheric Administration (NOAA) is the coordinator of U.S. participation in GARP. NASA has been assigned two major tasks: conduct of a Data Systems Test (DST) and preparation of the Plan for the First GARP Global

Experiment (FGGE). During 1972 NASA completed an overall project plan for NASA participation in GARP, and a detailed plan for the DST. The DST is a year-long activity to take place during 1974.

Earth and Ocean Physics Program.—The Earth and Ocean Physics program plan was completed during 1972. This comprehensive plan sets forth the objectives and activities envisioned for the Earth and Ocean Physics Applications Program (EOPAP) over the next decade. This applications program is based on the disciplines of Earth and ocean dynamics. Its primary goals are to identify, develop, and demonstrate relevant space techniques that will contribute significantly to the development and validation of predictive models for earthquake hazard assessment, ocean-surface conditions, and ocean circulation. In related program areas, the GEOS–C mission is planned for launch in the second half of 1974. Some of the objectives of the GEOS–C project are to demonstrate the feasibility of satellite altimeters for measuring the topography of the ocean surface, and contribute to the calibration and improvement of ground and satellite systems (such as C-band radar and satellite to satellite tracking) that can be applied to problem solving in the Earth physics discipline. During 1972, the final configuration of the GEOS–C spacecraft was resolved with the decision to include an intensive data rate mode in the altimeter radar, and work on the development of the spacecraft was begun.

A significant amount of planning was also accomplished during 1972 on technical details leading to the Laser Geodetic Satellitte (LAGEOS). The LAGEOS concept is a very dense (high mass/area ratio) laser reflector satellite which will provide a permanent reference point in a very stable orbit for precision Earth-motion measurements such as crustal motions, fault motions, polar motion and Earth-rotation variations, solid Earth tides and other kinematic and dynamic parameters associated with earthquake analysis. In the fall of 1972, the San Andreas Fault Experiment (SAFE) got underway with the establishment of laser ranging sites on Otay Mountain near San Diego and on Mount Shasta near Quincy, Calif. The baseline between these two sites nearly parallels the San Andreas Fault. By determining the distance between the two sites, and what changes occur over time, the relative motion of the crustal plates causing the fault can be inferred. This information will form the basis for estimating the rate of energy build-up in the fault area. Initial data was acquired during the last few months of 1972.

Aeronautics and Space Technology

Quiet Engine Program.—A major accomplishment in the experimental Quiet Engine Program was made this April with demonstrations of the Quiet Engine with complete nacelle treatment. The noise levels demonstrated were even lower than the original goals of the program. Comparing the flyover noise of a DC–8 with a hypothetical aircraft using the NASA Quiet Engine shows that takeoff noise is reduced by 26 EPNdB and approach noise by 29 EPNdB. The extremely low noise levels of the Quiet Engine are actually 14 EPNdB below the current regulated levels of FAR 36 at takeoff and 17 EPNdB lower at approach.

A second Quiet Engine utilizing a higher top speed fan was completed and testing began at the contractor's test site in March. Noise levels of a fully suppressed configuration were slightly higher than those of the first Quiet Engine.

Clean Combustor Program.—Research is continuing in the important area of engine exhaust emission pollution reduction. The knowledge gained from research to date will be incorporated in a new technology program started in late 1972, the Clean Combustor Program, aimed at the development and demonstration of a practical combustor with very low pollutant emission levels. The goal is to reduce carbon monoxide and unburned hydrocarbon levels by at least 60 percent and the level of oxides of nitrogen by 75 percent, and to emit no visible smoke.

Advanced Supersonic Technology.—The Advanced Supersonic Technology program continued to provide an expanded technology base in the technical disciplines of propulsion, structures and materials, aerodynamics, and stability and controls. This expanded technology base can give the industry of our country the technology option to proceed with the development of an environmentally acceptable and economically viable supersonic transport if and when it is determined that it is in the national interest to initiate such a program. Airframe and engine systems studies are underway to assess the impact of new technologies on the concepts and characteristics of supersonic aircraft for the 1985–1990 time period, to identify major technology problems, and to submit recommendations for research programs. The airframe systems contractors are the Boeing Co., Seattle, Wash.; McDonnell-Douglas Aircraft Corp., Long Beach, Calif.; and Lockheed Aircraft Corp., Burbank, Calif. The engine systems contractors are General Electric Co., Cincinnati, Ohio and United Aircraft Corp., Pratt & Whitney Division, East Harford, Conn.

Hypersonic Research Engine.—The hypersonic research engine project was initiated to advance the technology of air-breathing propulsion for hypersonic flight. Last year, a test program was completed which verified the validity of flight-weight, hydrogen-cooled engine structural design and fabrication techniques in

an environment simulating Mach 8 flight. Currently, a model incorporating combustion capability is being tested at Mach numbers of 5 to 7 in the Lewis Research Center hypersonic test facility at Plum Brook, Ohio. This test program will be completed early in 1973.

NASA–USAF YF–12 Flight Research Program.—Two YF–12 aircraft are involved in the supersonic flight research program conducted at the NASA Flight Research Center, Edwards, Calif. Early in 1972, one of the aircraft completed the flight portion of the structures program and has recently completed static and thermal laboratory tests in the High Temperature Loads Calibration Laboratory.

The second aircraft was acquired from the Air Force to conduct propulsion research. The instrumentation was installed in May 1972 and flight tests were initiated immediately to obtain data on the steady state performance characteristics of the air induction system and dynamic distortion measurements. The two YF–12 aircraft completed 20 flights in 1972.

Noise Reduction Flight Procedures Experiments.—NASA, in conjunction with an airline, has demonstrated with operational equipment in a Boeing 727 aircraft that two-segment approaches are operationally feasible and can result in significant noise reduction in the airport community.

Joint DOT/NASA STOL Operating Experiments Program.—The objective of this program is to develop a data base for use by industry and government in establishing system concepts, design criteria, and operational procedures for STOL aircraft, STOL avionics, and air traffic control. This will be accomplished through analysis, simulation, and flight tests.

Flight experiments will include the use of research aircraft equipped with an avionics system with sufficient capability and flexibility to allow investigation of alternative avionics functional configurations, flight paths, operational procedures, levels of automation, and landing aids.

An advanced integrated avionics and display system has been developed. Unique flexibility has been obtained by the use of a single, general-purpose digital computer for all navigation, guidance control, and display computation. Modularity of the software insures easy change of the experiments. Flight experiments are now scheduled for April 1973.

STOL Air Traffic Control Integration Simulations have been conducted to determine the airspace, air traffic control equipment, and handling techniques to accommodate the STOL aircraft in a downtown STOLport and at STOL runways at major hub airports. The design characteristics, avionics equipment, and flight procedures required to operate the STOL aircraft in the ATC system have been determined during the simulation. STOL operations can be accommodated in high-density terminal areas.

Aircraft Wake Turbulence.—NASA is accelerating its research on wake turbulence, the swirling air masses which trail from the wing tips of aircraft in flight.

Vortices coming from large, heavy aircraft can be hazardous to other aircraft encountering these strong winds. NASA's Ames, Flight, and Langley Research Centers and Marshall Space Flight Center are engaged in wake turbulence research, using wind tunnels, water tanks, instrumented aircraft and towers, laser doppler velocity measuring systems and analytical techniques.

General Aviation Aircraft.—A program to demonstrate an application of technology developed for commercial transports to light general-aviation aircraft has entered the flight test phase. A representative high-wing general-aviation aircraft has been modified with an advanced technology wing optimized for cruise flight. Conventional approach and landing characteristics are provided through the use of high-lift slotted flaps, Krueger leading-edge services and aerodynamic spoilers both for lateral control and flight path control. Initial results of the flight program have shown the expected increase in cruise speed and a marked improvement in idle qualities and gust response characteristics.

Short Take Off and Landing Aircraft (STOL).—The C–8 augmentor-wing STOL research airplane was delivered to NASA in July 1972, following modification to incorporate a high-lift concept which previous wind-tunnel model tests have shown to have promising performance and safety characteristics. By September 1972, the aircraft had been calibrated for the research proposed, and procedures for operating the vehicle in the STOL configuration had been established. A program was then initiated to measure in flight the low-speed aerodynamic, stability, control, performance and noise characteristics of the research aircraft, to verify the results obtained in the wind-tunnel, and to determine operational characteristics and limitations. The program is a joint one with the Canadian Department of Industry, Trade, and Commerce.

Wind-tunnel model research on the STOL augmentor-wing concept continued with emphasis on means of reducing the noise to a level acceptable in civil transport operation, and in comparing high and low pressure ratio augmentors. Small-scale model tests were completed which compared the characteristics of the augmentor-wing concept with four other promising STOL high-lift concepts: an internally blown flap; a conventional flap with deflected thrust; and exter-

nally-blown flaps with the engines mounted either below or above the wing.

Vertical Take Off and Landing Aircraft (VTOL).—Research on the lift-fan VTOL transport concept included wind-tunnel tests of the cruise characteristics of small unpowered models of designs having several pod-mounted arrangements, to determine the most attractive configuration for planned powered-model tests. The large-scale model of a lift-fan transport is being modified to incorporate tip podded lift fans for full-scale wind-tunnel tests in 1973. Measurement of the jet noise of a lift-fan aircraft (the NASA XV–5B fan-in-wing research aircraft) in flight and in the Ames 40- by 80-foot wind-tunnel showed good agreement and indicated the future potential of predicting aircraft flyover noise characteristics from large-scale powered model tests in the tunnel.

Basic studies continued at the Langley and Ames Research Centers, generally in joint programs with the Army, to aid in the development of rotorcraft with improved performance and reduced vibration and noise. Initial study was made under contract of such concepts as the variable-geometry rotor, air mass injection at the tip of the rotor blade, and of tip geometric changes intended to alter the vortices, resulting in a reduction of rotor noise and vibration. Follow-on large-scale wind-tunnel and flight studies are planned.

VTOL handling-quality and pilot-display requirement research included continued use of the CH–46 variable-stability helicopter at the Langley Research Center. Early in 1972, this aircraft carried out the first fully automatic landing by a full-scale manned helicopter at a predetermined spot. Flight path angles from 6° to 15° were covered. This capability, when fully developed, will aid future VTOL operation in poor visibility weather.

Transonic Maneuverability.—The joint United Kingdom-NASA program to investigate the use of thrust vectoring for improved maneuverability was continued. Initial flight tests using a Hawker-Siddeley-Kestrel P–1127 at the NASA Langley Research Center and a Harrier prototype in the United Kingdom to document the effect of thrust vectoring on acceleration, deceleration, and turn performance were completed. A related program to check out and validate the Langley Differential Maneuvering Simulator for evaluating the effectiveness of vectoring in forward flight has also been completed. The results of these studies show promise of significant improvements in combat maneuverability.

Advanced Transport Technology.—The objective of the Advanced Transport Technology program is to expedite technology advances to assure that the next generation of U.S. air transports will be competitive on the world market and will have acceptable environmental and safety features.

During the past year, in-house and industry-funded systems studies (airframe and propulsion) were completed. These systems studies were conducted to: (1) examine the practical application, to postulate new subsonic/sonic transport designs, of projected advances in the key disciplines of aerodynamics, structures, propulsion, controls and avionics (including air traffic control interfaces); (2) identify the technology advances offering the greatest potential economic and competitive position benefits; and (3) define the actions required to bring the advanced technologies to a state of readiness for industry utilization by the late 1970's.

Studies indicate that the application of supercritical aerodynamics and related configuration technology, engine noise and emission suppression techniques, composite structures, and active control systems result in a quieter, safer, more economical subsonic/sonic transport having greater productivity than the current wide-body jet transports. The combined advanced technologies of supercritical aerodynamics, active control systems, and composite materials when incorporated in a three-engine, 195-passenger, 3,000-nautical-mile aircraft with a reduced noise level of 10 EPNDdB below FAR 36, result in a 50 percent increase in return on investment compared with equivalent current-technology transports with noise similarly suppressed. This increase, if realized, would represent a return on capital investment equal to the total average annual profits of the U.S. trunks over the past several years.

As a result of the systems studies, research and development activities required to bring each promising technology area to an acceptable state of readiness have been identified, and these technology needs have been factored into on-going NASA programs.

Flight tests were continued to examine two applications of the supercritical wing—a thick wing to permit structural weight savings, and a wing designed for high-speed cruise. A joint program with the Navy, incorporating a thick wing on a T–2C trainer to investigate the performance of the wing at moderate subsonic speeds, was completed. Performance, pressure distributions, buffet, and shock-boundary layer characteristics were investigated. The preliminary results reported last year have been substantiated by later flights: the drag of the T–2C with thick supercritical wings at the design Mach number is identical to that of the T–2C with the conventional thin wing; the lift coefficients for the buffet onset is greater for the supercritical wing for all Mach numbers up to the maximum Mach number tested; and the boundary layer velocity distributions in the region of the shock showed similarity to wind-tunnel measurements. This validates the new wing design concept as providing better structural

efficiency and maneuvering performance than the old concept.

The first phase of the high-speed supercritical wing flight tests on a TF–8A airplane was also completed. Performance, pressure distributions, stability and control, buffet, and flutter were investigated, and wake surveys were made. The drag and handling qualities reported last year have been substantiated by later flights and were as predicted from wind-tunnel tests. Beyond the predicted buffet onset, buffet was intense but not severe, and no flutter was experienced.

Upon completion of the first phase tests, the airplane was modified to contain side fairings designed to further minimize drag. Wind-tunnel investigations have indicated that improvement of the overall area distribution for the existing test vehicle through the addition of fuselage fairings will allow the supercritical wing to achieve near optimum performance.

Community Response to Aircraft Noise.—The Stanford Research Institute, under NASA Langley contract, studied in the laboratory the electro-encephalographic and behavioral responses of eight women subjects during sleep. The aircraft noise stimulus intensities were 101, 113, and 119 PNdB for subsonic jet fly-over and .67, 2.50 and 5.0 psf. for for the simulated sonic booms.

The data analysis showed that women were awakened by approximately 42 percent of the fly-over noise and by approximately 15 percent of the simulated sonic booms. When this data was compared to that of earlier studies using men as subjects it was found that women were awakened more frequently by the subsonic jet noise than were men, while men were awakened more frequently by the simulated sonic boom. Additional work on sleep disturbance is underway; once enough data is collected to clearly establish trends of sleep disturbance, it will be submitted to other interested agencies, such as EPA, DOT, and HUD for possible inclusion in models describing the community response to aircraft noise.

A unique facility has been completed under a NASA Langley grant with Columbia University. The facility is located off-campus northeast of the John F. Kennedy International Airport. It is designed to analyze community response to aircraft noise, under laboratory conditions, while simulating take-off, landing and sideline noise. The laboratory is so designed that it appears to be a modern living room. Subjects view television and the background noises of the room are precisely controlled. Simulated aircraft sounds are controlled for intensity, frequency, duration and direction. The laboratory is currently being used to evaluate the acceptability of the quieter engines demonstrated by the FAA JT8D nacelle.

Head-Up Display for Air Transports.—A head-up display (HUD) designed to improve approach and landing precision under visual flight rule (VFR) conditions has been certificated by the FAA for use on Pan American World Airways' Boeing 747 jet transports. NASA Ames Research Center and Pan American, coordinating with the FAA, have also conducted studies both in a simulator and in flight which indicate that the HUD may be useful in flying steep approaches for noise abatement.

Studies at Ames are being continued to optimize the information content and symbology in the HUD and to evaluate the tradeoffs between a HUD and a ground VASI (Visual Approach Slope Indicator).

Aircrew Thermal Protection.—The pilots of helicopters operating in hot, humid areas such as the southeastern United States and southeast Asia are sometimes subjected to heat loads so severe that their bodies cannot maintain normal temperature. Due to power and weight limitations total cockpit cooling is impracticable. In laboratory and field tests, conducted by the Ames Research Center, a new liquid-cooled helmet concept has been proven an effective way to improve subjective comfort and physiological heat balance without extensive suit cooling or air conditioning. The liquid-cooling fabric is integrated into a standard Army helicopter helmet without changing its fit or structure. The helmet is attached to a cooling unit by a quick-disconnect, zero-leak, connector. The connector is a special walk-away design which may be separated instantly by a pull by the helmet. The cooling unit weighs only 5 Kg (11 pounds), draws 16 amps of 28VDC current, and has no moving parts except a circulating pump. The liquid-cooling liner with its tubing and attachments adds about one-fourth Kg (9 ounces) to the weight of the helmet.

Military Support Programs.—In a continuing effort to more effectively make NASA's capabilities available for support of the military, a NASA aeronautical engineer has been co-located in the USAF Prototype Program Office at Wright-Patterson AFB, Dayton, Ohio.

Rotor Systems Research Aircraft.—The joint NASA/Army program established in November 1971 for the procurement and flight test of two Rotor Systems Research Aircraft was continued through 1972. The Rotor Systems Research Aircraft will be used to flight test the most promising of new advanced rotor concepts. First flight is expected to take place in early 1976. Costs and management are shared equally by NASA and the Army.

Tilt Rotor Research Aircraft.—The joint NASA/Army program established in November 1971 for the procurement and flight test of two Tilt Rotor Research Aircraft was continued through 1972. Two competitive preliminary design contracts were awarded in Oc-

tober. Evaluation of these designs will result in the selection of a single contractor to complete the detail design, fabricate, and flight test the Tilt Rotor Research Aircraft. First flight is expected to take place in late 1975. Costs and management are shared equally by NASA and the Army.

Transonic Aircraft Technology Program (TACT).—The joint NASA/USAF program for the procurement and flight test of a superficial wing on an F–111 aircraft was continued through 1972.

An F–111 aircraft was assigned to the program in February 1972. Baseline flights with the unmodified F–111 were completed in October 1972 and instrumentation and preparation for modifications to the aircraft to receive the supercritical wings has begun. The supercritical wings are nearing completion and first flight of the F–111 with supercritical wings is expected to take place in late summer 1973.

Space Shuttle.—Evaluation of the aerothermodynamic characteristics of candidate Space Shuttle configurations was continued. With the decision to use recoverable solid rocket engines for launch with both solid rockets and orbiter engines burning simultaneously (parallel-burn concept), an extensive wind-tunnel study has been undertaken to determine the rocket plume effect on aerothermodynamic characteristics.

Planetary Entry Technology.—During 1972, progress has been made in developing thermal protection material for use on planetary entry probes. A reflecting type heat shield has been recommended for study since it has the potential of reducing the heat shield weight and thereby permitting additional instrumentation in a probe.

Further studies of graphite, a candidate heat shield material for planetary entry, were accomplished in the past year. In order to study mass loss rates, a high-power gas dynamic laser was used as a source of radiative heating to drive graphite to its sublimation temperature. Study has shown that much higher mass loss rates are experienced in a simulated high-temperature environment than can be predicted by theory.

Lifting-Body Flight Research.—The joint NASA/Air Force Lifting-Body Flight Research Program has been underway for several years and has developed a valuable technology base for safely landing manned space-type vehicles in a horizontal mode. The three vehicles used in this program (the M2, HL–10, and X–24A) have demonstrated that the safe operation of these vehicles in supersonic and transonic flight, as well as during landing, can be accomplished by man. These flights have increased the confidence in the development and use of horizontal landing vehicles such as the reusable Space Shuttle. During 1972, the M2–F3 was the only aircraft flown in this program and completed a total of nine flights. These flights had the objectives of investigating the stability and control of this vehicle over the operational speed range and of investigating an improved rate command augmentation system combined with a previously tested reaction control system.

Filamentary Composite Materials in Structural Applications.—Filamentary composite materials composed of strong fibers of boron or carbon imbedded in a plastic or metallic matrix have been investigated for some time as a possible alternate to conventional metals for aircraft and spacecraft structures. These fibrous composite materials hold promise of significant weight savings over metallic structures. The structural weight thus saved could improve performance of military vehicles and increase passenger capacity or lower cost operation of civilian airliners. These materials, however, do not behave under load like metals do; NASA is working to gain fuller understanding of their behavior.

During the past year NASA has conducted programs to advance basic understanding of composites and is proceeding to design and build components that will be installed on aircraft to demonstrate two types of application. One concept is called "selective reinforcement" of metal parts and makes use of the strength and stiffness properties of the composite by attaching it to a metal structure in areas where the composite will produce the greatest benefit. This concept has been applied to the tail cone of a CH–54B Army helicopter and is planned for the wing box of a C–130 aircraft. Another concept is the "all composite" structure. Planned applications of this concept include wing spoilers, fairings, and panels on commercial transport aircraft.

Multichannel Photoelectronic Sensor.—A miniature photoelectronic device, which exceeds the capabilities of 10 ordinary photomultiplier tubes, has been developed for the observation and analyses of remote stars. The heart of the device is an array of 10 miniature channel electron multipliers which initiate cascades of secondary electrons and result in output pulses with gains as high as a factor of 100 million. Star intensities can be investigated with orders of magnitude of greater sensitivity than is possible with photographic plates and 10 times more quickly and precisely than can be done with standard photoelectronic devices.

Optical Mass Memory Technology.—Optical memory technology is being developed for storing large quantities of data on-board space vehicles. During the past year, a demonstration optical memory system capable of storing 10^5 bits of data in an area of one square inch has been constructed and operated. Read-write

techniques using laser beams are being examined. Materials for storing data are being evaluated.

Digital Fly-By-Wire Experimental Program.—The first flight of a piloted aircraft in which the control surfaces are moved through electrical signals inputs and digital computers with no mechanical reversion capability was made by NASA at the Flight Research Center on May 25, 1972.

The flight involved a modified F–8 aircraft utilizing Apollo derived hardware in place of its original mechanical control system to demonstrate the feasibility of this space-developed technology in aeronautics. When fully developed, this can improve performance and reduce weight and cost of future generation civil air transports.

CV 990 Shuttle Autoland.—A program to evaluate power-off automatic landings such as those anticipated for the Space Shuttle has been successfully completed by NASA's Ames Research Center in 1972 using a CV 990 aircraft. The system installed in the aircraft for this program provided terminal area energy management and landing guidance, utilizing a digital computer for central management with conventional radio and aircraft navigation aids. The flight tests indicated that unpowered automatic or manual landings of a Shuttle orbiter are possible with existing ground navigation aids.

General Aviation Low Cost Control and Display Systems.—Recent advancements in NASA's continuing program to enhance the safety and utility of general aviation aircraft have allowed design of a new split-surface control system and a low-cost flight director display system, which minimize pilot workload by providing limited augmented stability for the aircraft and by combining several individual displays into one to lower the pilot's scan pattern.

VTOL Autoland System.—Continuing its research to bring downtown vertiports into practical reality, NASA's Langley Research Center demonstrated a VTOL automatic-landing system concept early in 1972 with a totally automatic landing on a CH 46 helicopter. The helicopter used a vertical velocity command system concept developed at Langley. The concept is being explored further to determine mechanizations for cost-effective commercial applications.

Approach Guidance Experiment MM 71.—A novel guidance technique, which combines onboard observations of planetary satellites against a star background through existing science television cameras with spacecraft radio tracking, has been verified during the Mariner Mars 1971 mission.

The technique reduced guidance errors to less than half of the originally predicted errors, and the improved accuracy permits up to 50 percent payload weight increases for future outer planet missions.

Detectors for Near Infrared Radiation.—Industrial researchers working on a GSFC contract developed a sensitive detector for laser radiation at 1.06 microns. Efficient detectors will permit direct detection of communications signals without the necessity of expensive and inefficient frequency doubling.

Solid Propulsion Technology.—The Astrobee F, an advanced technology, low-cost sounding rocket system finished its test program during this report period. The 3,000-lb. solid-fuel motor boosts a 400-pound payload to about 200 miles. Advanced features include: a propellant design which develops an initial high boost thrust of 40,000 lbs. for two seconds, then drops to a sustaining level of 10,000 pounds for 50 more seconds; a new low-cost propellant composition which is more resistant to temperature extremes; and a one-piece-molded plastic nozzle. The program was climaxed by a successful launch in September. Performance was unusually close to predictions—altitude was 124 miles, vs. 126 miles predicted and the ground impact was within 5 miles of the expected point, 95 miles away. Negotiations are in progress to procure more flight systems. This program has been an excellent example of predicting a need, developing a technology to meet the need, and transferring the result to a user.

The environmental impact of the exhaust products of solid propellant boosters has been of interest in past years because of the use of Scout, Delta, and Titan III C/D launch vehicles. The decision to use solid boosters on the shuttle has renewed this interest. Solid boosters of this type exhaust hydrogen chloride (HCl) gas, and aluminum oxide dust along with other gases. Although there have been no problems from firings of any operational solid boosters, a research program has been started to develop a better understanding of the composition of the exhaust, its interaction with the atmosphere and its effect on the ecology.

Laser energy has been used to operate mechanical devices without any gas-producing pyrotechnic. A ruby laser pulse through a glass window onto a thin film of aluminum on a plastic sheet causes a brief, but intense pressure pulse of considerable power. For instance, in one experiment a piston restrained by a 250N (55 lbs) shear wire was freed and driven 2.5cm (1 in). Such a pin puller or pusher is a common actuating device in spacecraft systems, and is normally driven by pyrotechnic charge which develops shocks. The laser system has no shock, is not affected by long-term storage, by radiation or heat, and can be remotely activated without connecting wires. In another application, this same system was used to simultaneously ignite a series

of widely separated pyrotechnic squibs through separate 3.7 meter (12 ft) long fiber optic cords.

Planetary Spacecraft Propulsion.—The JPL Space Storable Propulsion Module Technology program directed toward advanced planetary spacecraft propulsion, progressed into system demonstration testing. Initial system feasibility was demonstrated by modifying surplus Mariner '71 orbiter propulsion hardware for the space storable flox monomethylhydrazine propellant combination and conducting system testing under simulated space conditions in the Air Force TAPR test facility at Edwards Air Force Base, Calif.

Shuttle Auxiliary Propulsion.—The Shuttle auxiliary propulsion technology program was redirected to Earth storable and monopropellant hydrazine design concepts due to the shift of the Shuttle orbiter to external main propellant tankage. Contracts were awarded to evaluate long life, reusable engine and propellant system component designs. The oxygen-hydrogen auxiliary propulsion technology work was discontinued except for propellant conditioning system and thruster contracts that were nearing completion.

Electric Propulsion.—High specific impulse propulsion systems are of interest because of their potential for reducing cost to carry out future space missions. Current programs in electric thrusters, the only known practical rocket engines capable of achieving specific impulses in excess of 1000 seconds, are aimed at developing the technology for both primary and auxiliary propulsion.

In the area of primary propulsion for high energy interplanetary and geocentric missions, a 1500-hour functional demonstration test was completed on an integrated breadboard of an electric propulsion system operating in a closed loop, automated mode. This test has provided the initial experience in the integration, operation, and interactions between components of an electric propulsion system.

In the area of auxiliary propulsion, initial testing of a small one millipound ion engine system for flight on the Application Technology Satellite (ATS)-F as an experiment to demonstrate north-south station keeping has been successfully completed. A second ion engine experiment has undergone over 8000 hours of endurance testing without failure.

Liquid Propulsion Technology.—A major focus of the liquid rocket propulsion program is the increase of useable life of rockets. Some deep space missions will require flight durations of up to 10 years, and other missions will realize large cost savings from re-using rocket stages many times. To predict how long metal and plastic parts can function after exposure to liquid propellants, a number of new concepts have been evaluated. The goal is to trace the processes involving degradation of materials by sensitive short-time tests, eliminating the need for life tests which could last for many years. It has been shown that there are three methods sensitive enough to detect .02 parts per billion of iron, chromium and other metals. The first employs radioactive tracers and uses nuclear counting devices to measure the amount of material. The second method is based on neutron activation of the trace elements resulting from reactions with propellants, followed by detection of the resultant radioactivity. A third method recovers the trace elements in organic complexes called chelates, and finally measures the amount present. These tests offer good promise of providing accelerating aging procedures for predicting lifetime of propulsion systems.

Another aspect of long life systems is the need to inspect them after a use to determine if something has failed or is wearing out. Methods for non-destructive inspection of parts of rocket motors have been evaluated with good results. The approach involves a combination of ultrasonic scan, holographic diffraction patterns, and acoustical shock wave emission scan. It shows the state of brazed or diffusion-bonded joints, common in rocket motors, and can indicate when joints are weakening, before failure has occurred.

A basic research program has been started to discover concepts which could provide large increases in the specific impulse of rockets. The individual tasks, some at universities and some at NASA Research Centers, include investigations of atomic hydrogen, activated helium, and other new concepts. If successful, the specific impulse of chemical rockets will be increased by more than 100 per cent above current levels.

Reusable Oxygen-Hydrogen Propulsion.—Reusable vehicles offer the key to low cost space transportation in the future. The Lewis Research Center is working on the technology of high performance, reusable oxygen-hydrogen propulsion systems applicable to upper stages that could deliver significant payloads to geosynchronous orbit and beyond and then return to the Space Shuttle low Earth orbit for recovery and reuse. Studies to define the optimum high performance reusable engine for such an application were initiated. Work also started on developing design analyses and fabrication techniques that will maximize combustion chamber low-cycle thermal fatigue life, necessary for extended reusability.

Solar and Chemical Power Systems.—Advancements were made in furthering the reliability and lowering the cost of solar and chemical power systems.

A new effect in solar cell fabrication was identified, wherein an electric field at the rear of the cell can be employed to increase cell voltage and efficiency. This effect is being investigated experimentally and theoret-

ically, together with other methods of increasing cell efficiency.

Investigations were underway toward reducing solar cell cost, both for space use and potential terrestrial applications. Two promising approaches were being pursued, i.e., fabrication of single crystal silicon cells in ribbon form and development of automated cell assembly concepts such as FEP covered modules.

NASA now has the first operating cells of a new type nickel-cadmium battery which are virtually non-gassing. These cells, currently under test, offer a significant advancement in battery life and reliability.

Studies and analyses were completed and work initiated toward development and demonstration of high voltage (100–16,000 volts) dc power processing and distribution systems, as needed for future large aerospace vehicles. Experimental solid state control and protection devices were delivered.

Space Nuclear Systems Program.—The space nuclear program investigated ways to use atomic energy in the research and development of power and propulsion systems.

The power systems investigated are designed to deliver power from watts to hundreds of kilowatts. Advanced nuclear propulsion concepts promise specific impulses (I_{sp}) as high as 5,000 seconds with long system life.

Systems Design Studies (Experimental Programs).—Development of the 75,000-lbs.-thrust nuclear rocket engine was terminated. Definition effort was conducted on a small nuclear rocket engine in the 15,000–20,000 lbs. thrust range. The program also included advanced propulsion comparison studies aimed at determining which of four advanced propulsion systems (i.e., chemical, solar-electric, nuclear-electric, and nuclear rockets) would be best suited for the conduct of missions under consideration for the 1980's and beyond.

In the space nuclear program, highlights during the year included the following: the successful test series of the Los Alamos Scientific Laboratory Nuclear Furnace (NFX1) containing advanced solid-core reactor fuel elements at the Nuclear Rocket Development Station in Jackass Flats, Nevada; the launch of the Pioneer F spacecraft powered by four SNAP–19 RTG's in March 1972; and the launch of the Transit Navigational satellite into Earth orbit in September 1972. In December, Apollo 17, containing the fifth SNAP–27 powered ALSEP, was launched to the Moon.

New Tunable CO_2 Laser.—The GSFC laser team has developed a new, small size waveguide capillary CO_2 laser. The tuning range of the laser is in excess of $\pm$700 MHz, enough to compensate for the doppler frequency shift encountered in tracking and communicating between a geosynchronous satellite and a low orbit satellite. The tuning is accomplished by changing the length of the laser cavity and the device will permit coherent communication and tracking of space vehicles, hitherto impossible at CO_2 wavelengths.

Frequency Multiplication at Light Wavelengths.—Stanford University researchers working on a NASA grant have succeeded in tripling light frequencies. The technique uses a mixture of an inert gas (Xenon) and a metal (rubidium) vapor at a temperature of about 500° C. This permits direct conversion of radiated light, from infrared to ultraviolet, without multiple doubling as it was necessary before, and opens new possibilities and applications in microscopy, spectroscopy, air pollution studies, combustion engine exhaust studies and possibly in thermonuclear fusion.

Precision Tracking Technique.—GSFC has developed an improved laser tracking technique which gives measurement precision of about 10 centimeters, down from 25 centimeters of previously best measurements. The technique is based on tracking of the centroid of the laser pulse rather than the very often highly distorted, leading edge. This kind of precision will be invaluable in studying of tectonics motions of the Earth crust, earthquake faults, polar caps and other geological phenomena, and may assist in predicting earthquakes and volcanic eruptions.

Tracking and Data Acquisition

The Tracking and Data Acquisition Program continued to play a significant part in support of NASA flight missions—both manned and unmanned. During the year, the tracking networks furnished support to two manned lunar landing missions, Apollo 16 and 17. Throughout these missions, the network stations relayed realtime color television which permitted millions of Americans to visually accompany the astronauts to the Moon and back.

The networks also supported over 50 other flight projects, several of which were launched during 1972. The new launches included the first Earth Resources Technology Satellite, and Pioneer F, the first spacecraft launched to Jupiter.

In addition, progress continued on the construction of two new large antenna facilities in Australia and Spain.

Spaceflight Tracking and Data Network.—The Spaceflight Tracking and Data Network (STDN) reflects a combining of the Satellite Network and the Manned Space Flight Networks. This change brings the budget structure into alignment with NASA's longer-range plan to merge the capabilities of the two networks into a single integrated network of fewer stations to support all Earth-orbital missions.

The STDN will continue to provide support to the manned program on a priority basis from the eleven land stations, four instrumented aircraft, and one instrumentation ship which formerly comprised the Manned Space Flight Network. The past year's operational activities of these facilities were highlighted by the support rendered to the Apollo 16 and 17 missions.

On both missions, from launch until splashdown, the network served as the vital communications link between the in-flight astronauts and the ground controllers in the Mission Control Center (MCC) at Houston, Texas. The network not only transmitted data critical to the success of the missions, but also provided the means for millions of persons to share the experiences of the astronauts as they watched on their television sets.

Apollo 16 was plagued by a number of technical problems at various points in the flight, but all were successfully overcome through the teamwork of the astronauts and ground personnel, working closely together by means of the communications link.

Apollo 17, after its initial problem during countdown, went smoothly. On both missions, while the network stations were supporting the astronauts on the lunar surface, the same facilities were tracking the command ship orbiting the Moon. Also, the stations were simultaneously receiving and recording data from the Apollo lunar surface experiment packages (ALSEP) deployed by the crews of previously completed landing missions as well as those emplaced by the current ones. Adding to this workload were subsatellites placed in orbit by Apollos 15, 16, and finally, 17.

During the Apollo 16 and 17 missions the network transmitted liftoff of the lunar modules for the first times televised by a camera left at each landing site, remotely controlled from the Houston Control Center.

With the successful completion of the Apollo 16 mission, the network prepared for the launch of the next major NASA mission, the Earth Resources Technology Satellite (ERTS–1). Launched July 24 into a perfect polar orbit, ERTS–1 placed new requirements on the Tracking and Data Acquisition Program in the area of data processing.

A major new data processing facility was required to process the large quantity of video data transmitted by ERTS. The facility, located at the Goddard Space Flight Center (GSFC), became operational early this year and its performance to date in support of ERTS has been excellent. Shortly after the launch of ERTS–1, the image data processing facilities at GSFC began supporting users of the data from the Return Beam Vidicon and multi-spectral scanner sensors on the spacecraft. At present, this facility is handling some 13,000 scenes per week.

In addition to providing information to those 300 investigators who are individually under contract to NASA, copies of all information processed by the facility are sent to both NOAA and the Department of Interior's facilities at Sioux Falls, South Dakota, at the same time the primary users receive their data. The information at the Sioux Falls Facility is in the public domain, available to anyone for a nominal fee.

During the year, the network rendered support to over 50 other NASA flight projects, including the Orbiting Astronomical Observatory, OAO–3. The spacecraft, named Copernicus in honor of the famous 15th-century Polish astronomer, was successfully launched from Cape Kennedy on August 21.

The network also continued its support to projects of the Department of Defense, other Government agencies such as the National Oceanic and Atmospheric Administration, and other countries and international organizations engaged in space research.

Deep Space Network.—During the reporting period, the Deep Space Network (DSN) continued its support of NASA's planetary and interplanetary space flight missions. The standard 26-meter-diameter antenna stations located around the world and the 64-meter-diameter antenna at Goldstone, Calif., provided support for the extended mission activity of the Pioneer 6, 7, 8, and 9 spacecraft in orbit around the Sun. Selected DSN stations were also used in joint operations with the Spaceflight Tracking and Data Network in support of the Apollo 16 and 17 missions.

Adding significantly to this workload was the launch of Pioneer 10 on March 2 ,1972. One of the most difficult scientific space experiments ever undertaken by NASA, Pioneer 10 levied many new and complex requirements on the ground network. For example, when the spacecraft reaches the vicinity of Jupiter next December it will have traveled about a half-billion miles in approximately 2 years. During this entire period the network must provide continuous coverage to monitor the spacecraft's condition and its 13 experiments, about twice the number carried by early Pioneer spacecraft in solar orbit.

As Pioneer 10 continues toward Jupiter, construction work is progressing well on two large antenna facilities needed to support the encounter phase of the mission in December 1973. The new antennas, updated duplicates of the 64-meter Goldstone antenna, are being constructed in Spain, forty miles from Madrid, and in Australia at Tidbinbilla, a short distance from Canberra. Although designed, constructed, and required to meet the increasing demands of the planetary program, the antennas will also be used to support other projects, including radio science activities. The Goldstone antenna, in fact, played a prominent role in support of Apollo.

In late July 1972 the Pioneer 7 spacecraft was in

solar orbit some 312 million kilometers (194 million miles) from the Earth when its radio transmissions ceased. Flight directors for the project theorized correctly the problem which caused the spacecraft to stop transmitting data to the Earth, and by analyzing past tracking data were able to determine the spacecraft's position in space. Turn-on commands were sent to Pioneer 7 from the 64-meter Goldstone antenna and 35 minutes and 624 million round-trip communications kilometers later, the Goldstone antenna received a strong signal from the spacecraft.

Network support to the highly successful Mariner 9 project was terminated on October 27 when the spacecraft on-board gas supply, needed to operate the attitude control system, was depleted.

Since mid-July the Deep Space Network has been collecting precision tracking data to test Einstein's general theory of relativity which states that electromagnetic radiation—in this case the spacecraft radio signal—passing close to the Sun will be slowed by the Sun's gravitational field. Scientists will compare these tracking data to similar data acquired from the Mariner 6 in 1970.

International Affairs

The principal events affecting the NASA international program in 1972 were the May 24 US/USSR Agreement Concerning Cooperation in the Exploration and Use of Outer Space and the European decision to proceed with system definition studies of a Sortie Laboratory for use with the Space Shuttle.

US/USSR Cooperation.—The May 24, 1972, U.S./U.S.S.R. Agreement Concerning Cooperation in the Exploration and Use of Outer Space committed both countries to:

> Fulfill the NASA/Soviet Academy of Sciences agreement of January 1971 on *space science and applications.*
>
> Conduct a *joint experimental flight* during 1975 to test compatible rendezvous and docking systems.

In space science and applications, the principal developments have been continued exchange of lunar samples, exchange of findings from United States and Soviet missions to Mars, joint working sessions on exploration of the planets, work on a common system of lunar coordinates, exchange of detailed physiological data from the Soyuz and Apollo programs, exchange of meteorological data acquired by meridional sounding rocket networks in the eastern and western hemispheres, and progress in defining coordinated projects in remote sensing of the environment, as well as experiments designed to advance knowledge of temperature sounding from satellites and microwave observations of such parameters as sea surface roughness and temperature.

In the case of the 1975 experimental mission, Joint U.S./U.S.S.R. Working Groups met in Houston in July and agreed on three basic documents to govern future work. They further agreed on detailed technical documents defining such subjects as timelines for crew transfer activities, requirements for the docking systems, and radio and cable communications between the Apollo and the Soyuz spacecraft, and on a launch sequence that would provide maximum flexibility in launching and rendezvous opportunities. At a meeting in Moscow in October, joint working groups made substantial progress in a number of project areas, including the atmospheric pressures to be maintained in the Apollo and Soyuz spacecraft during the docked phase, the definition of launch windows and trajectory plan, and the attitude profile and control of the spacecraft during rendezvous and docking.

Under an earlier NASA/Soviet Academy agreement of October 1965, a Joint U.S./U.S.S.R. editorial board is reviewing chapters prepared for inclusion in a joint review of space biology and medicine.

Post-Apollo Participation.—Significant progress was also made in defining European participation in the post-Apollo program. Discussions with members of the European Space Conference concerning their development of a Sortie Laboratory as part of the post-Apollo program have been proceeding. The Sortie Laboratory is envisioned to be a low-cost payload carrier to increase the capability of the Space Shuttle to perform manned and man-tended research in space science and applications.

On October 9, the President announced a policy for launch assistance to other countries and international organizations. The availability of these launch services makes it possible for other nations to have access to the advantages of space.

International Satellite and Probe Launchings.—During 1972, one cooperative and five reimbursable international launchings were conducted:

> *HEOS A–2,* an ESRO-built scientific satellite was launched January 31 by NASA on a reimbursable basis on a Delta vehicle from the Western Test Range (WTR) to conduct interplanetary physics investigations.
>
> *TD–1,* an ESRO satellite (the largest and most complex scientific satellite yet built in Europe) was launched March 12 on a Delta on a reimbursable basis from WTR to conduct a variety of stellar astronomical observations.
>
> *ANIK–1,* a Canadian operational telecommunications satellite was launched November 9 on a Thor Delta on a reimbursable basis from Cape Kennedy.
>
> *Explorer 48,* a gamma-ray astronomy satellite was launched November 16 by Italy for NASA

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on a reimbursable basis from the Italian San Marco Platform off the coast of Kenya.

ESRO–4, an ESRO scientific satellite to investigate particles and fields in the ionosphere and lower magnetosphere was launched November 20 on a Scout vehicle from WTR on a reimbursable basis.

AEROS, a cooperative aeronomy satellite carrying U.S. and German scientific experiments was launched December 16 on a Scout vehicle from WTR.

An agreement was reached with Spain to fly a Spanish ionospheric beacon satellite (INTASAT) in 1974. Work also continued on several major cooperative projects, including HELIOS, the German solar probe; CTS, a Canadian experimental communications technology satellite; ANS, a Dutch ultra-violet and X-ray astronomy satellite; and UK–5, the fifth in a series of U.K./U.S. scientific satellites to conduct stellar X-ray observations.

Foreign Participation in Approved NASA Missions.—Three foreign experiments were selected for flight on NASA missions. BIOSACK II, a German experiment to study the biological effects of cosmic radiation flown on Apollo 17, carried further the investigations begun with a similar type experiment flown earlier in the year on Apollo 16. Two foreign experiments (one from Japan and one from Belgium) were selected to utilize the multipurpose electric furnace facility aboard Skylab in 1973.

Announcements of Flight Opportunity (AFO).—During 1972 NASA issued 19 announcements opportunities to participate in NASA programs through development of experimental flight hardware, membership in misison definition teams, conduct of ground-based investigations, and analysis of data. Programs included in these solicitations included materials science and space manufacturing experiment proposals for Skylab, proposals to use an airborne infrared observatory on a C–141 jet transport and selection of Science Working Teams for the proposed Mariner Jupiter/Saturn planetary mission. In response to these announcements NASA received more than 140 letters of intent and/or proposals involving foreign participation. The evaluation of these proposals is in most cases still underway.

Earth Resources.—One hundred seven foreign investigations proposed by 94 scientists in 38 countries and two international organizations were selected for post-flight analysis of data returned by the Earth Resources Technology Satellite-1. In addition some 44 investigations which will use the data returned from the Earth Resources Experiment Package aboard Skylab have been approved. The remote sensing cooperation agreements with Mexico and Brazil were also extended.

Sounding Rocket Programs.—New agreements for sounding rocket and/or meteorological rocket programs were signed with Norway, Sweden, Germany, United Kingdom, Brazil, and France/India. During the year, launchings occurred from ranges in India, Argentina, Brazil, Spain, Canada, Norway, and Sweden.

Lunar Sample Program.—Fifty foreign scientists are participating as Principal Investigators in the Apollo 16 program. Proposals for analysis of samples returned by the Apollo 17 mission were received at NASA in October and selection will be announced in early 1973. Countries and organizations currently having approved investigators are Australia, Belgium, Canada, Republic of China (Taiwan), ESRO, Finland, France, Germany, India, Italy, Japan, Norway, South Africa, Switzerland and the United Kingdom.

Tracking and Data Acquisition Cooperation.—In preparation for support of Project Skylab two new agreements were signed in 1972; an agreement between the United States and Canada providing for establishment of a temporary space tracking facility in Newfoundland, and a memorandum of understanding between NASA and the Argentine National Commission for Space Research authorizing the stationing of a NASA tracking and data acquisition ship, the USNS VANGUARD, in an Argentine port. Continuance of a satellite telemetry/telecommand station of the European Space Research Organization (ESRO) in Fairbanks, Alaska, was arranged through extension of the 1966 agreement between ESRO and the United States establishing the station.

New tracking and data acquisition assistance by NASA to other countries included support of the launching of the Japanese Radio Exploration satellite in August and accommodation at NASA's Hawaii tracking station of an ESRO transportable ground facility required to read out directly the ESRO TD–1 satellite, which suffered tape recorder failure.

Industry Affairs

Inventions and Contributions Board.—The Board, under recent revised NASA patent regulations, has been given greater latitude in recommending the granting of patent licenses and patent waivers to industry. This year the Board made recommendations on 102 petitions for patent waivers received from NASA contractors and recommended the granting of approximately $90,000 in awards for scientific and technical contributions by NASA and contractor employees.

Industrial Relations.—Coordination between the Headquarters Industrial Relations staff and Center management eliminated any adverse impact of labor-management problems on overall Agency goals and important launches.

Master Buy Plan Procedure.—After a test procedure over two years, NASA has formally adopted the Master Buy Plan Procedure. Under this procedure, each installation submits a Master Buy Plan to NASA Headquarters, prior to the beginning of a fiscal year, and lists thereon every known procurement which is expected to exceed an established dollar level for that installation. This procedure will: reduce the number of procurement actions requiring Headquarters approval; permit better visibility of those procurement actions submitted to Headquarters; permit better planning of workload and more effective use of personnel resources at both Headquarters and installation levels; shorten the review and approval cycles at Headquarters; and increase the responsibility and authority of each installation.

Small Business and Minority Business Programs.—During fiscal year 1972 small business firms received $164 million in direct NASA procurement awards, which was 7.6 per cent of NASA's total awards to all business firms. Additionally, small firms received in excess of $125 million in subcontract awards from major NASA prime contractors. During this same period, NASA more than doubled its total awards to small minority firms in placing $3.2 million in contracts under authority of Section 8(a) of the Small Business Act.

Cost Accounting Standards.—Regulations have been issued to implement initial requirements of the Cost Accounting Standards Board, an independent body established by Congress to regulate the accounting practices used by Federal contractors in connection with the pricing and administration of negotiated defense contracts. The activities of the Cost Accounting Standards Board are designed to achieve uniformity and consistency in the cost accounting practices employed by contractors.

Presently, Board requirements, as implemented by Agency regulations, deal primarily with various aspects of the requirement that would have the contractor disclose and adhere to his cost accounting practices, including compliance with applicable cost accounting standards promulgated by the Board. Agency regulations also prescribe the contractual provisions to be employed, and provide the necessary procedural guidance for the administration of the Board's requirements.

Reliability and Quality Assurance.—Efforts to improve microelectronics reliability continues with the establishment and implementation of a NASA-wide standardization program for obtaining qualified microcircuits. Coordination with the Department of Defense and other government agencies in the development of microcircuit specifications, and testing and inspection techniques, in which NASA is a leading developer, continues to improve the product as well as government relations with industry.

Progress in avoiding or minimizing parts, materials and process failures continues with the release of an Experience Handbook summarizing accumulated data on basic design and application problems from NASA Alert reporting system.

Cost effective methods for obtaining electronic parts, while maintaining or improving uniformity and reliability, continue to be implanted and evaluated for possible adoption NASA-wide.

Stabilization of Prices, Rents, Wages, and Salaries.—The Procurement Office, NASA Headquarters, has served as the focal point in NASA's implementation of the contracting aspects of Executive Order Numbers 11627 and 11640, as amended, providing for stabilization of prices, rents, wages, and salaries. Procurement personnel were directed to consider as a decisive factor whether contractors are in compliance with the stabilization program in all of their transactions. Contractors are required to certify that they are in complete compliance with Executive Order 11640, if applicable, and that insofar as the Executive Order is applicable, amounts invoiced under contracts will not exceed the lower of the contract price or the maximum levels established in accordance with the Order.

Technology Utilization Program

The Technology Utilization Office is charged with the Agency's prime responsibility for stimulating non-aerospace application of NASA technology. The program employs a variety of broadly disseminated technical publications and highly focused problem-solving teams in assisting users in the public and private sectors of the economy.

The 1972 program has been directed toward the continued expansion of the technology base and industrial response capability and increased effort to apply NASA technology to specific problems in health/medical care, air and water pollution, transportation, urban construction and fire safety.

Publications and Dissemination.—The inventory of NASA Tech Briefs—single-page announcements of specific new materials, devices or methods—increased by 720 during 1972 to a total of 5,143. Approximately 1,600,000 copies were distributed to over 100,00 firms,

research groups and individuals throughout the United States. More than 100 significant scientific and technical publications were produced.

The six NASA-sponsored Regional Dissemination Centers—located in Connecticut, Indiana, North Carolina, Pennsylvania, New Mexico, and California—continued to expand their subscriber enrollment, adding 200 industrial and public sector organizations nationally. The services available to the more than 1,800 clients were increased to include NASA patent information and patent licensing assistance.

The Computer Software and Management Information Center (COSMIC) in Athens, Georgia, increased its computer program inventory to more than 1,100. A total of 2,499 program tapes and documentation were sold to industrial, university and government customers.

Technology Applications Projects.—The Technology Utilization Program's efforts to apply NASA technology to problems in areas of public concern were greatly expanded through the initiation of 31 new applications engineering projects at eight NASA field centers.

Staff scientists and engineers at Marshall Space Flight Center, Jet Propulsion Laboratory and Langley Research Center are adapting existing NASA technology to improve prosthetic devices for the handicapped, working in conjunction with the Veterans' Administration Hospital (Miami) and Prosthetics Center (New York City), Walter Reed and Huntsville hospitals and the National Academy of Science Committee on Prosthetics Research and Development.

Other projects now underway include:

Adaptation of NASA power supply technology to rechargeable cardiac pacemakers (Goddard Space Flight Center—Johns Hopkins University).

Modification of vitreous carbon-graphite compounds for use in bio-compatible devices for implantation (Marshall Space Flight Center—Rancho Los Amigos Hospital, Los Angeles).

Application of NASA reliability, quality assurance and safety procedures to medical instrumentation in hospitals (Manned Spacecraft Center—Boeing Co.—Baylor University).

A low-cost chemical drug detector using chromatography (Ames Research Center with the Army Surgeon General and New York City).

Use of ultrasonic techniques in cataract surgery (Lewis Research Center—Baylor University).

Several Technology Utilization projects in air pollution have been closely coordinated with EPA. Examples are two projects initiated (1) to adapt a NASA hydrogen detection system to measure hydrocarbons and methane concentrations in auto exhausts, smokestack discharge, and ambient air; and (2) to use laser radar techniques to measure and track hazardous aerosols in the atmosphere in several locations in California.

Fire safety has received specific program attention through projects jointly defined with the National Bureau of Standards Office of Fire Research and Safety and with a user design committee representing seven major cities. An improved fireman's self-contained breathing apparatus is being developed by the Crew Systems Division of the Manned Spacecraft Center.

Interagency Cooperation.—A broad range of ties with other Federal agencies has been developed or strengthened during 1972. Cooperative arrangements for purposes of technology dissemination have been expanded with SBA, AEC, and the National Technical Information Service (U.S. Department of Commerce). In addition to those mentioned, joint project activities have been established with the National Eye Institute, National Academy of Engineering, HUD, DOT, Department of Interior, EPA, and U.S. Postal Service.

Equal Employment Opportunity Program.—To develop a more comprehensive Equal Employment Opportunity (EEO) program, EEO was transferred from NASA's Personnel Office and combined with the Agency's Contract Compliance Office to form an independent Equal Employment Opportunity Office, reporting to the Associate Administrator for Organization and Management. The new Office will be directly responsible to the Administrator and Deputy Administrator.

Research Grants and Contracts

NASA funded 1,574 project-oriented research grants and contracts at 219 universities with obligations of $119 million to support research related to the mission of the Agency. Considerable emphasis this year has been placed on science involving unmanned explorations, Earth observations, and aeronautics. The Agency made project research grants to 20 predominately black colleges and universities in 1972.

The Office of DOD and Interagency Affairs continued to coordinate and monitor activities involving the National Academies of Sciences and Engineering; Federal Council for Science and Technology; Interagency Committee for Marine Science and Engineering; Intergovernmental Personnel Act; U.S. Bureau of Standards studies on the impact of increased use of the international metric system of units; interagency activities associated with the Mississippi Test Facility where in 1972 the Coast Guard joined other agencies in conducting research; significant foreign activity and achievements in aerospace endeavors; and the exchange of technology between NASA and other agencies.

This office also continued to be active in coordinating NASA's Earth observations programs—remote sensing of the environment from aircraft and spacecraft—at the policy level with other agencies including the White House, Office of Science and Technology, National Aeronautics and Space Council, Department of State, Department of Defense, and others. There has also been considerable effort in effecting a technology interchange between NASA and other agencies in the areas of remote sensing equipment, procedures for processing and handling data, and in data interpretation and analysis techiques.

IV Department of Defense

Introduction

Significant progress in space communications and technology was a highlight of the Department of Defense space programs for 1972. Launched in 1971, the first two satellites of Phase II of the Defense Satellite Communications System (DSCS), became operational early in 1972, although operational problems with one of these satellites later prevented its use. A new development earth terminal was placed into service to extend the operational use of the DSCS. Development of the Navy Fleet Satellite Communications System continued and the contract for five Atlas-Centaur launch vehicles was awarded late in the year. Agreements were negotiated in 1972 with the United Kingdom (U.K.), NATO, and the Soviet Union. The U.K. and NATO agreements provide for the development and launch of additional advanced communications satellites for use in the U.K. Skynet II and NATO Phase III communications satellite systems. The agreement with the U.S.S.R. provides for the implementation of an improved Direct Communications Link (DCL) between the two governments. The Soviet Molnyia II and the Intelsat communications satellites will be used.

Important milestones were passed in the major aeronautics programs.

The first prototype B–1 bomber aircraft is in final assembly while the prototype engine has accumulated over 300 test hours toward flight certification. A recent design change in the engine nacelles of the B–1 will reduce weight and cost with a minor change in aircraft performance. Over 500 of the F/FB–111 aircraft have been delivered and the F–111 force had passed 200,000 total flying hours by September with the lowest accident rate of any modern day Air Force fighter aircraft. First flights of the A–9 and A–10, prototype aircraft in the A–X program, occurred in May. The aircraft were delivered to the Air Force for the flight evaluation that was completed in December. The Navy F–14 carrier-based tactical fighter has accumulated over 1700 flight hours and has successfully fired a variety of missiles. The Air Force F–15 advanced tactical fighter flew for the first time in July and its development program proceeds on schedule.

Development of the lightweight fighter prototype was continued to determine the feasibility and operational practicality of low cost, high performance, relatively austere fighter aircraft that incorporate new aerodynamic concepts and design ideas. Two contractors were selected to design, fabricate, and flight test two prototype lightweight fighter aircraft each. The first production aircraft of the Navy airborne early warning command and control aircraft, the E–2C, successfully completed its first flight in September, one month ahead of schedule. The maiden flight of the new Navy carrier-based, anti-submarine aircraft (S–3A) took place on January 21, 2 months ahead of schedule. The E–3A airborne warning and control system (AWACS) will provide command and control of interceptor forces and for sustained air operations. Two competing AWAC radar systems, designed to detect low-flying targets in the presence of severe ground clutter, were evaluated and one design was selected for further development. The procurement of three 747 aircraft and the start of development of the advanced electronics for the advanced airborne command post (AABNCP) were approved in October. The heavy lift helicopter (HLH) program is intended to develop an increased lift capability for rotorcraft. Development of a single austere prototype HLH, configured with advanced technology components, started in 1972. Engineering development began on the utility tactical transport aircraft system (UTTAS), a helicopter intended specifically for the tactical troop as-

sault mission. When in the inventory, this helicopter will significantly improve the Army's air mobility.

Space Activities

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

Phase I, the Initial Defense Satellite Communications System, was acquired primarily for research and development purposes with limited operational use as a secondary objective. This system continued to provide essential service during the year. These small nonsynchronous, limited capability satellites have greatly exceeded their design life and are scheduled to automatically turn off by late 1974. Of the 26 satellites in Phase I, 16 are still operational, 5 having failed during 1972.

Implementation of the Phase II system proceeded during the year. The objectives of this phase are to provide significantly increased capabilities through the development and acquisition of new earth and shipboard terminals, the development and acquisition of new modulation devices, and the modification and improvement of earth terminals from Phase I.

A Phase II contract was awarded in early 1969 for development and production of six high-power, geostationary satellites for three launches of two each, utilizing Titan IIIC space boosters. The first two Phase II satellites, launched on November 2, 1971, were positioned during 1972 to provide service to Pacific and Atlantic users. Due to operational problems encountered with the Pacific satellite, it has been necessary to use the lower quality Phase I satellites in its place until after mid-1973 when plans call for a Phase II satellite from the second launch to become available. Corrective technical action is being taken on the four satellites for the second and third launches to prevent the operational problems experienced with the first launch satellites.

Phase I Earth terminals were converted for use with the Phase II satellites and some of the 29 Earth terminals were moved to new locations to meet changed operational requirements. The Earth terminal modification program to provide increased capability and reliability was continued with a number of significant contracts awarded during the year.

Concomitantly, the Army continued development of new Earth terminals and put the engineering model of a new heavy terminal into operational use to satisfy a critical requirement. The Navy continued its program to develop shipboard terminals. In early 1973 some off-the-shelf shipboard terminals will be installed on major command ships for interim service until production terminals are available from the development program.

A comprehensive study was made to provide a basis for future DSCS planning. It examined user requirements in relation to available transmission media, identified those that were postulated for fulfillment via satellites, and translated them into recommendations for numbers of operational satellites and replenishments as well as numbers, types and locations of Earth terminals for the DSCS.

Fleet Satellite Communications System.—The Fleet Satellite Communications System (FLTSATCOM) is intended to provide improved communications for Navy ships worldwide and, in addition, to satisfy important Air Force communications requirements. Development of the system continued in 1972 and a contract for five Atlas-Centaur launch vehicles was awarded late in the year. The FLTSATCOM is an outgrowth of TACSATCOM, an experimental program to investigate the use of spaceborne communications receivers to satisfy selected communications needs of our mobile forces. The success achieved in the TACSATCOM program has permitted the use of these assets in an interim operational status. The number of ships, shore stations, and aircraft using TAC SATCOM terminals increased steadily during the year, and there was heavy use of the TACSAT I satellite by units of the Navy's 7th Fleet.

International Cooperation.—The United States has developed, procured, and launched several advanced communications satellites for the United Kingdom (U.K.) and NATO. The U.K.'s Skynet DSCS initially achieved full operational status in 1971. By early 1972, it had failed, making the U.K. dependent on the NATO satellite. The U.S. and the U.K. reached an agreement for a new follow-on Skynet II program. Skynet II will consist of two satellites, built by the U.K., to be launched by the U.S. in middle to late 1973. A new agreement is being prepared for a joint U.S.-U.K. military communications satellite system employing either U.S. Phase II DSCS satellites or advanced Skynet III satellites.

The NATO Phase II communications satellite system became operational in 1972 with the orbit of two satellites similar to the U.K. Skynet I. The equipment for the 12 Earth terminals is either operational or on site and in the final stage of acceptance testing. One of the NATO satellites has failed and the U.K. and NATO are now sharing the remaining NATO satellite. A new agreement between the U.S. and NATO has been approved to cover the development, procurement, and launch of two satellites in a NATO Phase III communications satellite program. A new agreement with NATO and the U.K. is being developed to cover use of NATO and U.K. earth terminals by the

U.S. in return for NATO and U.K. use of U.S. military communications satellites to provide more effective use of the assets of both systems and as a contingency against the failure of the remaining satellites.

The United States has continued to participate in NATO's research and development program in tactical satellite communications. The effort is part of a cooperative test program using the synchronous Lincoln Experimental Satellite 6 and a network of small tactical terminals operated by 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.

Policy discussions were successfully concluded between U.S. and U.S.S.R. government representatives concerning the implementation of an improved Direct Communications Link (DCL) between the two governments. Both the Soviet Molniya II and the Intelsat systems will be used. Discussions regarding technical and operating procedures are in progress. Contracts for the construction and operation of the U.S. earth terminal for use via the Soviet Molniya system and for the telegraph coders to meet both U.S. and U.S.S.R requirements were awarded.

Titan III.—The Titan III family of launch vehicles continues to serve for the bulk of DOD satellite launches. There has been a total of 64 Titan launches, and an additional 35 launch vehicles are on order to meet firm mission requirements. The first launch of a Titan III modified to launch a NASA Centaur upper stage (the "E" model) is scheduled for January 1974.

Navigation Satellite Activity.—The DOD continues to emphasize space technology as the means to provide precise, worldwide, three-dimensional position and velocity data in a common reference grid to passive users.

The Defense Navigation Satellite System (DNSS) program represents a major, tri-service effort to develop an advanced navigation capability for the 1980's. DNSS ground-based simulator testing was started at White Sands Missile Range in 1972 to confirm the attainable accuracies of such a system. Under Air Force lead, a major space experiment is planned for the late seventies. The Air Force will concentrate upon space segment design and cost evaluation and all three services will investigate user equipment design, cost, and operational value. Civil agency participation in the DNSS space experiment is being encouraged.

In addition to this long-range effort, the Navy is investigating potential improvements to the Navy Navigation Satellite System (Transit) as an interim, near-term, DOD-wide, space-based navaid. Possible improvements to the Transit system include: (a) more satellites in orbit to improve fix-taking opportunities; (b) a new type of signal in addition to the existing doppler signal to reduce the time required to get a fix; and, (c) use of a special sensor, called Discos. The Discos will detect orbit disturbances caused by solar radiation pressure and atmospheric drag and compensation of these disturbances can improve system accuracy. The first experimental Discos sensor was launched for test in October 1972.

Space Ground Support

DOD National Range and Tracking Facilities.—Department of Defense space activities are principally supported by the Air Force's Eastern Test Range, Western Test Range, and Satellite Control Facility, and by the Army's White Sands Missile Range. These facilities are available to other government agencies that may require this kind of support.

Eastern Test Range (ETR).—The Air Force's ETR provides launch range data acquisition support and range safety for DOD space and missile operations originating from the Cape Kennedy area. Support is extended to other users on a reimbursable basis.

The ETR is now in the early phases of modernization of the range instrumentation complex to achieve simpler operation, improve efficiency, and reduce costs.

White Sands Missile Range (WSMR).—This range provides ground support to DOD and NASA Aeronautics and Space programs, including radar, photo-optical, real-time trajectory, and telemetry services for a wide variety of programs.

The programs supported include the NASA–WSMR Test Facility, the newly operational Tethered Balloon Facility, the Skylab Calibration Rocket Program, the Rendezvous Radar Program, and the Viking Lander Deceleration System in a simulated Martian environment. A new 5-year agreement for support of NASA activities at WSMR was signed in June.

Satellite Control Facility.—During 1972, the increased complexity of satellite systems was reflected in a heavier workload. Studies, analysis and basic system design work were undertaken to increase the data handling and communications capability, the reliability, and the responsiveness of the overall satellite control system. The second of three new 46-foot antennas was completed at the Hawaiian Tracking Station, and facilities work for the third antenna began at the Vandenberg Tracking Station.

Western Test Range (WTR).—Under the operational control of the Air Force's Space and Missile Test Center (SAMTEC), the WTR provides data acquisition and safety support for all space vehicles and bal-

listic missiles launched from Vandenberg Air Force Base, Calif.

The range's instrumented ship fleet was further reduced by the deactivation of the general support ship, the USNS *Watertown,* in early 1972, leaving only the USNS *Huntsville* operational. Work is in progress to refine range instrumentation and to consolidate facilities and operational support functions. The range terminal site in the Phoenix Islands is essentially complete. The new midcourse radar at Kaena Pt., Oahu, Hawaii, will be operational in January 1973.

Aeronautics Activities

B–1 Bomber Program.—The B–1 bomber program is on schedule. The first of the three prototype aircraft is in final assembly and the manufacture and testing of the static and fatigue components has begun. The prototype engine for the B–1 has accumulated over 300 actual test hours completed towards flight certification and the initial four flight-test engines are being manufactured.

As a result of a design change to the engine nacelles, total aircraft weight and manufacturing costs will be reduced. The design change improved the aircraft's performance in its primary mission in the subsonic regime with a slight degradation of performance in the supersonic regime and is in keeping with the established philosophy of continuing to assess cost and performance trades throughout the development program. The planned flight test program has been extended to 15 months prior to a production commitment in order to accommodate increased testing of the offensive avionics subsystem.

F/FB–111 Aircraft.—Development and production of the 550 currently authorized F/FB–111 aircraft are nearing completion with over 500 aircraft having been delivered. All of the F–111As and Es and all of the FB–111s have been delivered and are combat ready with the operational commands. The first squadron of F–111Ds achieved its initial operational capability in September 1972 and all of the D series will be delivered early in 1973. The F–111F wing became combat ready in November 1972. By September 1972, the F–111 force had amassed over 200,000 total flying hours with a lower accident rate than any other modern day Air Force fighter aircraft.

A–7D Attack Airplane.—Production deliveries of the A–7D aircraft to the third wing at England AFB are continuing. The first operational wing deployed from Myrtle Beach AFB to the Pacific area in October 1972. The second wing achieved combat ready status at Davis Monthan AFB, where crews are receiving training in the A–7D. The highlight of this airplane's operational experience to date is the outstanding accuracy of weapons delivery.

A–X Program.—The Air Force completed the competitive prototype development of the A–X, a specialized aircraft to provide close air support for ground combatants. The A–X design requirements stress responsiveness, maneuverability, survivability, and simplicity combined with low cost.

The development program is being conducted in accordance with the fly-before-buy and design-to-cost concepts to insure that the systems performance goals are demonstrated and that the cost goals are shown to be achievable before large sums of development and production money are invested. First flights of the A–9 and A–10 prototype aircraft took place in May 1972 at the Air Force Flight Test Center, Edwards AFB, Calif. Both contractor flight test programs progressed rapidly and satisfactorily and were completed in October and the prototype aircraft were delivered to the Air Force for the flight evaluation that was completed in December 1972.

F–14 Carrier-Based Tactical Fighter.—By November, the F–14, a new advanced carrier-based tactical fighter, had accumulated 860 flights and 1,700 flight hours among the 19 aircraft that are flying. In tests, the F–14 has successfully fired Phoenix, Sparrow, and Sidewinder missiles and the installed 20mm guns. The F–14A, with its capability to simultaneously engage multiple targets, will fill the Fleet Air Defense role and carry out other fighter missions. The first two squadrons have been commissioned and are training in preparation for delivery of the aircraft.

F–15 Advanced Tactical Fighter.—The F–15 is being developed as an air superiority fighter to counter the threat predicted for the late 1970's and early 1980's.

The program continues to proceed on schedule and within planned costs. The first F–15 flight was on July 27, 1972, at the Air Force Fight Test Center, Edwards AFB, Calif.; and the flight test program has progressed very well. Highlights include the achievement of the Initial Aircraft Performance Milestone 6 weeks ahead of schedule.

Lightweight Fighter Prototype Program.—The Lightweight Fighter Prototype program is an Air Force advanced development in which the advantages of emerging technology are explored with a view to reducing the risks and uncertainties of full scale developments. This prototype program will determine the feasibility and operational practicality of low cost, high performance, relatively austere fighter aircraft that incorporate new aerodynamic concepts and design ideas. In April 1972, two contractors were selected to design, fabricate, and flight test two prototype fighter aircraft

each. Design and performance goals were selected to emphasize the very high maneuverability required for close-in visual air combat. Configuration designs are nearly complete and fabrication of components has begun.

S–3 Carrier Based Anti-Submarine Warfare Aircraft.—In 1972, the Navy executed a contract for the first 13 production S–3A aircraft. The S–3A, with its crew of four is equipped with the latest ASW sensors which are integrated for optimum effectiveness by a digital computer. The first aircraft made its maiden flight on January 21, 1972, 2 months ahead of schedule. At present there are four S–3A aircraft flying with an accumulated flight time of over 500 hours. So far all project milestones have been met and no major problems have been encountered.

E–2C Airborne Early Warning Command and Control Aircraft.—The initial production model of the E–2C, the Navy's latest aircraft of this type, successfully completed its first flight on September 23, 1972, one full month ahead of schedule. This latest version of the E–2 family incorporates an entirely new avionics system that uses the most recent technological advances. The major objectives of the E–2C program are to improve overall reliability; to increase operational utility and flexibility; and to improve radar performance. Two preproduction prototypes that have been flying since January 1971 have accumulated almost 1,500 flight hours, and actual performance indicates that all specifications have been met or exceeded.

E–3A Airborne Warning and Control Systems (AWACS).—Two competing radars, designed to detect low-flying targets in the presence of severe ground clutter, were evaluated in 1972. One design was selected for further development. This radar, when mated with the other mission avionics, has demonstrated that it is capable of extended low-, medium-, and high-altitude surveillance over both land and water. Design of the total warning and control system will continue in 1973.

Advanced Airborne Command Post (AABNCP).—The AABNCP is planned to provide a significantly improved, survivable command and control facility to support the National Command Authorities (NCA) in the event of a general war. These aircraft will accommodate larger battle staffs and the necessary data processing and communications equipment to enable the NCA to control our general war forces effectively and flexibly throughout international crisis situations.

The procurement of three 747 aircraft and the start of the development of the advanced electronic configuration of the AABNCP were approved in October 1972. Two of the 747s will be configured as interim National Emergency Airborne Command Posts (NEACP) by transferring the equipment from the EC–135s that they will replace. The third 747 will be used first as a test bed to support development of the advanced configuration and then will become the first operational Advanced NEACP.

Heavy Lift Helicopter (HLH).—The goal of the HLH program is to develop a tandem rotor, crane-type helicopter designed to carry bulky cargo weighing 22.5 tons, more than twice that of any current free world helicopter. With fuel and range tradeoffs, it will carry all tactical and logistical cargo of the 1980's time frame except tanks. Development of advanced technology components for the HLH, such as the flight control system, rotor drive system, and cargo handling system, has been underway since 1971. Last year a program was approved to test these advanced technology components in a single austere prototype in order to verify that HLH technology is in hand and that mission requirements can be met.

Utility Tactical Transport Aircraft System (UTTAS).—The UTTAS will be the first true infantry squad assault helicopter. This development will result in significant improvements in maintainability, reliability, survivability, and performance, enabling reductions in personnel and operating costs from those required for an equal capability UH–1 fleet. UTTAS will replace the UH–1 in assault helicopter, air cavalry, and aeromedical evacuation units. Contracts for engine and airframe development were awarded during 1972.

Advanced Attack Helicopter.—In November 1972 the Army solicited bids on a development program for an Advanced Attack Helicopter (AAH). This new start program will respond to an updated requirement for a helicopter which is more agile, somewhat smaller, possesses good low speed and hover performance, is more survivable and less costly than Cheyenne (program terminated in August 1972). This competitive posture, technological and producibility advances in the helicopter industry, and prudent cost/performance goals will assure the most cost effective AAH for support of ground combat missions.

Supporting Research and Development

Space Vehicle Subsystems Technology Program.—The aim of this program is to develop and demonstrate satellite subsystems technology that will be essential to DOD space missions in the 1975–1985 time period. To meet advanced mission requirements, efforts are being made to reduce the volume and weight of satellite subsystems and to improve their performance and survivability, and lengthen their lifetime.

A 1.5 kilowatt, flexible, roll-up type, solar array has been tested in earth orbit since 1971. This high performance array demonstrates that the technology is available to reduce weight and volume of existing solar cell array subsystems by one-half.

Space Test Program.—On October 2, the Space Test Program successfully launched a satellite into earth orbit carrying the Defense Advanced Research Project Agency (DARPA) gamma ray spectrometer and four other experimental payloads. A refurbished Atlas F with a Burner II upper stage was the launch vehicle under this program. Advanced development payloads are tested in space orbit to evaluate their potential contribution to new or improved space systems.

DARPA–501 Space Experiment.—This experiment was designed to investigate the earth's radiation characteristics by means of a high-resolution gamma ray spectrometer on a satellite platform. These spectrometers, plus five charged particle detectors, were configured to measure the radiation background in space as seen in polar orbit at an altitude of 400 nautical miles. One spectrometer operated successfully for 10 days and obtained an excellent mapping of the radiation background over the entire earth.

Remote Sensing Oceanography.—There is a continuing need for oceanographic information throughout the world, both to increase the effectiveness of military operations and to provide information for safe navigation. Remote sensing from aircraft and satellite platforms offers one means of obtaining oceanographic data over ocean areas in a timely and economical manner.

The Navy is developing airborne and satellite oceanographic remote sensing techniques to aid in the collection of environmental data. Data from NASA, NOAA, and DOD satellite programs has been used to investigate the feasibility of interpreting and analyzing ocean and sea-ice features on a global scale. Studies of sea-ice features in polar regions for the purpose of long- and short-term ice forecasting were accompanied by pilot experiments in interpreting satellite infrared imagery in selected ocean areas for sea surface thermal pattern recognition as an aid to forecasting water mass identification.

Advanced Control Rocket Technology.—The purpose of the Army program on advanced monopropellant control rockets is to develop and demonstrate the critical technology associated with exoatmospheric positioning of missiles and space vehicles. In 1972, this program emphasized experiments aimed at determining the ability of hydrazine monopropellant rockets to produce high thrust from a minimum rocket volume. A twofold increase in thrust/volume ratio was demonstrated in heavy weight hardware. In another series of experiments the performance of monopropellant blends designed to extend the operational temperature range of control rockets was characterized. This work is closely coordinated with NASA.

Advanced Aircraft Propulsion.—The Air Force advanced development program in aircraft propulsion has the goal of demonstrating advanced propulsion system design concepts to insure their timely, low-risk application into future aircraft systems. This work was formerly done as the Aircraft Propulsion Subsystem Integration (APSI) and Advanced Turbine Engine Gas Generator (ATEGG) programs, which are now separate projects under this program. The consolidated program now covers the advanced development of the entire propulsion system. In addition, this program is developing advanced technology directed toward reducing the cost of developing, acquiring, and operating future propulsion systems.

Under the ATEGG project, the core of the engine is developed and tested in a realistic environment to demonstrate new technology and advanced design concepts. A secondary objective of this program is to help maintain a solid competitive industrial base from which to procure advanced engines for future weapon systems.

The APSI project encompasses the total propulsion system from the inlet through the nozzle. This includes developing the turbine-engine components for both isolated testing and testing with the ATEGG cores in a full demonstration of advanced engine technology.

Current work on turbine-engine components includes the application of high-temperature and composite materials in advanced engine design. Advanced fan and control components also are being developed to be compatible with ATEGG hardware.

These programs served as a base line for evaluation of the F–15 and B–1 propulsion systems and, more recently, the propulsion systems for the Lightweight Fighter Prototype program.

Navy effort in advanced aircraft propulsion is integrated with the ATEGG program and covers the development of components for high-temperature engines, advanced lift engines, composite engines for the high-speed flight regime, and advanced augmentation systems.

A major goal is to increase gas turbine engine operating temperatures to gain maximum cycle efficiency. Such engines could produce optimum thrust for takeoff and high-speed flight and benefit from optimum fuel economy for cruise. In addition to their inherent operational flexibility, these high-temperature engines will be of minimum size and weight for a given output.

Development of the technology required for lightweight, compact engines for vertical/short take-off

and landing (V/STOL) aircraft is another major effort. Inlet ducting and exhaust nozzles based on advanced system analysis will be developed to achieve the technology for ultralight, reliable, high-performance lift and lift-cruise engines.

The Army's aeronautical propulsion research and technology program differs from that of the Air Force and the Navy in that it is aimed specifically at the lower power spectrum. The results of the Army's component-technology work, in the form of small centrifugal compressors, combustors, axial turbines, accessories and integral inlet separators, resulted in significant reductions in engine weight, size, and specific fuel consumption. This technology is being applied to the T–700 engine for the UTTAS.

In the Small Turbine Advanced Gas Generator (STAGG) program, contracts were awarded in November 1971, with four contractors participating in a 36-month core engine demonstration program. The configuration design phase was completed in October 1972. This advanced development will include the integration of essential gas generator components for engine environment tests. STAGG technology will support future Army aircraft and auxiliary powerplants in the range of 200 to 1000 shp.

Composite Materials for Military Aircraft. —A major portion of the Army's materials research program addresses problems involved in improving the performance of rotary-wing aircraft. The use of manufacturing techniques for computerizing the production of fiber-reinforced plastic composite rotor blades will result in advanced-geometry airfoils that have uniform properties as well as optimized aeroelastic characteristics.

Materials processes, specifications and properties have been established so that fiberglass-reinforced composite rotor blades can be produced with confidence. Advantages include reduced weight, reduced corrosion problems, reduced operation and maintenance cost, longer structural life (3,000+hours), and decreased vulnerability to ballistic damage. For example, both of the UTTAS designs will use fiberglass skin on the rotor blades and much of the secondary structures and fairing are either fiberglass or an organic fiber composite that result in significant weight savings. One of the UTTAS systems is using a fiberglass-elastic pitch beam rotor that not only saves weight but eliminates mechancial moving parts, thus reducing maintenance requirements and total system costs.

The Navy will also acquire flight experience through service operational demonstrations of composite materials. A horizontal stabilizer and a flap for the A–4 aircraft were built out of graphite epoxy and successfully tested in the laboratory. Their actual flight evaluation will include weathering properties, lightning protection, tolerance to battle damage and the repairability in the fleet environment.

Advancing Blade Concept (ABC) Demonstrator Vehicle.—The ABC rotor system consists of two coaxial, contrarotating, rigid rotors that utilize the aerodynamic lift on the advancing side of each rotor disc to gain full lift capability without incurring penalties imposed by the retreating blade. A significant improvement in lift capability for a given size rotor system is expected. An additional advantage of this concept is the elimination of a conventional tail rotor and related components. The Army started a program in December 1971, to develop and flight demonstrate the ABC concept. Flight tests will investigate this rotor's high-speed and low vulnerability characteristics and its flight maneuverability without tail rotor. Preliminary and detail designs of the demonstrator vehicle were completed in April and November 1972, respectively. The ABC vehicle's first hover flight is scheduled for August 1973.

V/STOL Aircraft Operations.—The Navy has negotiated a Memorandum of Understanding with representatives of the Governments of Canada and the United Kingdom to investigate the potential of V/STOL aircraft to achieve an operational instrument flight capability. The memorandum covers the installation and flight evaluation of a British electronic display system in a Canadian CL–84 V/STOL aircraft. The program will include approximately 100 hours of flight test at the Naval Air Test Center, Patuxent River, Md. over a 12-month period, and is intended to provide essential data on display and control requirements for operating V/STOL aircraft in confined areas. Through this cooperative effort, the cost of the program to each participating government is minimized.

Survivable Flight Control System (SFCS).—The first flight-test activity in the SFCS program was successfully completed on September 8, 1972. For the first time in the U.S., an all-electrical flight control system designed to function independently of a mechanical control system was flight tested in a high performance tactical fighter. This kind of system, commonly referred to as fly-by-wire, offers the advantages of more precise control of the aircraft's flight path, lower system cost, and less weight and volume.

In 25 flights on the F–4 test aircraft all the SFCS performance objectives have been met. The performance and reliability demonstrated by the SFCS through September were good enough to justify removing the backup mechanical flight control system from the aircraft. The first flight of the aircraft without the mechanical system took place in November 1972.

Remotely Piloted Vehicles (RPV).—The objective of this program is to develop small, lightweight, low-cost, remotely piloted vehicles, with appropriate day/night sensor combinations, to perform weapons and combat support functions for battlefield commanders. Selected vehicle and sensor combinations, including associated propulsion, command and control, and data transmission systems are being investigated. Specific tasks in the continuing program are investigations of fixed and rotary wing concepts, electric and gas-driven propulsion systems, new concepts in autopilots and stabilization systems, methods of tracking and accurately locating the RPVs in space, methods of reducing observables (i.e., visual, aural, radar, and infrared), secure data link techniques, and the development of tactical mission scenarios.

Relationship With Other Government Agencies

The Department of Defense continued its close coordination and cooperation with other government agencies by means of interagency committees, joint use of facilities, and joint test programs.

Aeronautics and Astronautics Coordinating Board (AACB).—The AACB, the principal formal coordinating body between the DOD and NASA, met three times during the year. Working principally through its five panels, the Board continued planning for large aeronautical facilities, examined ways to better correlate NASA and DOD aeronautical planning; approved the selection of Atlas/Centaur for launch of Navy Fleet Satellite Communication payloads; examined planned DOD and NASA facilities before inclusion in the President's Budget; and devoted special effort to joint DOD and NASA studies and plans to reduce the cost of future space systems.

Space Shuttle.—The Space Shuttle being developed by NASA offers the potential of improving the means of conducting space operations because of its flexibility, capability, and lower operational costs. During the past year, the DOD has continued to work closely with NASA to define our requirements and to conduct analyses and to make plans that will help assure that the Shuttle is developed to meet the needs of both NASA and the DOD.

Studies so far indicate that the Shuttle's capability to recover payloads and refurbish or repair them for reuse could represent a considerable economy in space activities. They also indicate that the system could add flexibility and capability in the performance of the DOD mission. As NASA's design progresses and the operational concepts, capabilities and costs are better defined, the utility of the system to the DOD will be more fully explored.

Rotor Systems Research Aircraft (RSRA).—In 1971, the Army and NASA entered into a formal agreement to develop and test the RSRA for subsequent use in aeronautical research and development. The versatile RSRA design will permit timely and economical flight research on new rotor concepts, rotorcraft components and subsystems, and composite material structures in a common test bed. Predesign studies of the research aircraft were completed in August 1972 and feasibility testing of critical components for the RSRA concept is continuing.

Aerospace Feeding Systems.—The Army's Natick Laboratories participated in the Skylab Food Evaluation Team's final review of Skylab food specifications. Flight-qualification tests were completed on flexibly packaged, thermally stabilized meats that were furnished to NASA for use in the Apollo 16 mission. Samples of a nutritionally balanced, flexibly packaged fruitcake and two lots of irradiated ham have been produced, subjected to flight qualification tests, and furnished to NASA for screening for the Apollo 17 flight.

Medical Projects.—The Naval Aerospace Medical Research Laboratory at Pensacola, Fla., conducts a wide range of studies in aeronautics and space-related medicine. Vestibular studies deal with the calibration of susceptibility to motion sickness, adaptation and training at normal gravity to overcome motion sickness in the weightless condition, and the development of hardware to test vestibular function in flight. Study of methods for evaluating the vector cardiogram under weightless conditions for Skylab and the effects of enhancing tolerance to gravitational forces by the use of lower body negative pressure are continuing.

Flight Test Support.—The Air Force Flight Test Center, Edwards AFB, Calif., supported NASA in the test of two supercritical-wing projects—the YF–12 and the X–24 lifting body. Planning has begun to test the NASA Viking (Mars Landing Vehicle), scale flying models for the F–15, and the X–24B advanced lifting body.

V Atomic Energy Commission

Introduction

Efforts continued during 1972 on the development of space nuclear power systems for future space applications. Highlight events include the following:

Space Nuclear Power.—Last two SNAP–27 radioisotope thermoelectric generators (RTG) placed in operation on the Moon by Apollo 16 and 17 astronauts,

Four modified SNAP–19 RTG's launched on the Pioneer 10 spacecraft in March 1972. Transit RTG, developed for the Navy's Transit Improvement Program, successfully launched in September 1972, into orbit and providing stable power for navigation satellite. Multi Hundred Watt (MHW) Generator successfully demonstrated capability to withstand launch vibration levels associated with the Lincoln Experimental Satellite (LES) launch in 1974. AEC accepted commitment to provide MHW RTG for Mariner Jupiter/Saturn outerplanet missions scheduled for 1977. Engineering design selected for the AEC/NASA long-lived 5 KWe uranium-zirconium hydride reactor/thermoelectric power system.

Space Nuclear Propulsion.—Completed first operation of Nuclear Furnace at 4400° R for 108 minutes. Successful first operation of high temperature, hydrogen gas, fission product cleaning system. Developed high fidelity manipulators approaching dexterity of man. Completed early preliminary design of small nuclear rocket engine. Completed mid-term report on advanced propulsion comparison study.

Space Electric Power

The objective of the joint AEC–NASA space electric power program is to provide operational systems and advanced technology development which will satisfy the needs for nuclear electric power in space applications. During 1972, the major emphasis was on operational isotope power systems for near-term NASA and DOD space applications. Some effort was also continued on isotope and reactor power system technology areas which are candidates for future space missions.

Space Radioisotope Power Systems

SNAP–27/ALSEP.—The Apollo 16 and 17 astronauts placed two additional SNAP–27 powered Apollo Lunar Surface Experiment Package (ALSEP) stations on the lunar surface in April and December of this year. They joined the three previous SNAP–27 RTG's left on their respective missions, to complete the nuclear-powered ALSEP network which is expected to transmit data from the lunar surface for many years to come. All five SNAP–27 RTG's continue to operate extremely well, including the first unit deployed during the Apollo 12 mission in November, 1969, which has operated over three times its design lifetime requirement. The long lifetime capability of the RTG's is allowing the network of experiment packages to provide compounded scientific data about the moon which would not have been possible without the RTG's and which will extend the benefits of the Apollo program well beyond the last planned lunar landing of Apollo 17.

SNAP–19/Pioneer.—The use of nuclear energy to enhance the exploration of space passed another milestone with the launch of Pioneer 10 in March 1972. This spacecraft, which is scheduled to pass by Jupiter in December 1973, receives its electricity for data collection and transmission from four modified SNAP–19 RTG's. Each Plutonium-238 fueled generator is designed to provide at least 30 watts of electrical power at the time the spacecraft completes its 21-month journey to the nearest of the outer planets. The spacecraft has successfully traversed most of its path through the unknown hazards of the asteroid belt with all systems, especially the RTG's, functioning as well or better than expected. The nuclear-powered Pioneer 10 is expected to continue to transmit information well beyond Jupiter as it follows a course of escape from the solar system. Four additional RTG's have been fabricated and delivered to NASA for use on a similar Jupiter fly-by mission of Pioneer G scheduled for launch in April 1973.

Transit RTG.—A 5-year, 30-watt RTG is the electrical power supply for an experimental Transit navigation satellite which was launched on September 2, 1972, as a part of the Navy's continuing Transit Improvement Program. The RTG continues to operate as expected in space. Preliminary discussions on providing RTG's to the Navy for their follow-on satellite program were initiated.

MHW/LES 8 AND 9.—In 1971, the AEC accepted a requirement to provide modular Multi-Hundred Watt (MHW) RTG's which were currently under development for use on the DOD's Lincoln Experimental Satellites (LES 8 and 9) to be launched in 1974. The final design of the SiGe generator was selected and verified by dynamic testing during 1972. Extensive analysis and testing was conducted to support the design and safety of the high temperature heat source. Each satellite will carry two RTG's designed to produce 125 watts each after 5 years of operation. These MHW RTG's are designed to improve the performance, safety and versatility of Plutonium-238 fueled generators at a power level twice that of previously launched generators.

MHW/MJS-77.—The versatility of the MHW RTG will be demonstrated by its use on the NASA Mariner Jupiter/Saturn (MJS–77) fly-by missions in 1977. These outerplanet missions, which have been substituted for the previously planned Grand Tour missions, will require three MHW RTG's per spacecraft with mission lifetimes of 5–9 years.

SNAP-19/Viking.—Minor design modifications and environmental testing of the SNAP–19 RTG's were continued to meet the requirements of the NASA Viking Mars Lander missions scheduled for launch in 1975. Two 35 watt RTG's will provide the electrical power required to operate the Lander on the surface of Mars for an extended period of time.

Low Cost RTG Studies.—Studies were conducted in cooperation with the U.S. Air Force to define an RTG power system for operational military communication satellites which provides the reliability, compactness, and environmental insensitivity of RTG's at a lower cost. Increased emphasis is being placed on less-expensive, more available space fuels, such as Curium-244, and on lower-cost power conversion systems.

Standardized Nuclear Powered Spacecraft.—A preliminary study was completed which demonstrated the feasibility of satisfying practically all NASA and DOD earth orbital missions planned for the 1979–1990 time period, when the space shuttle is expected to be available, with a few standardized, modularized, isotope or reactor powered spacecraft. The versatility of a nuclear-powered spacecraft for missions to be flown at any orbit altitude or inclination is permitted by the insensitivity of the design to its location in orbit with respect to the Sun, the Earth, and the radiation belts. This is not possible with a solar dependent spacecraft design. The extension of the standardization and multiple use of space equipment to a step beyond the launch vehicle (shuttle) to include the spacecraft, on which the mission dependent equipment is carried, is expected to derive significant cost-savings in the area of design, test and qualification of tailor-made spacecraft designs. These systems traditionally have been a major fraction of space program costs, so that more space missions could be accomplished within the same funding availability. Further studies are continuing to build upon this standard nuclear spacecraft approach.

Space Reactor Power Systems

UZrH Reactor/Thermoelectric Technology.—The AEC and NASA are jointly developing the technology for a long-lived, uranium zirconium hydride reactor heat source coupled with a compact thermoelectric power conversion system to provide from five to twenty KW of electrical power for space applications. The reactor/thermoelectric power system would be a low cost candidate for high-powered unmanned military and communication satellites. Air Force studies have selected this type of power system for possible use in a future military satellite program which is still undergoing review in the DOD. A similar, but heavier, shielded version of the reactor/thermoelectric system has been extensively studied and could be used in manned space missions of the future. A high-powered version of a standard nuclear spacecraft is being studied which employs the reactor/thermoelectric system. The joint NASA/AEC technology program uses the AEC developed reactor technology and the compact tubular thermoelectric technology which has been under development for many years. The program is aimed at demonstrating, in a ground test, the 5-year life capability of such a system. During 1972, components were tested and the design of the five KW system to be tested at the Santa Susana Reactor Test Facility in 1977 was selected. AEC is responsible for the nuclear components while NASA is responsible for the non-nuclear components and the overall system engineering.

Thermionic Reactor/Nuclear Electric Propulsion.—The in-core thermionic reactor power system is under development for applications which require more than a few 10's of KW, such as in high performance nuclear electric propulsion missions to the outer planets or to perform comet rendezvous missions, such as with Halley's Comet in the mid-eighties. The key component of such a power system is the thermionic fuel element. Therefore, current emphasis in the program has been toward developing this thermionic fuel element for long lifetimes. During 1972, a milestone was achieved by passing the 5,000-hour life tests of a full scale thermionic fuel element. Useful lifetimes of 10,000 to 20,000 hours are required for most of the high performance nuclear electric propulsion missions being contemplated. An example of a possible application of thermionic power for electric propulsion is to propel an unmanned spacecraft to rendezvous in 1985 with

Halley's Comet, which passes near the earth every 76 years. This would be a mission of unique scientific interest, and it would require the high energy propulsion capabilities offered by the nuclear electric propulsion system. When developed, the thermionic fuel element may also provide a useful power capability for underwater or special terrestrial applications.

Space Nuclear Propulsion

For several years, and through the start of 1972, the major objective of the joint AEC–NASA space nuclear propulsion program was the development of a 75,000-pound thrust NERVA engine for a variety of space flight missions. The program also included a variety of advanced research and technology activities designed to support NERVA development, to extend the performance of the solid-core nuclear rocket reactor and to explore novel concepts for applying fusion and fission to propulsion.

In February, 1972, as a result of a reassessment of the national space program, the planned missions for which the NERVA engine was intended were deferred and the decision was made to cancel the NERVA program.

During 1972, a comprehensive comparison study was initiated, and is now in progress, of the various competitive candidate systems for a variety of future potential missions of the 1980's and 1990's, including the outerplanet exploration missions. These studies involve not only performance comparisons but also technological status, development and recurring costs and mission and spacecraft considerations. The studies will permit the evaluation of relative merit of the various systems based on a consistent set of data and will determine both the long and short range benefits of the introduction of advanced propulsion into the space flight programs.

In addition to the advanced propulsion comparison studies, work continued at the Los Alamos Scientific Laboratory to define the design of a small nuclear rocket engine. This engine design will incorporate the same basic technology that the NERVA engine used and will also draw upon the Los Alamos experience with the small Pewee reactors that they have designed and tested in the past few years. This successful Pewee experience has demonstrated that engines of this smaller size are feasible and that for the missions of the early 1980's very high performance can be achieved.

Advanced Research and Technology Activities.—The Los Alamos Scientific Laboratory (LASL) has been conducting a broad range of research and technology activities on solid-core reactors for propulsion. Fuel element and materials technology represent the key pacing activities in this program. The reactor core materials goal is operation at 2700 K in a hydrogen atmosphere and ability to withstand large temperature gradients and many thermal cycles.

Two principal efforts are underway at LASL to upgrade reactor performance and improve reliability of the fuel elements. These have to do with test techniques to improve fuel-element performance and the development of new fuel-element concepts for higher temperature capability. Initial tests of new fuel element design innovations are generally conducted in the laboratory in electrically-heated corrosion furnaces. Tests conducted during the year in these furnaces indicate major gains in time and temperature were possible with composite fuel materials. In May, June, and July of this year, the first test series utilizing the Los Alamos Nuclear Furnace design was conducted at the Nuclear Rocket Development Station in Nevada. The nuclear furnace gives a capability of testing a relatively small number of fuel elements in a nuclear reactor environment and provides an improved simulation of the reactor environment as compared to electric furnace testing. The NF–1 contained 49 fuel elements of the graphite/carbide composite variety. Because this test was the first test of the nuclear furnace, its purpose was primarily to explore the furnace operating characteristics.

Test results demonstrated the Nuclear Furnace design was suitable for the evaluation of reactor fuel elements and related hardware and provided good test data (108 minutes at 4400° Rankine) of the composite test components. The test also demonstrated the successful operation of a new exhaust effluent cleanup system for both particulate and gaseous fission products. The next step in the program to advance solid-core reactor technology is to fabricate and test Nuclear Furnace No. 2 (NF–2). The test goals for this experiment are ambitious and include test operation of up to two hours at fuel element exit gas temperatures of 4900° Rankine.

In addition to the work on composite fuel materials and hardware, research also continued at Los Alamos on the solid-solution uranium carbide-zirconium carbides which exhibit little or no free carbon. This material continues to show great promise for large increases in nuclear rocket performance, beyond that of presently available technology. Various candidate fabrication processes have been evaluated at Los Alamos and many prototype fuel elements have been fabricated. Testing of prototypes in hot hydrogen resulted in low weight loss at temperatures up to 2700° K. There appears to be potential for very high temperature operation with very long lifetimes. Some tests have achieved up to 30 hours of successful operation. Research will continue to improve methods of fabrication and evaluate the performance of these materials.

VI Department of State

Introduction

Expansion of international space cooperation in support of foreign policy objectives and the National Aeronautics and Space Act was again a matter of high priority to the Department of State during 1972. Attention continued to be focused during the year both on expanded cooperation with individual countries and on space endeavors with multilateral and international organizations.

Progress in international space affairs during 1972 included discussions with foreign officials on participation in major new U.S. space programs in the 1970's and 1980's, increased cooperative activities with the Soviet Union, increased international cooperation in communications satellite systems, several new bilateral space cooperation agreements, and a very definite expansion of interest and activities in earth resources satellite programs.

On October 9 the President announced a policy for launch assistance to other countries and international organizations. Under the terms of this new policy, reimbursable launch services will be provided for satellites which are for peaceful purposes and are consistent with obligations under relevant international arrangements. The availability of these services makes it possible for all nations to have access under equal conditions to the advantages of space applications.

Activities within the United Nations.—On July 23, 1972 the United States successfully launched ERTS–1, the first experimental satellite designed to survey earth resources and environment. In addition to the extensive international participation in experimental use of data obtained from ERTS–1, the U.N. Working Group on Remote Sensing of the Earth by Satellites will draw upon results of the satellite's operation in preparing its report to the Outer Space Committee on international aspects of earth resource survey technology.

The United States continued to support U.N. informational and promotional activities concerning potential benefits to the international community deriving from space applications. It participated in an ongoing program of experts' panel meetings under the auspices of the U.N. Export on Space Applications.

On October 6 the U.S. Senate by a 67–0 vote gave its advice and consent to ratification of the Outer Space Liability Convention, which had entered into force September 1.

In the principal U.N. negotiating body for outer space legal matters, the Legal Subcommittee of the Outer Space Committee, considerable progress was made toward agreement on a treaty governing activities in the exploration and use of the Moon. Several important issues, however, remained unresolved. These included the question whether (as advocated by the United States) the treaty's scope should be expanded to cover other celestial bodies besides the Moon; whether advance notification to the international community of planned missions to the Moon (and other celestial bodies) should be required; and whether provisions should be included governing the exploitation of natural resources of the moon (and other celestial bodies).

Less progress was achieved in the Legal Subcommittee on a possible convention on the registration of objects launched into outer space. The United States indicated that it could not accept reporting requirements as extensive as those proposed by Canada and France, the cosponsors of the draft convention; we did indicate that we could envisage a mandatory system to replace the present arrangements of voluntary launch reports to the U.N. Secretary General.

A controversial outer space legal issue was raised in two forums—UNESCO and the General Assembly—concerning possible restrictions on direct broadcasting by satellites from transmitters in one country to individual receivers in another. The United States indicated that it could not accept provisions embodying the principle of prior consent to such broadcasts by the receiving State, because of the implications this would have for our traditional support for the free exchange of information and ideas. Nevertheless, the UNESCO General Conference adopted a declaration of principles containing such a provision.

In the General Assembly the U.S.S.R. sought to have a highly restrictive draft convention made the primary basis for negotiation of rules governing direct television broadcasting by satellites. The Assembly instead adopted a resolution calling more broadly upon the Outer Space Committee to work out principles with the eventual aim of reaching "an international agreement or agreements." Although this resolution rep-

resented a substantial improvement over the original Soviet proposal, the United States could not accept it because it prejudged the need for international rules governing satellite direct broadcasts; in our view such a judgment is premature since the technology is still in an early developmental stage.

Cooperation with Europe.—Discussions undertaken in 1970 with the European Space Conference (ESC) concerning the possible participation of Europe in the post-Apollo program were continued in 1972. A meeting of U.S. officials with the ESC Committee of Alternates, hosted by the State Department in June 1972, laid the groundwork for European consideration of undertaking the task of developing and manufacturing the Sortie Module, a key element in the post-Apollo program, the first element of which, the space transportation system which is scheduled to start operation in 1979. A major step forward was achieved on November 9 with the unanimous endorsement by the ESC Ministers of a proposal which would permit interested European governments to proceed with Phase B (project definition) studies of the Sortie Module. Funding of this work will be undertaken by the German, Italian, Spanish, and Belgian Governments.

If Europe subsequently undertakes full responsibility for development and manufacture of the Sortie Module, representing an investment of about $250 million, this will assure that the post-Apollo program becomes one of the most important cooperative projects of the decade.

During 1972, NASA launched on a reimbursable basis two European scientific satellites designed and manufactured under ESRO auspices, the TD–1 and the HEOS A–2. In an interesting reversal of roles, an Italian launch crew launched NASA's SAS–B satellite from the equatorial San Marco launch facilities in Kenya.

Cooperative sounding rocket activities with European countries continued in 1972. The Department provided assistance as NASA concluded four arrangements with Norway, Sweden, Germany, and France for sounding rocket projects.

Cooperation with Japan.—Space cooperation between the United States and Japan during 1972 was dominated by an increased flow of space technology to Japan, as authorized under terms of the 1969 United States/Japanese Space Cooperation Agreement. This technology being transferred under United States/Japanese industry arrangements subject to the approval of the Department's Office of Munitions Control, is to be used in Japanese efforts to develop a space launch vehicle and a number of scientific and practical applications satellites for launch starting in 1975.

The Department has in 1972 explored other areas of cooperation wth Japanese officials to enhance their space efforts. Cost estimates were furnished to the Japanese for launch vehicle and launch services costs associated with the possible use of uprated Thor Delta to place Japan's Meteorological Satellite contribution to GARP into geostationary orbit. In addition, the Department has been exploring with other agencies the possibility of assisting the Japanese with the establishment of a downrange tracking site. Resolution of this latter question is expected early in 1973.

Cooperation with the Soviet Union.—On May 14, the President signed in Moscow a pioneering Space Cooperation Agreement which featured plans for a joint docking mission of United States and Soviet-manned spaceships in 1975. The Agreement also endorsed at the highest level a variety of on-going cooperative programs in such areas as space meteorology, space biology and medicine, space science and exploration, and the use of space for studies of the natural environment. Until two years ago, space cooperation between the two leading space powers had been a frail and inconsequential affair. It is now a strong and growing phenomenon which, in the words of last May's agreement, is dedicated to making the results of space exploration "available for the benefit of the peoples of the two countries and of all the peoples of the world."

Communications Satellites.—The Definitive Agreements for the International Telecommunications Satellite organization "INTELSAT" will enter into force in early 1973. They will replace Interim Arrangements negotiated in 1964 by 11 countries, including the United States, and in which 83 countries now participate as members. The United States actively encouraged acceptance of the new agreements which are intended to provide the permanent basis for the global commercial telecommunications system utilizing satellite technology. INTELSAT has already deployed satellites over the Atlantic, Pacific, and Indian Oceans. As of December 31, 1972 there were 64 Earth stations with access to these satellites, thereby handling telephone, telegraph, television and data communications directly for 49 countries.

The International Telecommunication Union, the specialized agency of the United Nations with responsibility for maintaining and extending international cooperation for the improvement and rational use of telecommunications of all kinds, will convene a Plenipotentiary Conference in September 1973. Preparations have begun for that meeting which will determine the general policies for fulfilling the ITU's purposes, and establish a budget and elect a Secretary General and Deputy Secretary General for the next plenary period. Cross utilization of satellite facilities was a subject of discussion during 1972. The United States and Canada formally recognized that there were certain

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special circumstances where it would be in the interest of both countries to permit our domestic satellite telecommunications systems to provide assistance to one another. One such case would be the provision of support and assistance, subject to the availability of facilities and to the extent it is technically feasible, in the case of catastrophic failure of either system.

In November NASA launched ANIK–1, the first Canadian domestic communications satellite. This launch was conducted pursuant to the bilateral United States-Canadian agreement of 1969.

Apollo Program Support.—The Department and its posts overseas continued their support during 1972 of the Apollo program by arranging for the basing of recovery, tracking and other support forces at foreign installations for Apollo 16 and 17 missions. Apollo contingency recovery procedures in the event of an emergency landing were rewritten and activated for the two missions.

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

Earth Resources Survey Program.—ERTS–1, the first satellite dedicated entirely to the survey of earth resources from space, was launched on July 23. The initial results from the ERTS experiment are encouraging, and the reports on its performance before various U.N. committees have been well received.

The President specifically cited remote sensing of earth by satellite in his speech before the UNGA on September 18, 1969 when he spoke of our wish to share the adventures and benefits of space. Experiments from 38 foreign nations and two international organizations are included in ERTS, and Canada has established its own receiving station for ERTS data. NASA has also accepted a large number of foreign earth resources experiment proposals for Skylab, the manned space laboratory which is scheduled for launch in April 1973.

Extension of a bilateral remote sensing agreement with Mexico until June 30, 1974 was accomplished this year.

Technology Transfer.—The Department of State's Office of Munitions Control continued its efforts aimed at reducing the number of space-related items covered by export controls under the International Traffic in Arms Regulations. In 1972, the bulk of license requests for export of space-related hardware and technology processed by the Office of Munitions Control involved transfers under the United States/Japanese Space Cooperation Agreement and exports to the European area. Greater stress is being given to exporting hardware rather than the technology necessary to produce the hardware.

Cooperation with the Department of Defense.—During 1972 the Department of State continued to work closely with the Department of Defense on various military space issues having international implications.

VII Department of Transportation

Introduction

The Department of Transportation has made substantial progress during 1972 in its program of operational and developmental application of aeronautics and space technology to the solution of many transportation problems. While most of the advancements are understandably directly associated with air transportation, it is particularly gratifying that some major advances have been achieved in the translation of the aeronautical skills to non-aeronautical services. The San Francisco Bay Area Rapid Transit (BART) has become operational this year utilizing many aerospace skills from information processing, automation and flow control, to equipment and structural designs which have been proven in the aerospace industry. An experimental traffic flow control system has been put into operation in the District of Columbia utilizing aerospace developed system capabilities for information processing, signal conditioning, and flow control.

TRANSPO '72 provided an opportunity to show the public preliminary design and test configurations of

innovative Personal Rapid Transit Systems (PRTS). Following the evaluation of public reaction and the technical demonstration at the TRANSPO site, test installations are being prepared by UMTA for major metropolitan areas. The first space age PRT system is now operating at the test site on the campus of the University of West Virginia and its home city of Morgantown. Testing and evaluation of this advanced demonstration program has begun. The Tracked Air Cushion Research Vehicle, designed and built by an aerospace company for the Federal Railroad Administration, was delivered to the test site in Pueblo, Colo. this year and is currently being readied for extensive tests and operational development.

Aeronautics.—In the field of safety in transportation there have been some notable developmental successes which have been palled by the continuation of the skyjacking threat to the world's, as well as our own domestic, air system. This one subject area has been the center of an intensive interagency and international development and test activity. Our objective is to eliminate the threat. Our success to date has been disappointing. Priorities will not be relaxed until an acceptable level of air passenger and air cargo security has been assured. The anti-hijacking programs that were begun in 1971 and continued into 1972 have primarily addressed the problem of detecting weapons carried by boarding passenger selectees. The basic technology has been demonstrated to provide for highly effective screening systems that will prevent travelers from boarding aircraft carrying weapons such as guns and knives. Weapon detection devices have been bought by DOT/FAA, using general funds, and provided to the airlines. The key to effectiveness now lies with the consistent use of systems that are available.

Notable progress has been achieved in improving the effectiveness of the air transportation system through the acceleration of the operational deployment of the new terminal radar system (ARTS III). Following the first two operational facilities accomplished late last year (Chicago, O'Hare Field (September 1971) and Denver's Stapleton Airport (December 1971)), 41 new installations have been completed, tested, and certified as operational this year and the pace will continue in the remainder of fiscal year 1973. This acceleration and associated airport improvements have been made possible through the effective application of funds derived from the Airports and Airways Trust Fund. Development of improved flow control, surveillance, and conflict prediction capabilities are being accelerated in a similar fashion.

Efforts to provide for substantially improved quality of air transportation have centered on the actions and developments required to reduce noise and other pollution from air transportation. Major successes have been achieved with the certification of three new aircraft models to the FAA's FAR–36 noise rule and the recent development of a new model of a current production design which will similarly meet the new tougher standards. Major attention is being given to means for reducing the noise exposure from existing aircraft through potential retrofit modifications, as well as improved operational procedures.

Substantial progress has been made in reducing solid particle pollutants by engine improvements and current development activity is aimed at reducing the remaining emissions. In some cases, we do not fully understand the interaction of various chemical compounds in the atmosphere. An aggressive program, which is international in scope, has been initiated to obtain information on the existence, persistence, and impact of emissions at high altitude. This Climatic Impact Assessment Program (CIAP) is a major activity involving interdepartmental, Government, industry, and academic institutions in a very thorough worldwide program.

Continued improvement was achieved in the effectiveness with which research and engineering activities sponsored, coordinated, and conducted by the various elements of the Department are combined in a cohesive effort toward solution of transportation problems. This advance is represented by the development of a new DOT-R. & D. Management System which addresses fully the planning, budgeting, and monitoring phases of the activities. Major accomplishments have been: the preparation of guidelines for the first set of Administrations' 5-year R. & D. plans; the establishment of R. & D. objectives and the identification of issues for budgetary analysis and management review; the Transportation Research Activity Information System (TRAIS) was put "on line" containing past and current DOT-R. & D. contracts and will be expected to facilitate the process of data retrieval in the future.

Major Emphasis of Civil Aviation R. & D.—The Civil Aviation Research and Development Policy Study (CARD) mentioned in last year's report (sponsored jointly by the Office of the Secretary of Transportation, the National Aeronautics and Space Administration, and the Federal Aviation Administration and completed in March 1971) and the Northeast Corridor Transportation Project (NECTP), have been used as the basis for continued planning and evaluation of technical developments and evaluation of new air system options.

Both studies concluded that substantial effort was required in the air and ground systems to improve the environmental quality of transportation, to relieve congestion, and to improve short-haul efficiency. More specifically, it was clear that there were many more factors than just the development of new operating

systems which should be accomplished. Finally, subsequent events and pragmatic consideration of budgetary constraints have generated some detailed redirection of effort in consideration of a more balanced program.

A Civil Aviation R. & D. Review Group has been established which includes the Executive Secretary of the National Aeronautics and Space Council, the NASA Associate Administrator for Aeronautics and Space Technology, and the DOT Assistant Secretary for Systems Development and Technology. Also, a Joint DOT/NASA CARD Policy Implementation Office has been established within DOT. This office reports to the CARD Review Group and its mission is to assist both DOT and NASA in planning programs of action which are coordinated and consistent with the recommendations of various policy studies, and to assist in the performance of future policy studies.

The ultimate technological products of the research and development activities and plans are expected to be readily applicable to the needs of general aviation, the air transportation system, and of all other elements of civil aviation. Furthermore, it is clear from what has already occurred that the products of this effort will be readily applicable to other modes, as well, through transfer of technology and hardware developments.

The most effective result to date has been the improved focus on the most urgent needs for civil aviation R. & D., providing a roadmap for their satisfaction, and establishing relative priorities in a broader format than have other studies. In a large number of situations within both DOT and NASA, fundamental approaches were already at work which had been identified as being required and desirable. The CARD study results have led to support for some of these approaches as well as to the establishment of some new approaches and to increasing support for some programs which were already in being. A few of the accomplishments which have resulted from the influence of the CARD study are illustrated by the following actions.

CARD recommendation.—"Aircraft noise is the largest single impediment to the orderly growth of air commerce, and should be minimized by a vigorous industry/Government noise-reduction program. * * *"

Resultant Actions. The Joint DOT/NASA Noise Abatement Office was initiated last year. Significant progress has been made this year toward the development of an environmentally acceptable air transportation system. Type certificates were issued for compliance with noise standards by the Lockheed L–1011, the Boeing 747–200B, and the latest models of the Boeing 727 and 737 transport aircraft. These aircraft join the Douglas DC–10 in meeting and/or bettering the noise emission standards of Federal Aviation Regulations, Part 36. Changes in flight operational procedures were developed, adopted, and implemented nationally to achieve immediate noise reduction near airports. NASA has initiated a developmental program aimed at a whole new family of quiet engines which should be available by the 1980's. Ground and flight tests were completed for the three-engine turbofan transport aircraft and ground tests for the four-engine aircraft, to demonstrate the effectiveness of noise suppression nacelle hardware. These milestones are part of an overall program to show economical and technical feasibility of engine retrofits of currently used commercial airliners in order to reduce noise impact around airports.

The Federal Aviation Administration published a notice of proposed rule making which will require:

> Newly produced aircraft of models with type certification prior to December 1, 1969 (the effective date of FAR Part 36 noise standards) must comply with the Part 36 requirements after July 1, 1973, for aircraft with maximum weights of more than 75,000 pounds, and after July 1, 1974, for aircraft with maximum weights of 75,000 pounds or less.

Air pollution caused by aircraft is of increasing concern. The objective of the Environmental Protection programs is to reduce aircraft noise and air pollution to levels which will be acceptable to the communities effected while maintaining safe, economical, and convenient air transportation service. The efforts related to pollution control follow two paths—one to determine the extent and influence of aircraft pollutants and the other to provide technology for reducing pollutant emissions. As a part of the quiet engine programs already mentioned, NASA has implemented clean combustor research to provide low engine pollution technology. The DOT has initiated a significant effort intended to provide an understanding of the character of aircraft emissions and their effects on meteorology and the structure of the earth's atmosphere, particularly at very high altitudes.

The Climatic Impact Assessment Program, established in the Office of the Assistant Secretary for Systems Development and Technology, provides overall management to a program to assess, by mid-1974, the effects upon the climate of high altitude subsonic and supersonic aircraft projected in the time period 1985–1990. The action in 1972 has been formulating required research effort and identifying related on-going research throughout the Government agencies, universities, and industry. Approximately 65 contracts have been initiated during this period. A general survey conference was held at the Transportation Systems Center, Cambridge, Massachusetts, in early February, to explore the objectives of CIAP with leading scientists throughout the world and to solicit their proposals and

contributions to CIAP. The interest and response of the attendees was enthusiastic in approval and support of the program.

A second CIAP Program review and survey conference was held November 14–17, 1972, at the Transportation Systems Center. The purpose of this conference was primarily to allow the participating scientists to present the results of their effort to date as well as to identify any missing links in the overall CIAP Program effort. These accomplishments fall into the broad categories of: developing laboratory prototype instruments to measure atmospheric nitric oxide concentrations; correlating particulate measurements as determined by in-situ observation and ground-based detectors; and fundamental measurements of atmospheric chemistry and emission characteristics.

CARD recommendation.—"A new short-haul system, separate as much as possible from the long-haul system, would help. * * * Research and technology related to STOL aircraft is needed to develop this system and to assist the FAA in establishing criteria. * * *"

Resultant Actions.—Brought focus to alternative solutions for the short-haul air transportation problems; influenced the decision to expand the area of concern of the FAA Special V/STOL Project Office to include the total subject of short-haul transportation and change in the name of the office to Quiet Short-Haul Air Transportation Systems Office; led to initiation of system studies intended to define the critical factors in short-haul system effectiveness.

The V/STOL project office, initiated last year, was reoriented and its view extended to include all types of short-haul air service in the transportation system. Its name was changed to the Quiet Short-Haul Air Transportation (QSATS) Office and it was charged to foster "the development of a QSAT system that is safe and convenient for the passenger, economically profitable to operate, compatible with other segments of aviation, and acceptable to the public * * *" One of the first actions by this office was to organize interagency coordination, with the objective of assuring totally responsive complementary Federal programs. Initially, this ad-hoc group is focussing on the identification and evaluation of airports to be so functionally designated in the National Aviation System as short haul airports. They are expected to reach maximum effectiveness when new technologies of aircraft and ATC are available.

This effort has been supported by a rapidly increasing capability at the Transportation Systems Center (TSC) in Cambridge, Mass. The Office of the Secretary is also assuring an integrated effort of the Federal Railroad Administration, Federal Highway Administration, and the Urban Mass Transportation Administration in support of aviation interests.

Systems studies are being conducted in order to evaluate the characteristics of short-haul markets, to define desirable aircraft characteristics as well as to evaluate possible changes to airports and the air traffic control system which will permit improvement of short-haul service. As an example of these activities, the FAA has just given notice through a notification of proposed policy that it is its intention to designate and procure an interim Standard Micro-wave Landing System (ISMLS) for use and implementation in designated short-haul airports. The CARD Study and subsequent analyses have pointed out that the economics of low-density short-haul are such that this mode of air transportation is not serving the Nation's needs, in spite of being financially supported, for the most part, by Federal subsidy. The broad objective of activities in this area is to identify and foster the technology which will permit improvement of short-haul economics and to evaluate the alternatives of utilizing the special aspects of integrated multi-modal short-haul transportation to enhance the total air system.

CARD Recommendation.—"To the user of civil aviation, service is of prime concern. The tremendous growth of the commercial airlines and the user demand for services have produced serious congestion in and around airports—an undesirable by-product of success * * *".

Resultant Actions.—Added emphasis on the need for the DOT/FAA microwave landing system; contributed to formulation of a long-range program to define an advanced air traffic management system concept for greater capacity development; led to increased attention to terminal area operations for all types of operations.

Increased emphasis has been added to the FAA's system engineering and development activities. A major reorganization of the activity under the Associate Administrator for Engineering and Development has been accomplished. The general effect is to increase the focus on systematic development of the air traffic control process to enhance the total effectiveness in the most expeditious manner. Those efforts associated with detailed support of initial installations of NAS Stage A En route and ARTS II & III systems have been transferred into the Airway Facilities Service organization allowing greater concentration within the development organization on system optimization.

The upgraded Third Generation System includes development of a Discrete Address Beacon System (DABS) for ground and aircraft installation which will function integrally with the Automated Radar Terminal System (ARTS). A major element of the upgraded system is the Microwave Landing System (MLS) development which completed the preliminary design Phase I this year and for which Phase II proposals have been received. The full upgraded system is planned to be in operation by the early 1980's.

The Advanced Air Traffic Management System (AATMS) Study is investigating new concepts for air traffic management for application in the post-1985 period that will, with a high degree of assurance, meet the air traffic demands of that era. The study builds upon the work of the DOT Air Traffic Control Advisory Committee in 1969. During 1972, the concept formulation phase was completed wherein candidate system concepts were described and future research needs were identified. This work was based upon a preliminary cost/performance/feasibility evaluation of alternative system concepts synthesized to satisfy an initial definition of future air traffic management requirements. Surviving candidate concepts include: satellites for surveillance, communication and navigation; greatly expanded use of automation in the ground control function; utilization of integrated waveform techniques for signal transmission and means to minimize the complexity and cost of on-board equipment.

A direct tie-in with the FAA work on the upgraded system provides definitions of its further capabilities (1985 and beyond) as a part of the AATMS study. The results of these studies are expected to be a basis for FAA Air Traffic Control R. & D. Planning for fiscal year 1975 and beyond.

Another important aspect of system capacity, which significantly effects the system safety as well, is associated with wake turbulence requirements to avoid potential high energy vortices which increases spacing between aircraft resulting in a decrease in system capacity. Some interesting concepts for reducing the severity of this problem have been advanced. However we continue to be constrained by a fundamental lack of ability to qualify the vortex energy over an extended period of persistence. DOT has expanded its program in this area in cooperation with the NASA, USAF and industry. In order to better avoid the problem, we are continuing the development of detectors to locate and track the hazard. The field tests mentioned last year have been completed as have some others using lasers. We have initiated the definition of a system which is concerned to provide avoidance guidance.

Congestion is experienced not only in the air and in the aircraft landing areas, but, for the passenger, it is also experienced in the terminal building as well as to and from the airport. Plans have been laid for an increased emphasis in this developmental activity in the next few years with the Office of the Secretary taking the responsibility to affect improvements in total service connectivity.

Aviation Safety.—Safety is of vital concern to civil aviation and in fact all of the R. & D. activities are directly related in one way or another either to design or operational safety. The particular activities discussed here are those which are motivated by safety alone rather than by economic or utility needs. Because of the continuing importance of safety, these activities tend to be continuous and place emphasis on both accident prevention and crash survival.

The accident prevention activities include continuing efforts by the FAA to update and improve aircraft design and operations airworthiness criteria and regulation. An extensive program involving personnel permanently assigned to NASA's Ames Research Laboratory has been initiated using the simulation capability that exists there. Pilot proficiency is a most important factor in accident prevention and both NASA and DOT are conducting activities intended to improve pilot proficiency. Flight simulators are a key element in pilot training and proficiency evaluation.

Another important aspect of accident prevention, which actually affects the system capability as well, is associated with wake turbulence. Some interesting concepts for reducing the severity of this problem have been advanced. However, we continue to be constrained by a fundamental lack of ability to quantify the vortex energy over a period of persistence approaching two minutes. We are pressing for more activity in this area. In order to better manage the problem, we are continuing the development of detectors to locate and track the hazard. The field tests mentioned last year have been completed as have some others using lasers. We are continuing this activity and we have initiated the definition of a system which is conceived to provide avoidance guidance.

In the area of post crash safety, significant results were obtained in the testing of "modified" fuels to reduce post crash fire hazards. Previously reported results have shown that a number of gelled fuels have excellent fire-reducing qualities, but the high viscosity of these fuels makes them incompatible with the fuel systems of modern jets. A new fuel stabilizing ingredient, that does not appear to have the disadvantages of gelled fuels, has shown very good results in preliminary tests. Full scale demonstrations and flight tests are expected to take place early next year. The FAA continues to maintain a strong program of man/machine experimentation in passenger crash survival with particular emphasis on general aviation aircraft.

Civil Aviation Security.—The most intense effort in the field of safety is addressed to solution of the hijacking problem. Significant contributions to transportation security systems development have been accomplished in fiscal year 1972. FAA has completed initial test and development work in improving behavioral passenger screening techniques, developing aviation security regulations and standards, testing and improving the passenger screening system, and assessing new technological potentials for detecting weapons.

However, the users needed information on the qualification and availability of metal detectors for pas-

senger screening. Elaborate laboratory tests were designed, developed, and implemented. The results were distributed to representatives of 76 governments and eight international organizations as well as officials of the major U.S. airlines and airport managers. The equipment investigated covered the gamut from inexpensive, simple, hand-held devices to the highly sophisticated weapon detectors capable of discriminating guns, including "Saturday Night Specials" from other metal objects. Exotic detection techniques such as infrared, radar and even electroluminescence were explored for potential advantages.

Hijacking incidents in the United States and abroad were carefully analyzed to identify any new threats. Explosives detection has been emphasized as a consequence of these recent episodes. All of the commercial "sniffers" were researched and tested. A successful technique was developed to calibrate these systems for sensitivity. Initial experimentation is being conducted with a novel sensitive "sniffer" which has a potential of breaking the cost barrier of the existing systems because of the simplicity of its design.

As an alternative countermeasure to the increasing threat of terrorism, a pair of specially trained bomb detection dogs were tested in an airport environment to evaluate environmental and operational effects. The assistance of dogs revealed a significant advantage in time of discovery. Regardless of distractions, the targets were generally found within 3 minutes and often in seconds.

Long Haul Technology.—Although the SST prototype development effort was terminated as a result of Congressional action in March 1971, certain key technology efforts were continued. These advanced technology projects were identified by a multi-agency review panel and represented carefully selected R. & D. projects. The initial phases of this effort were completed this year. Passage of enabling legislation by Congress last year continues this vital effort, and contracts have been awarded. Test and evaluation effort will continue into 1973.

The broad objective of activities in this subject area is to provide a technology base for future decisions and development programs which will permit a broad latitude of long-haul aircraft options. The technology areas being addressed are engine noise, emissions, and efficiency; flutter; stability augmentation systems; cockpit display systems; and materials development.

Aeronautical Satellite Activities.—The joint international Aerosat program proposed in early 1972 was not approved and efforts to develop a new approach were undertaken. In early October a new U.S. position resulted in a renewal of negotiations with participating foreign governments in late November, with promising results. In a parallel action, development of space segment capability requirements was undertaken and agreement in substance was reached in December with final approval anticipated at the next Aerosat meeting scheduled to be held in Ottawa, Canada, in January 1973. At that time agreement is also expected on the final draft of the Memorandum of Understanding relating to the Joint Intermodal Test and Evaluation Program. In addition to AEROSAT activities, extensive planning and intention of procurement of equipment was accomplished to prepare for a joint DOT/NASA test program utilizing the ATS–F satellite scheduled to be launched in April 1974.

MARSAT.—Activity Within the Intergovernmental Maritime Consultative Organization (IMCO).—At the January 1972 meeting of IMCO's subcommittee on radio communications (RCS) a plan for initiating action to develop a worldwide Maritime Satellite System (MARSATS) was proposed by the USSR. Action was taken at the March meeting of the Intergovernmental Maritime Consultative Organization's Maritime Safety Committee to establish a Panel of Experts to meet in July in conjunction with a RCS subcommittee meeting. This was followed by a second Panel of Experts meeting in November 1972. The thrust of these activities is directed toward developing the foundation for a series of international conferences of Maritime States in 1973 and 1974 to act on recommendations of plans to establish a worldwide MARSAT system.

VIII Arms Control and Disarmament Agency

Introduction

The Arms Control and Disarmament Agency continues to have a strong interest in space programs, both international and national. ACDA has consistently supported international space programs, seeking to insure that these programs are directed towards peaceful rather than military purposes. The agency has also long been investigating means of providing for high-confidence, non-intrusive verification of arms control agreements. Advanced space technology is monitored for possible verification use, such as in the case of the DOD's VELA system that is used for verification of the Limited Test Ban Treaty. In addition to these purely space-related ACDA activities, the SALT negotiations also have a significant impact on world space activities. SALT ONE provided that neither side would interfere with national technical means of verification and established an improved, space-based "hot line" system.

SALT.—The ABM treaty and the interim executive agreement limiting offensive strategic arms, signed on May 26 in Moscow, specifically provide that neither the United States nor the U.S.S.R. will interfere with legitimate national technical means of verification of these arms control measures or employ deliberate concealment measures to impede such verification.

The non-interference provision is relevant to space activities since this provision would, for example, prohibit interference with a satellite in orbit used for verification of the Treaty. Thus, SALT reinforced the Outer Space Treaty that, in Article III, states that "Parties to the Treaty shall carry on activities in the — — — use of outer space — — — in the interest of maintaining international peace and security and promoting international cooperation and understanding." The improved "hot line" agreement, negotiated during SALT ONE and signed in Washington on September 30, 1971 provides for a secure, spacebased, communications link between the national command authorities of the United States and the U.S.S.R.

International Space Programs.—Space programs can provide outlets in many countries for national ambitions that might otherwise be channeled into the development of sophisticated weapons. When carried out on a bilateral or a multilateral basis such programs can also set useful precedents for cooperation between nations in other constructive areas employing high technology. ACDA has long recognized the significant overlap between nonweapon launch vehicle technology and the technology for strategic ballistic missiles. The agency believes, however, that space programs can result in minimal risk of proliferation if hardware design and application are carefully controlled. ACDA is an active participant in this control process. Besides helping to prepare U.S. positions on general issues of international space policy, ACDA cooperates with other agencies at a detailed technical level in formulating and implementing international space agreements. The agency has participated this year in the effort to involve other nations in the U.S. Post-Apollo Space program and with implementing the Japanese-American Space Cooperation Program.

The Outer Space Treaty.—The Outer Space Treaty serves two major purposes. First, it seeks to insure that space exploration and development will be carried out in accordance with international law and for peaceful purposes only. By banning the emplacement of "weapons of mass destruction" in space, on celestial bodies or in earth orbit, it closes off the largest of man's new environments to the strategic arms race. Second, the treaty establishes a desirable precedent for generality in arms control agreements by banning all such weapons, not just nuclear weapons. Along with the Antarctica Treaty and the Seabed Arms Control Treaty it has provided impetus for closing off other frontiers on earth to the arms race.

In 1972 Cyprus and Italy ratified the treaty, bringing to 67 the number of states that are parties.

IX Department of the Interior

Introduction

The Department of the Interior has used aircraft on an operational basis for a long time to meet its needs both for transport and for data collection. The types of data have increased as technology has provided new tools for natural and cultural resources data collection. It was in anticipation of the benefits to resources management and in a desire to assist in the development of new remote-sensing systems that the Department created the Earth Resources Observation Systems (EROS) Program. The EROS Program office cooperates with NASA and other agencies in research and development pertaining to remote sensing of earth resources. Departmental activities include international cooperation in wildlife regulatory administration, scientific research projects, technical training programs, and technical assistance. The Department has also contributed to astronaut training and provided scientific analysis of lunar and Martian data.

Aeronautics

Operations.—During 1972 aircraft were used operationally by the Bureaus of the Department in the following ways:

The Bonneville Power Administration owns and operates both helicopters and fixed-wing aircraft. The small fleet of helicopters is used for the aerial patrol of transmission lines, transportation of personnel to remote microwave stations, for the movement of men, tools, and equipment in restoration of interrupted transmission service, and for line location investigations and construction of new lines. Two fixed-wing twin-engine aircraft are used for transport of personnel to remote locations not served by commercial airlines or when commercial flight schedules are inadequate.

Primarily high-altitude photography was obtained by contract aircraft and NASA aircraft over the Quinault, Colville, Oneida, Salt River, Gila River, and Pine Ridge Indian Reservations for use in preparing orthophoto base maps or in preparing resource inventories and land use maps of these areas.

The Bureau of Land Management continues to operate and contract for both helicopters and fixed-wing aircraft in cadastral surveys, fire suppression, weather modification, and forest, range, and soils inventory work. High-altitude photography was obtained over areas in Oregon from which orthophoto maps were made and timber resources were evaluated as part of the development of a resource management tool. In New Mexico high-altitude photography was used in soil identification and inventory programs.

The Bureau of Mines had regular flights flown over Hurricane Agnes flood trash dump sites (old surface pit mines, filled and covered with dirt) in the vicinity of Wilkes-Barre, Pa., to obtain thermal imagery for use in assessing their burning or nonburning status and to determine potential hazard to underlying coalbeds.

The National Park Service utilized aerial photography for land acquisition, park planning, and road site selection. Aerial coverage of the Cape Hatteras, Cape Lookout, and Assateague National Seashores, obtained cooperatively from NASA Wallops Station on a regular basis, is being used in making operating management decisions. A significant amount of the coverage is now provided by ERTS–1 imagery. Aerial census of large ungulate populations in various national parks is continuing with activity in Yellowstone National Park, Grand Canyon and many others.

The Bureau of Reclamation utilized their own and contract helicopters and fixed-wing aircraft for investigations and inspections required for project operation and maintenance, for transportation of control survey parties and equipment, and in the collection of photography and scanner imagery used in planning, development, and management of multipurpose water resource projects.

The Bureau of Sport Fisheries and Wildlife operates a fleet of approximately 45 aircraft for use in aerial surveys. The data collected are for research purposes and development of regulatory authority. The surveys cover parts of the United States, Canada, and Mexico.

The Geological Survey obtained standard aerial mapping photography for 188,000 square miles of the United States. Of this total, 27,000 square miles were from high altitude, up to 36,000 ft. This reflects the trend toward acquisition of quad-centered high-altitude photography, in which one photograph covers an entire 7½-minute quadrangle area. U–2 photographs taken at 21 km (70,000 ft.) altitude were converted into orthophotoquads at 1:24,000, 1:50,000, and 1:250,000 scales. These quads were lithographed utilizing a newly developed random dot process which in-

creases the resolution of the final product. The first series of 1:24,000-scale orthophotoquads, designed for publication and sale to the public, involved 49 quadrangles in the Phoenix area.

The Geological Survey utilized its own, contract, and other Federal aircraft to acquire photographic and other remote-sensor data for the support of geological and geophysical investigations. These include reconnaissance and detailed geological mapping, monitoring volcanic activities, evaluation of mineral and geothermal resources, appraisal of wildlife areas, and environmental studies. Helicopters and other aircraft were used routinely in Alaskan field studies and for additional environmental studies along the route of the proposed oil pipeline. Airborne sensors were used to produce aeromagnetic, gravity, radioactivity, gamma-ray, INPUT, Very Low Frequency (VLF), and geochemical surveys. Other sensors, used singly or in combination, included cameras for conventional, high-altitude and multiband photography, thermal infrared scanners, and radiometers. Contract helicopters are used in the management of Federal Outer Continental Shelf mineral resources, mostly in the Gulf of Mexico, and to a very limited degree in the management of Federal onshore mineral resources. Contract fixed-wing aircraft are used along the coast of California off Santa Barbara on a regular basis to locate and monitor sources of oil spills.

Research.—Many Bureaus of the Department have used aircraft as platforms for obtaining data as part of a continuing effort to improve their operational techniques and management.

The Bureau of Mines supported the preparation of three experimental compendia using thermal infrared aerial imagery for use by Bureau field personnel in monitoring fire projects. Two compendia are of burning coal refuse banks in an anthracite mining area and a bituminious mining area, and the third is of mine fires in the Anthracite Region of Pennsylvania. They are being evaluated to establish the operational potential of airborne thermal imagery in fire control. Hand-held aerial photography was used in Pennsylvania in an attempt to discriminate damages to Christmas tree plantations caused by SO_2 from damages from lophodermium fungus and other blights. Although only partially successful, the technique was demonstrated to be a useful, low-cost method of rapidly determining vegetation damages around powerplants. The Bureau is also studying a method for determining volumes of material removed from a mine and for monitoring the results of seeding on waste banks using aerial color and color infrared photography of the Black Mesa mine in Arizona.

The National Park Service, in cooperation with the Geological Survey, is assembling orthophotographic map coverage of the Everglades National Park. These maps are to form the base for vegetation and other subject maps of the National Park. In cooperation with NASA's John F. Kennedy Space Center, aerial multispectral coverage of Virgin Islands National Park has been obtained in order to map underwater features of coral reefs and to provide the basis for vegetation and natural resource mapping of the National Park. Archeological prospecting is continuing after several successful attempts at locating shipwrecks of historical interest in Florida Bay, using contract acquired imagery. Continuing aerial surveillance of the volcanic activity in Hawaii Volcanoes National Park is being carried out in cooperation with the Geological Survey and the County of Hawaii.

The Bureau of Reclamation, in an effort to broaden its use of aircraft remote sensing in water and land resource development has undertaken the following studies: to detect, by means of aerial color-infrared photography and thermal infrared imagery, sediment-laden waters of the Clarks Fork of the Yellowstone River of Montana and Wyoming; to detect with multiband thermal infrared imagery near-surface ground water in irrigated agricultural land; to evaluate the impact of a pump storage powerplant on the hydrologic and biologic conditions of a reservoir using infrared photography and imagery; to evaluate the use of aircraft remote sensing as a possible means of detecting the locations of plant infestations on water storage and distribution systems and for evaluating the effects of weed control eradication measures; to determine the feasibility and utility of employing thermal infrared imagery to identify cold air drainage patterns which would result in frost damage in orchard areas and to determine the value of such techniques for classification of land for irrigation; and to develop a mobile short pulse radar system to measure the depth to shallow ground water on irrigated land. The Bureau continued to use aircraft as platforms for cloud seed generators, air sampling, air motion studies, observations of cloud forms and behavior, and placement of instruments in remote locations.

The Office of Water Resources Research supported research utilizing infrared photography and botanical land surveys to establish mean high water lines in Florida's lakes; using aerial photography and thermal infrared imagery to explain biological and chemical phenomena observed in the Medicine Lake area, South Dakota; using radar imagery to explain how summertime lake conditions influence precipitation patterns over southern Lake Michigan; on the use of aerial remote-sensing techniques for siting sampling locations on streams and lakes; on the use of aerial photography in determining hydrological effects of manmade changes in watersheds; and on the determination of snow depth and water equivalent volume by remote sensing.

The Bureau of Sport Fisheries and Wildlife ob-

tained multispectral aerial data over the Chesapeake Bay in an effort to measure the quantity and quality of submerged vegetation. They also conducted research on differentiation of waterfowl species using aerial multispectral photography.

The Geological Survey is applying the interdisciplinary approach of physics and geology in the development of remote-sensing techniques as a part of geologic analysis by identifying the parameters by which rocks and soils can be remotely discriminated and developing the methods to display and analyze remote-sensor data. The feasibility of mapping bedrock in hard rock areas is being tested using the VLF system. Prospecting for mineral deposits through the determination of geochemical plant stress is being investigated by studying spectral reflectance and the use of multiband photography.

Space

Research.—The EROS (Earth Resources Observation Systems) Program is responsible for the development of programs to apply aircraft and spacecraft data to Department of the Interior functions. This includes acquisition, processing, utilization, and dissemination of remotely sensed data concerning natural and cultural resources. A major event in the activities of the EROS Program was the launch of the first Earth Resources Technology Satellite (ERTS) on July 23, 1972. Imagery obtained by and data relayed through the satellite has permitted, for the first time, an evaluation of what has been envisioned as a mutually complementary three part data collection system (satellite, aircraft, and ground) to provide the input to resource management information systems. Although many experiments are in progress and the emphasis is currently on use of satellite-acquired data, there is a substantial research effort in the development of instruments and methodology using aircraft.

EROS Data Center has functioned as the primary public sales outlet for ERTS imagery since the launch of the satellite in July 1972. The Data Center also provides access to NASA aircraft photography and imagery, and aerial mapping photography flown for the Geological Survey. To supplement these products an Autographic Theme Extraction system (ATE) was defined and developed to depict in binary mode such themes as snow, water, infrared reflective vegetation, and the massed works of man. The system is designed to use ERTS data and thus provide periodic representations of these subjects. The ATE system is scheduled to commence operations at the EROS Data Center at Sioux Falls, S. Dak., early in 1973.

The Data Center also has facilities for data manipulation and training. The first training course in applications of remote-sensor systems to resources analysis and management was conducted from October 26 to November 21, 1972. The purpose of the course was to provide personnel of the U.S. Department of the Interior with information that would enable them to employ data that are available from satellite and airborne remote-sensing systems including satellite photography, aerial photography, airborne mapping radar, and airborne thermal mapping imagery to support their own activities. Twenty-six scientists from 10 Bureaus and Offices of the Department participated in the course. Instructional staff included EROS Program personnel and experts in the field of remote sensing drawn from the Departments of Interior, Agriculture, and Commerce, Corps of Engineers, from universities, and industry. The course included workshop experience in multidisciplinary approaches to the solution of environmental problems and planning, and the presentation of information on research in the field of remote sensing, the significance of that research, and the identities of the organizations conducting such research.

Regional research activities, established to consolidate remote-sensing data collection and encourage multidiscipline interpretation and cooperative investigations continued in the Central Atlantic, Arizona, the Pacific Islands, and beginning this year, in the Gulf Coast region. The Central Atlantic Regional Ecological Test Site (CARETS) embraces the Chesapeake and Delaware Bays and ther urbanized hinterlands. This demonstration project is being developed to serve as a model of an integrated regional land use information system encompassing inventory of the land resource base, monitoring changes and the effect of these changes on the quality of the environment. Data on land use and land use changes are derived from high-altitude aircraft and satellite imagery. Land use mapping and a photo-mosaic base map at a scale of 1:100,000, with a 1-km grid overlay, have been completed. Procedures for the analysis of change and environmental impact have been developed using the Norfolk-Portsmouth area, where an assessment of land use change over the decade corresponding to the decennial census has been made and a preliminary land use/environmental impact model has been developed.

The Arizona Regional Ecological Test Site (ARETS) project continued to coordinate research in air and spaceborne remote-sensor methods and their application to environmental and resource problems. The results of these efforts are practically displayed in the initiation of the cooperative Arizona Land Use Experiment in which the State of Arizona, NASA, and the U.S. Geological Survey are partners in the experiment. Acquisition of high-altitude photographic coverage of the entire State for preparation of orthophoto base maps is in progress.

The ARETS Office was able to respond to specific project needs by obtaining color, infrared aerial photography for use in a preliminary flood report, in an investigation of cotton bollworm infestations, and to

complete a crop inventory of the Salt River and Gila River Indian Reservations.

The EROS Program through its Experiments and Evaluation Office at the NASA Mississippi Test Facility cooperated with the State of Louisiana and other Federal agencies in the acquisition of remotely sensed data on which to base planning decisions for the Atchafalayan Basin; assisted the Mississippi Department of Archives and History in planning an aerial survey, data acquisition, field inspection and interpretation of data for 15 archeological sites near Natchez; and is participating in the Mississippi State-wide Land Use Inventory Project to compile a 1:24,000 land use map of the State using high-altitude photography.

The EROS Program coordinated preparation of project proposals and prepared the Department of the Interior response to the National Aeronautics and Space Administration's request for Earth Resources Technology Satellite-A (ERTS–A) and Skylab Earth Resources Experiments Package (EREP) proposals. At the end of 1972, 42 ERTS–A proposals were under contract and 22 EREP Skylab proposals were approved. The experiments are representative of the wide range of interests within the Department, covering such subjects as: evaluation of range land quality and quantity, evaluation of cartographic applications, study of coastal and estuarine dynamics, land use mapping, timber resources inventory, volcano monitoring, urban change detection, and watershed management studies.

The Bonneville Power Administration is a participant with the EROS Program and the Bureau of Reclamation in a continuing research program to use satellite meteorological data for input to water resources programs, such as the operation of hydroelectric systems. The project now involves testing previously established techniques on independent data and on independent watersheds.

The Bureau of Indian Affairs is continuing a study of the use of remote sensing in making a soil and range inventory of Indian lands in South Dakota using aerial multispectral imagery. The results of the first year's study show remote-sensing techniques can be applied to making, updating, and revising soil and range inventories. Improved soil and range maps were produced utilizing film optical density and slope gradient data derived from aerial photographs. These inventories and maps will be used to help make land management decisions. The Bureau of Indian Affairs and the Salt River Indian Community, adjacent to Phoenix, Ariz., are continuing a remote-sensing project for regional planning and monitoring. This project has an Indian project manager working under contract to the Federal Government. The basis of the Indian community project is an orthophotoquad base map prepared by the U.S. Geological Survey.

The Bureau of Indian Affairs and the Bureau of Land Management are furthering the design of a natural resources information system which includes graphic input and display, the use of remote sensing as a data source, and is useful at multiple management levels. This effort has been expanded to provide additional demonstrations to the Bureau of Mines, Bureau of Outdoor Recreation, Bureau of Reclamation, Bureau of Sport Fisheries and Wildlife, National Park Service, and the Geological Survey, and includes many sections of the country.

The Bureau of Land Management is actively engaged in research using aerial photography and ERTS–1 imagery. Several on-going projects include: study of the recreational impact along the lower Colorado River, study of ephemeral and perennial range quantity and quality during normal grazing season, study of conflicting land uses, erosion and soils inventory, an experiment to determine seasonal changes in the Rocky Mountain Front Range, and a study of land ownership patterns in the Powder River Basin surface coal mining area.

The Bureau of Mines has sponsored research on earth fracture systems as they are interpreted from aerial infrared photographs, thermal infrared imagery, ERTS–1 imagery, and panchromatic aerial photographs. The earth fractures were studied to determine their possible contribution to the hazard of vertical migration of waste chemical liquids from subsurface storage wells in West Virginia and to the hazard of roof fall in coal mines; and to aid in the selection of the location for an experimental gas well which was drilled in a nonproductive area in West Virginia. The well produced 103,000 cubic feet of gas daily after stimulation by explosive fracturing. Similar research was conducted to evaluate two energy research test sites in Kansas and Wyoming. The Bureau is also using aerial and space photography to monitor the environmental effect of an operating powerplant in the four corners area of the Southwest.

Bureau of Mines research has indicated a probable correlation between underground fires and early vegetation bloom with certain types of fires and vegetation. To further test this thesis, aerial color-infrared photography of areas in Wyoming containing known and suspected coal fires was acquired and areas of anomalous vegetation were checked on the ground for possible coal fires. The project was of only limited success due to weather conditions which prohibited flying all of the area during the critical period of premature vegetation bloom. In western Colorado, thermal imagery was obtained over an area of known fires, and all known fires, even small ones, were easily detected and other fires were indicated.

The National Park Service's New Mexico Archeological Center continued to use aircraft and spacecraft imagery to ascertain patterns of irrigation works and many other works of man in the Southwest desert.

Under contract, a preliminary study was made of the conterminous uses of land in the Redwood National Park, that indicated that spaceflight imagery provides an excellent means of determining conflicting land uses in these west coast watersheds. A successful training program for introducing 18 resources managers to remote sensing and photogrammetry was conducted for Park Service personnel. A similar course is planned for 1973.

The Bureau of Outdoor Recreation is evaluating various sensors and interpretation techniques for their potential value for the inventory of urban and rural recreation lands and waters and areas of critical environmental concern. A second objective is to predict the impact of proposed key facilities and to monitor developments and other land use changes upon existing and potential recreation and related environmental resources.

Research and development programs of the Bureau of Reclamation continue to make use of aeronautics and space technology. Research programs were initiated to test ERTS–1 data relay capability under a severe environment in the San Juan Mountains of southwestern Colorado, and to observe and monitor with ERTS imagery the hydrology, agricultural development, environment, and geology of three major Reclamation projects on the Front Range of eastern Colorado.

The Bureau of Sport Fisheries and Wildlife initiated an ERTS experiment to test the utility of spacecraft remote sensors in measuring biological parameters in the State of Alaska. Of specific interest are phenological records, occurrence of ice leads, upwelling currents, and snow and ice runoff. Supporting the ERTS experiment were aircraft flights throughout the State to acquire imagery replicating the spectral bands of ERTS. A second ERTS–1 experiment involves remote sensing of waterfowl production areas in the northern United States and Canada. This effort was supported by contract aircraft flights.

The Geological Survey's research to develop techniques to augment conventional geologic exploration methodology was directed along the following lines: determining physical property variations (spectral reflectance, thermal inertia, etc.) which can be used to discriminate and describe geologic materials; evaluating the synoptic overview of imagery acquired from satellites to observe tectonic and geomorphic relationships of regional and continental significance; and identifying and repeatedly observing active time-variant phenomena using imagery and satellite telemetry techniques.

Results of investigations include: Compilation of a thermal inertia map for the Oman region of Saudi Arabia from Nimbus III reflectances and Nimbus IV thermal emission data showing the distribution of major geologic units; development of visible and near-infrared imaging technique with applications to differentiation of iron-rich and iron-poor surface units including metallic mineralogical zones; mapping of major structural features in Alaska through analysis of cloud-free Nimbus III imagery; compilation of geologic-terrain factors maps of the Tucson-Ajo, Ariz., area for land use analysis; further development and demonstration of a thermal infrared ratioing technique for discriminating among silicate rocks and between silicate and nonsilicate rocks; also, fabrication of a trielement thermal infrared detector for ratioing; development of two mutually supportive volcano surveillance systems using satellite data collection, the seismic event counter network and thermal infrared monitoring; application of high-altitude thermal infrared images to analysis of structural zones in the Denver Urban Area and the Geysers, Calif.; use of thermal infrared images for stream curvature and orientation analysis in tree-covered granitic terrain near Mill Creek, Okla.; definition of a previously unmapped contact between two granites as a result of this analysis; use of high-altitude color and color-infrared photographs for monitoring flood-related erosion and sedimentation in northern California and the impact of this dynamic redistribution on land use practices; analysis of high-altitude multiband photographs of the San Francisco Bay suggests a correlation between film density and water temperature, salinity, and light transmission characteristics; and analysis of Cosmos 49 and OGO 6 satellite magnetometer data to determine crustal anomalies.

The Geological Survey continues to analyze ERTS image simulations and real images using edge gradient analysis to estimate image quality and resolution values, and continues to support a study to determine the metric quality of Return Beam Vidicon (RBV) cameras and methods and procedures that might be employed to attain the best possible geometric fidelity in the data obtained by them. This project has resulted in computer programs for in-flight calibration of RBV systems using ground control points. The reseau coordinates of all ERTS RBV cameras have now been measured for use in the NASA Data Processing Facility precision processor. These data are also used to evaluate the distortions inherent in ERTS RBV imagery and have influenced the design of new reseau patterns for future ERTS satellites. A data bank of photoidentifiable ground image points of the United States has been compiled to relate ERTS and other remote-sensor images to a specified earth reference system. The NASA Data Processing Facility is using these data in their precision processor for producing scene-corrected (precision processed) images. This data bank is now being refined and improved using actual ERTS images. The Geological Survey has also sponsored development of a dynamic method for correcting geo-

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metric and photometric errors in a television display system.

In the process of developing useful cartographic products from space and high-altitude aircraft remote-sensor data, objective tests have been conducted and experimental products have been produced from ERTS images. Six ERTS experiments are being conducted to study cartographic applications of ERTS data. In addition, five proposals for investigations with Skylab EREP data have been tentatively accepted by NASA to study cartographic applications of data from the multispectral scanner, multispectral camera, and an 18-inch focal length frame camera to be carried on board.

Remote-sensing studies in the Chesapeake Bay region have included projects relating runoff to spatial drainage basins characteristics that may be readily extracted from multispectral data; for delineation of wetlands based on determination of spectral reflectance curves for major species identification, plant succession, seasonal changes in individual species, and unusual events; and for analysis of urbanization effects on sediment and stream discharge. Coastal wetlands research and mapping continues as a contract study, utilizing data from selected areas along the Atlantic Coast, in an effort to improve the capability of remote-sensing technology to rapidly identify, delineate, and map coastal wetlands for management purposes. The dynamics of species boundaries with season and time are also being analyzed.

Work continues on the development of techniques to determine quantities of soil moisture, the delineation of areas of ground-water occurrence, the location of flowing artesian wells, and the interpretation of hydrologic anomalies from snowmelt patterns using remote sensors. Film densities have been correlated to the volume of plant canopy and quantities of evapotranspiration from phreatophytes in a continuing study in Arizona. Ecological predictive models are being developed for conservation, wildlife, and harbor management in Florida. A network of data platforms are being installed in southern Florida as a part of the Data Collection System (DCS) for relay via ERTS–1 for near real-time water management. ERTS–1 is equipped with DCS relay equipment. Data obtained by platforms at gaged points are transmitted to the satellite for relay to ground receiving stations, and the data are then telemetered to the appropriate center for computer processing. Within a total time of 2 hours the data are available for use in decisionmaking. A network of platforms for monitoring water quantity and quality has been implemented in the Delaware River Estuary in cooperation with the Delaware River Basin Commission. The system is working as intended and should be invaluable for early warning of potential hazardous conditions such as chemical spills and floods.

Passive microwave research is underway to develop the technology to make quantitative estimates of runoff expected from an areal snowpack. Three avenues of research in pollution detection are being followed. These are laser-stimulated Raman scatter, which shows promise for the detection of diatomic and polyatomic molecules; infrared specular reflectance or emittance, which is based on the nature of aqueous solutions of different chemical composition to reflect or emit electromagnetic radiant energy in its own characteristic spectral signature; and remote sensing solar-stimulated fluorescence, which is limited to relatively few constituents of natural waters such as oil, and some industrial and pesticide pollutants, but has potential as a dye tracer to determine circulation patterns. These studies should lead to the design of airborne sensors.

Data for the Phoenix quadrangle have been obtained from both high-altitude aircraft and satellite photos for a project to test the feasibility of mapping land use at a scale of 1:250,000, to use computerized techniques for updating the information, and to relate land use data to other environmental and socioeconomic factors. Thus far the land-use interpretation together with data on land ownership, soils, drainage, census tracts, and various locational codes have been computerized, and a map of detected land use changes for the period from November 1970 to February 1972 has been produced. The work on urban change detection continued with analysis of land use from high-altitude photography taken at the time of the 1970 census, and was completed for Boston, Cedar Rapids, New Haven, Washington, D.C., and San Francisco. Land use changes between 1970 and 1972 are being analyzed, some from ERTS–1 imagery. There is great promise for a multistage, multidate land use monitoring system which combines remote sensors aboard aircraft and satellites with integrated sample ground surveys.

Operations.—The Geological Survey supported NASA in the conduct of Apollo 16 and 17 lunar exploration missions. The Survey provides the chairman and members on the Apollo Orbital Science Photo Team. The team prepares the photographic flight plan for both command module and service module photography, trains the astronauts in photographic operations and geologic observations, provides real-time support during the flight through the Mission Control Center, monitors the processing and distribution of the flight film, and recommends the cartographic utilization of the photography. The Center of Astrogeology prepares the large topographic maps required for selecting sites and planning surface operations. Geologic analysis of photographs taken by orbital cameras during Apollo 15 and 16 was started, and geologic mapping of Mars continued making use of the more than 7,000 pictures transmitted by Mariner 9.

International Cooperation

Early in the year, the U.S. Geological Survey conducted a 3-month training course in remote sensing in Indonesia as part of an on-going geological assistance project sponsored by the U.S. Agency for International Development (USAID). Ten scientists representing several Indonesian agencies participated. Plans also were formulated for a remote-sensing applications project in Indonesia, using multispectral photography in multidisciplinary studies, principally on the island of Bali. This project, which includes training and acquisition and interpretation of data, is an attempt to apply remote-sensing techniques to the solution of varied problems in a wet tropical environment in a developing country.

Planning was completed for a remote-sensing training and consultation program in Thailand to begin in January 1973. This project, which is directly related to a Natural Resources Program of the National Research Council of Thailand involves the use of ERTS imagery in multidisciplinary studies by six agencies of the Thai Government.

The EROS Program arranged and participated in a 3-week course in applications of remote-sensing systems to earth resources analysis and management presented for 13 experts from Iran, 6 from Pakistan, and 11 from Turkey, in the fields of geology, water resources, topographic mapping, forestry, agriculture, oceanography, geography, and land use planning. The course, held in Tehran, Iran, September 15 to October 7, 1972, was sponsored by the CENTO (Central Treaty Organization) Secretariat and the Office of the USAID Economic Coordinator for CENTO Affairs. The Government of Iran was host country, providing the facility and services of the Geological Survey of Iran for presentation of the program. Objectives of the course were to apprise scientists of the CENTO countries of the status and methods of using satellite and aerial remote-sensing systems to obtain information in support of programs for research and management of earth resources and for land use planning.

The InterAmerican Geodetic Survey (IAGS) with EROS Program support began to serve as a remote-sensing training center for Latin America. Using the facilities of their cartographic school, IAGS presented a 12-week course, "Orientation and Application in Remote Sensing," to a class of 36 Latin American students from February 28 to May 20, 1972. A second course, accommodating 25 students was completed in November 1972, and a third course is scheduled for February 1973. IAGS is acquiring Gemini, Apollo, and ERTS data as well as a bibliography of remote-sensing reports on microfiche. These materials are available for use in the Canal Zone, and facilities have been developed to assist interested people in ordering duplicates.

At the request of the Brazilian Ministry of Mines and Energy, the EROS Program is providing assistance in carrying out a three-phase training program in the application of remote sensing for Brazilian earth scientists. The basic course was given in Brazil, with emphasis on geologic and hydrologic applications. Advanced training is to be given in the United States at the EROS Data Center. Manipulation, interpretation, and application of ERTS data are to be a significant part of this phase. A scientist-to-scientist technical information exchange program is the third phase and is envisioned as a continuing follow-on activity to the training.

A study is underway to develop techniques for using remote-sensor data to estimate seasonal hydrologic changes and annual departures from average conditions in arid basins where hydrologic and meteorologic data now permit only estimates of long-term average conditions. The study involves analysis of ERTS images of salars (salt-encrusted playas) within the region of interior drainage in South America (Chile, Bolivia, and Argentina). The second objective is to develop a better understanding of the factors controlling the distribution of these continental saline deposits.

A cooperative remote sensing effort by NASA, the U.S. Geological Survey, and Canadian scientists on Lake Ontario has been incorporated into the International Field Year for the Great Lakes. Several sets of aircraft data have been obtained over a simulation test site, equivalent in size to an ERTS frame. The basic goals of the remote-sensing studies are to study sediment and thermal discharges from contributory rivers, flow dynamics within the lake, factors of water quality, the hydrology of surficial deposits in the drainage basin, and ERTS simulation studies. Preliminary evaluation of ERTS data shows plumes of water discharging into Lake Ontario and factors relating to circulation dynamics that will be useful for the development of dispersion models. Geological Survey scientists have also been cooperating with Canadian scientists in applying remote-sensing techniques to snow and ice studies. Data from aircraft and spacecraft platforms have been used to evaluate the hydrologic significance of the snowline; to evaluate the circulation patterns, heat exchange, and ice dynamics of the Arctic Ocean; and to analyze the location, extent, thickness, and condition of the ice on Lake Ontario and the Gulf of St. Lawrence.

The use of fixed-wing aircraft and helicopters for logistical support of field operations continued, particularly in Saudi Arabia where the U.S. Geological Survey is involved in a geological mapping and mineral appraisal program. Aeromagnetic and radiometric data also were obtained through contracts with private companies during the year.

X Department of Agriculture

Introduction

Among the program responsibilities of the U.S. Department of Agriculture (USDA) is that of participation in establishing policy decisions on the sound use of agricultural and wildland resources, while also providing information and assistance to farmers, processors, homemakers, and consumers of agricultural commodities. As one of the steps in fulfilling these responsibilities, the Department during 1972 continued its research on the timely application of ground, aircraft, and satellite remote sensing data to the solution of major agricultural, forestry, range, and environmental problems.

One of the objectives of this Earth Resources Survey Program is to develop methods for the comprehensive and timely collection of data from earth orbit and to disseminate these data for rapid interpretation into meaningful information for the user community. USDA is working closely with other Federal agencies for this purpose.

Remote Sensing Activities

The Department recognizes the need for a remote sensing program that is technically feasible and economically sound. Such a program would utilize aerospace technology in collecting near real-time earth resources data to (1) inventory and evaluate for productivity the food, fiber, and other natural resources of the United States and the world, and (2) assess environmental and ecological conditions, as well as man-environment interactions.

Early in the Earth Resources Survey Program, USDA recognized the possibilities for using aerospace remote sensing methods in making timely and accurate crop and forest surveys, in determining soil types and moisture conditions, in detecting stress conditions in agriculture and timber crops, and in other similar efforts. The Department, under a NASA funding agreement, contracted with the Infrared and Optical Sensor Laboratory of the University of Michigan in 1966 to conduct a feasibility design study for developing a multispectral scanning device. This device was intended as a research tool for developing and evaluating automatic, spectral pattern techniques. A multichannel optical-mechanical scanning instrument was developed that would (1) provide for finer spectral resolutions than could be obtained via photographic systems, (2) provide for rapid automatic spectral discrimination of crops, and (3) provide a method that could be readily adapted in automatic data processing techniques.

It was also recognized that data in photographic form are not as readily adaptable for automatic processing as are data in electronic form. Since large quantities of data were to be expected from aircraft and spacecraft experimental multispectral scanner flights, the USDA with NASA funds contracted in 1966 with the Laboratory for Agricultural Remote Sensing at Purdue University to design and develop a flexible and automatic computerized data handling system. Such a system could supply scanner data, as well as data from other sources, to researchers rapidly and conveniently. This data handling capability would permit rapid data manipulation, i.e., analog-to-digital conversion, calibration, formating, editing, etc. This, in turn, would create a capability for rapid data analysis, thereby permitting further reduction of the data to such useful information as automatic pattern recognition, image enhancement, statistical analysis, etc.

Success in the use of multispectral scanners and automated data processing techniques has been well documented. It is the basis for establishing similar systems to meet current and future ERTS data handling requirements.

During 1972, USDA extended its capability for collecting, analyzing, and utilizing the synoptic and sequential data obtained from the ERTS–I experimental satellite. It is continuing to identify the kinds of data and instrumentation required for more effective use of future satellite systems. Currently six USDA–NASA ERTS–I research investigations are in progress. These are:

1. Spectral reflection studies on vegetation, soil, and water utilizing space data.
2. Utilization of ERTS data for determining wind soil erosion in the High Plains of Texas.
3. Investigation of the use of space data in watershed hydrology studies.
4. Spectral bands determination for recording gypsy moth defoliation.
5. Investigation of crop identification and acreage measurement utilizing ERTS imagery.

6. Evaluation of ERTS multispectral scanner imagery for identifying forest, rangeland, new forest, and water resources, and forest stress.

USDA is also preparing for five research investigations involving data to be acquired from the EREP package aboard Skylab scheduled for launch in 1973. These investigations will involve:

1. Early detection of insect infestation in agricultural crops.
2. The use of space observations to determine the need for crop irrigations, the distribution of saline soil, and temperature distributions associated with freezes.
3. An ecosystem study in a Colorado Basin area.
4. Use of space imagery in developing a timber volume estimate capability.
5. Detection of disturbances caused by mountain pine beetles.

A number of studies conducted in 1972 involved aerial remote sensing techniques. Among the advances made were:

1. Determination of the significance of temporal analysis of crops utilizing aerial multispectral scanner data.
2. Development of an ongoing operational survey method for using aerial color infrared photography in detecting citrus blackfly. This method has considerably reduced survey costs, while providing a faster and better means of surveillance.
3. Two remote sensing studies have been completed by the Forest Service at its Pacific Southwest Range and Experiment Station at Berkeley, Calif. One study in southern California attempted to assess oxidant injury to Ponderosa pine in the mountains. Successful results were obtained with large-scale (1:1,600) color aerial photography; multispectral scanner imagery yielded negative results.
4. A second experiment, carried out in cooperation with TVA and EPA, attempted to identify damage from the SO_2 emitted by a large coal-burning power plant. This experiment showed that damage could be detected in the 1:1,600 color aerial photographs when such damage exceeded 20 percent.
5. Also developed was a wildland resources information system using aerial photography and digital computers. This system was first developed for the Stanislaus National Forest and is being further adapted for other California national forests.
6. Identification of *Poria weirii* root rot in Oregon forests, with 80 percent success, utilizing aerial photography up to the scale of 1:32,000.
7. Very small aerial color transparencies (scale 1:420,000) have been used with better than 90 percent accuracy in estimating forest areas by separating nonforest from forest areas.

Other Activities

U.S. policy encourages international cooperation in remote sensing activities. USDA, in 1972, cooperated with U.N. Food and Agriculture Organization (Rome) in developing a several-month training course for Thai and Philippine personnel. These advanced students attended an academic-type, 6-week course at the Laboratory for Applications of Remote Sensing at Purdue University, and were then given field training at various USDA research centers in the United States.

USDA personnel participated in a remote sensing training program in Tehran and are preparing for an AID-sponsored program on remote sensing to be given in Bangkok.

The Department also presented papers at the Eighth International Symposium on Remote Sensing of Environment held at the University of Michigan in October 1972.

XI Department of Commerce

Introduction

The Department of Commerce programs contributing directly to the national aeronautics and space effort are administered and operated by the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Maritime Administration, and the Office of Telecommunications. Indirect contributions are made by the U.S. Patent Office and the National Technical Information Service. The goals of these organizations include improvement of man's comprehension and uses of the physical environment and its

oceanic life, and strengthening and advancing the Nation's science and technology to facilitate their application for public benefit.

Satellite Programs

Environmental Satellite Operations.—A major improvement in the national operational environmental satellite system occurred October 15 with the launch of the NOAA 2 spacecraft. NOAA 2, commanded and controlled by the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite Service (NESS), is the first in a new series of operational environmental satellites. Although similar in appearance to previous satellites in the Improved TIROS Operational Satellite (ITOS) series, NOAA 2 is the first operational spacecraft to rely entirely on scanning radiometers for imagery, and the first to carry a sensor capable of obtaining vertical temperature profiles of the atmosphere on a near-global basis. NOAA 2 carries two sets of primary sensors: Scanning Radiometers (SR's), Very High Resolution Radiometers (VHRR's), and Vertical Temperature Profile Radiometers (VTPR's); the second set is for back up in case of failure. The spacecraft also carries a single Solar Proton Monitor (SPM) as a secondary sensor.

The SR subsystem, which replaces the Automatic Picture Transmission and Advanced Vidicon Camera Systems carried by earlier NOAA satellites, gathers data in the visible and infrared spectrum both day and night. Global cloud cover imagery is stored for later readout to U.S. Command and Data Acquisition stations; direct readout of local cloud cover imagery is available to all nations.

The operational VTPR is a major step toward obtaining the quantitative global measurements needed for numerical weather forecasting. The VTPR measures infrared energy radiated from six levels of the atmosphere and from the Earth's surface or cloud tops. These data are used to calculate the vertical temperature distribution in the atmosphere.

The VHRR obtains data similar to that of the SR but at a resolution of one-half nautical mile rather than the two-to-four nautical mile resolution of the SR. Measurements from these instruments can be used to obtain cloud top temperatures, and, in clear areas, sea surface temperatures.

Development and Application of Environmental Satellite Technology.—An improved technique for analysis of tropical cyclone intensities from satellite pictures was developed and used by the NESS in 1972. Its use resulted in better tracking and forecasting of hurricanes and lesser intensity storms.

A computer technique for the derivation of low-level (1.5 kilometers) winds from Applications Technology Satellite (ATS) pictures, was developed and used operationally. About 250 winds were computed daily, 125 each from ATS 1 and ATS 3 pictures. After October, ATS 1 picture capability was lost. Approximately 80 winds at the 10Km level also are derived daily by manual techniques. All wind information derived from satellite pictures is used operationally by the National Meteorological Center.

Wind data derived from ATS pictures have been important in the derivation of a 4-year circulation climatology of the tropics. This climatology has revealed details of long-period mean circulations in large areas of the tropics where data were not previously available. Sun reflection patterns visible in ATS photographs were used to detect the areal extent of a localized wind and wave pattern affecting shipping along the west coast of Mexico and Central America.

Real-time use of the ATS 1 and 3 cloud cover photographs continued at the National Weather Service's National Severe Storms Forecast Center, the National Hurricane Center, and the National Meteorological Center. Real-time service was extended to the San Francisco Weather Forecast Office but was terminated in October following the loss of ATS 1 picture capability.

NESS has made preparations to obtain vertical temperature profiles in the atmosphere using information expected from new instrumentation on NASA's Nimbus E satellite. Global data from Nimbus E and NOAA 2 will be used to test and improve numerical weather predication models. NESS is developing a sophisticated Earth Radiation Budget (ERB) radiometer for test on Nimbus E. The ERB will provide accurate long-term measurements of radiation-induced heating or cooling of the Earth's surface and atmosphere both synoptically and globally. These measurements will provide bench mark data that should permit diagnosis of future climatic change from satellite radiation observations.

Detection and tracking of large eddies of cool water that break off from loop patterns of the Gulf Stream was resumed following launch of the NOAA 2 satellite. The eddies, representing enormous pools of stored energy, have been detected in the VHRR visible and infrared imagery.

NESS studies of satellite infrared and visible imagery of the Beaufort Sea show the characteristic seasonal changes in ice cover. These changes range from long north-south leads in spring, to giant floes in early summer, and finally to increasingly smaller floes at the autumn freeze-up. Some ice areas appear significantly warmer than others, thus suggesting consistently thinner ice in those areas. In spring, the 24-hr range of temperature was significantly larger for areas with high ice concentration than for areas with low concentrations of thin ice. Other studies demonstrated the use of satellite infrared imagery for ice mapping during the polar night.

Preliminary NESS studies show that imagery from the Earth Resources Technology Satellite (ERTS) is valuable in certain oceanographic research. Circulation patterns are revealed by sediment distributions in coastal areas; shore-line details, shoals, and shallow water bathymetry are delineated by light penetration into shoal water. Delineation is limited only by the degree to which light from the several spectral bands available on ERTS can penetrate the water surfaces. ERTS data confirmed an earlier finding that melting ice could be detected by noting the difference in near infrared and visible reflectance measurements. Atlantic Oceanographic and Meteorological Laboratory (AO ML) scientists have found ERTS imagery useful for detecting acid wastes outside of designated dumping areas off New York harbor. AOML and NASA are working together to obtain sub-orbital path, ground-truth oceanographic data to evaluate the ERTS observations; the data are being gathered by AOML research ships.

Other studies of satellite remote-sensing capabilities have identified the potential for measuring chlorophyll and ocean color from space, and improved methods and materials for studying coastal and estuarine circulations by dye dispersal and tracing.

Hydrologic studies conducted by NESS demonstrated the usefulness of satellite thermal infrared imagery in mapping the extent of snow cover, particularly in flat terrain. Snow covered areas have radiation temperatures 5 to 10° Celsius lower than the surrounding snow free areas.

NOAA's Weather Modification Program Office is correlating visible and infrared satellite imagery with quantitative radar measurements of precipitation. Preliminary results for the tropics suggest that the brightest and coldest cloud masses viewed from the satellite are the regions of active precipitation. When correlation and calibration are completed, it will be possible to use the satellite-rainfall relationship to make more accurate estimates of rainfall in remote regions than is now possible.

A little know facet of the space program is the full range of weather forecasting and observing services required. During the past year the National Weather Service provided:

Forecasts and briefings for the Apollo 16 and 17 missions.

Daily forecasts of cloud cover along the global ERTS track to assist in determining where useful observations could be obtained.

Almost daily weather forecasts for aircraft in the NASA Earth Resources Aircraft Program.

Meteorological support to the NAVY Pacific Missile Range stations at San Nicolas Island, Calif., and Barking Sands, Hawaii, and to the Army Missile Range on Kwajalein Island.

The National Marine Fisheries Service (NMFS) investigated application of remote sensing technology to improving fisheries research and management. With NASA cooperation, NMFS acquired aircraft and ERTS earth resources data to show correlations between remotely sensed environmental parameters and living resources. NMFS and NOAA's Environmental Research Laboratories conducted other experiments to evaluate the usefulness of ERTS data for detecting currents around islands. The Fisheries Service and the U.S. Coast Guard used data from Airborne Radiation Thermometer flights in determining currents and temperature structure along U.S. coastal areas.

Environmental satellite data are incorporated in weather forecasts and charts of sea surface temperatures routinely transmitted to the U.S. tuna fleet in the tropical eastern Pacific. In return, the fleet sends the Fisheries Service detailed oceanographic and meteorological reports for fishery prediction projects. NMFS receives much of their environmental data via the Automatic Picture Transmission system, and prediction products are prepared in cooperation with the National Weather Service.

The prototype hardware for the National Data Buoy Project (NDBP) was delivered for test and evaluation. This hardware included two experimental buoys (one now deployed in the Gulf of Alaska, the other in the Gulf of Mexico); position location devices for drifting buoys (using Omega and navigation satellite systems); drifting, moored, and deep keel hull buoys; and experimental polar application buoys which use the Nimbus IV satellite for data relay and position location.

International Cooperation.—Direct exchange of environmental satellite data continued between the United States and the U.S.S.R. over the direct Washington-Moscow circuit. The data exchanged included television and infrared photographs of cloud cover and analyses of meteorological information. Data flow in both directions has been uninterrupted except during short-period circuit outages. The U.S.S.R. discontinued transmission of television photographs in March but resumed on a sporadic basis in July. At the close of the year the exchange consisted of data from the U.S. NOAA 2 and the U.S.S.R. Meteor 10, 11, 12, and 13 satellites. The Meteor satellites have an experimental direct readout capability similar to the U.S. Automatic Picture Transmission system. However, this is only available over U.S.S.R. territory.

Under the World Meteorological Organization Voluntary Assistance Program, NOAA's National Weather Service completed installation of Automatic Picture Transmission ground stations in three countries and procured stations for installation in four others. Bilingual NWS and NESS instructors conducted classes

and training seminars in satellite picture interpretation in six Central and South American countries.

Representatives of the United States, the European Space Research Organization (ESRO), Japan, and observers from the World Meteorological Organization met in Washington in September to discuss coordination of efforts for establishing geostationary environmental satellite systems. Two ad-hoc working groups were established to study engineering aspects and user requirements.

Satellite ground stations in over 100 countries and trust territories around the world continued to receive spacecraft imagery by direct readout from polar-orbiting Automatic Picture Transmission satellites and by relay through the geostationary ATS satellites.

Navigation/Communication Satellites.—The Maritime Administration completed the development phase of the Navigation/Communication Satellite Program. Unique ground station and shipboard hardware were procured, and prototype models successfully tested. A Maritime Coordination Center, the focal point of the system, is located at Kings Point, N.Y. The Center functions as an earth station, communications interface, and computation center for computing ship positions from ranging data obtained through the NASA ATS 3 and 5 satellites.

The U.S. maritime industry and the Maritime Administration are closely coordinating definition of future experimental subsystems to improve fleet management, to provide more reliable telecommunication services, and to improve operational economics. Programs are underway on improved shipboard antennas, collision-avoidance equipment, and more precise position determination methods.

Geometric Satellite Triangulation.—Data processing and analysis for the Worldwide Geometric Satellite Triangulation Program was completed. Geometric data are being used, independently and in combination with Doppler data, to determine a world ellipsoid of best fit to the geoid.

The National Ocean Survey (NOS) cooperated with the Department of Defense in satellite positioning experiments using the Doppler method. In cooperation with NASA, NOS studied the magnitude of gravity gradients that would be sensed by a satellite-borne gravity gradiometer.

Satellite Tracking and Communications.—The Department of Commerce Office of Telecommunications studied problems related to satellite communications, including precipitation effects and propagation at many frequencies through the extremely high frequency bands. Results of the research supported the manned spaceflight program, the ATS F program, and the Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite program. A technique for precise synchronization of widely separated time bases was studied using satellite communications. This will be important for future communications, navigation, and positioning systems. A study of technical considerations in domestic satellite communications policy for the President's Office of Telecommunications Policy led to the conclusion that there is sufficient electromagnetic frequency spectrum available in synchronous satellite orbits to accommodate all initial applicants for proposed multiple domestic systems with minimum regulatory control.

Upper Atmosphere and Space Technology

Astrophysics.—The National Bureau of Standards (NBS) studies the kinetic and photochemical behavior of planetary atmospheres. Of particular interest is the nature of the Martian atmosphere, and the puzzle of the presence of undissociated carbon dioxide and water molecules with little evidence of molecular oxygen. NBS spectroscopic studies on hydrogen bonding may be important in understanding the atmospheres of the outer planets. Recent NBS measurements of the infrared spectra of cyanogen-halide and ammonia-like molecules are important in interpreting recent observations of Jupiter.

Theoretical studies of stellar atmospheres, complemented by a University of Colorado obseravtional program, provided useful information about the sun. Observations made of strong Fraunhofer lines in plages and sunspots have suggested several new techniques for determining the properties of the solar chromosphere.

Solar Physics.—The NOAA Environmental Research Laboratories' Space Environment Laboratory (SEL) provided solar-observing and forecasting services for NASA and other government agencies. Foremost among these was the operation of the Solar Proton Alert Network (SPAN), which consists of four stations spaced around the world to permit continuous solar observations. Solar disturbances are forecast and monitored as part of the environmental warning service provided to programs such as the Apollo 16 and 17 missions. The SPAN had an intense period of activity in August 1972 during the occurrence of the largest solar flare events of the current solar cycle. Geophysical effects of these flares were felt as disturbances in ground power distribution systems, in long-distance communications lines, and in high frequency and very high frequency radio propagation.

Studies of the magnetic field configuration of the solar disk and active solar regions resulted in successful tracing of the solar proton streams to the solar disk. These studies were done using interpretative analysis

of hydrogen-alpha photographs correlated with observed solar proton streams near Earth.

Upper Atmosphere Physics.—NASA's Small Scientific Satellite, for which NOAA's Space Environment Laboratory provided instrumentation, has obtained a variety of data on the magnetosphere. Among these were the first observations of the equatorial pitch-angle distribution of alpha particles and heavy ions. These data should provide a unique clue to the source of particles found in the Earth's near-space environment. Observations by this satellite of the evolution of plasma instabilities in the magnetosphere proton population provide a unique insight as to how such instabilities may evolve in a naturally occurring geophysical plasma.

NOAA's Aeronomy Laboratory continued research on optical emissions sensitive to abnormal heating of ionospheric electrons produced naturally during magnetic storms and artificially by a high-powered transmitter. The data obtained will clarify the source of the energy and the basic collision processes that occur during heating. High-powered radio transmitters also were used to produce artificial irregularities similar to the natural irregularities of equatorial and auroral regions that cause severe perturbations to communications relying on satellite relay.

A global model of the ionosphere is being produced by the SEL. The model incorporates useful features from studies made over the past half century and includes data on atmospheric densities, solar flux, and electron and ion densities. The Aeronomy Laboratory continued investigations of D-region ion composition using numerical modeling and laboratory controlled chemical reaction rates. Emphasis was on the composition changes likely to occur during periods of intense particle influx. The study has a direct bearing on the effects of high-altitude nuclear explosions.

Radar studies of the small-scale structure of the auroral ionosphere were made during periods of moderate geomagnetic activity. The studies show a correlation between some radar echoes and the edges of visual auroral forms, and an association of other radar echoes with the auroral electrojet current system. This information will provide a better understanding of communications in polar regions.

Analysis of Apollo Lunar Samples.—NBS is determining the chemical composition of lunar samples collected on the various Apollo missions. Analysis of the Apollo 14 and 15 samples is complete and work is underway on the Apollo 16 samples. The high precision techniques being used include electron probe analysis for accurate information about the identity and distribution of mineral phases in the samples; polarographic measurement of iron, titanium, and nickel concentrations; mass spectrometer determinations of the absolute abundance ratios of some 30 elements; and enhanced spark-source methods to determine the presence of various less-abundant elements in the samples. To date, very little difference has been found in the relative isotopic composition of lunar specimens and terrestrial matter.

Instrumentation for Mars Viking Mission.—NBS facilities were used to determine the frost-point of carbon-dioxide and to provide calibrations for the humidity sensors on the Mars Viking Mission. Ion-probe instrumentation is being designed for in-situ chemical analysis of microscopic particles on the Martian surface.

Cryogenic Engineering Support.—NBS is making a concentrated effort to provide NASA with basic data and engineering information on cryogenic systems used in spacecraft fuel cells and fuel storage. Work included thermodynamic, transport, and thermochemical properties of cryogenic fluids, mechanical properties of material at low temperatures, measurement methods, and safety procedures and standards. Technically important data have been published on oxygen, hydrogen, and helium. Special studies included the detection and prediction of liquid oxygen tank failures.

Space Vehicle Studies.—Precision measurements were made of the thermophysical properties of molecular fluorine to assess its potential for rocket propulsion. Design and evaluation of re-entry heat shields will be affected by the NBS studies of the oxide distribution in metallic alloys (titanium diffused-nickel-chromium materials).

Radiation Effects Studies.—NBS assisted NASA's Goddard Space Flight Center in testing and evaluating semiconductor nuclear radiation detectors and dosimeters. NBS provides information on the behavior of solid-state materials in radiation environments. Improved methods of predicting the long-term performance of semiconductor radiation detectors are important in the selection of instrumentation for future NASA interplanetary missions.

A number of theoretical and experimental investigations on the effects of different forms of radiation on materials and electronic components were completed by NBS. These studies will aid in the design of shielding to prevent undesirable exposure of instrumentation and personnel to space radiation. Calculations were made of the energy transported and deposited by charged particles impacting on various materials, the effectiveness of multilayer shielding, and the influence of radiation on electronic and communications elements. Evaluation of data gathered by sodium-iodide detectors used on Apollo missions has begun. The detectors determined the angular distribution of gamma radiation on the lunar surface.

Time Service.—Precise time information is essential to satellite tracking and space vehicle navigation and maneuvering. The NBS provides accurate time frequency signals through its radio broadcast stations and has completed a one year experiment in which time signals were disseminated through the ATS 3 satellite. A newly designed system, which integrates commercial television, satellites, and the Department of Defense Omega Navigational System, will make the time signals more widely available. The NOAA Earth Sciences Laboratories are cooperating with NBS in developing a system to telemeter timing information to and from remote observing platforms using NOAA's Geostationary Operational Environmental Satellite (GOES).

Precise Geodetic Measurements and Lunar Ranging.—Retro-reflector packages placed on the moon during previous Apollo missions have been used to determine rotational and polar motions of the Earth, and variations in the lunar orbit. The NBS, using improved calculations of laser signals sent and received through the McDonald Observatory telescope, established the distance to the lunar surface to an accuracy of about 30 centimeters over a distance of 400 million meters.

Aeronautical Programs

Communications for Aeronautics.—Despite a temporary slowdown in the rate of growth of aviation, available air-to-ground communications resources are near saturation. The Office of Telecommunications (OT) investigated means to improve the efficiency of present facilities, and analyzed fundamental characteristics critical to the introduction of digital communications. Digital communication should have the effect of expanding available air-to-ground communications resources and should permit the introduction of extended automation in the Air Traffic Control system. The ultimate result should be an increase in the useability of air space and greater flight safety. This research has improved understanding of the communications medium, and has contributed to improved design and management for 1972 and the future.

Improvements in ground communications to support modernization and automation of the Air Traffic Control system have resulted from OT research, particularly in the design of microwave systems to assure reliable connections between remote radars and central computer control facilities.

Safety Services for Aeronautics.—Congressional concern over the mid-air collision problem has resulted in a program to establish a national standard for collision avoidance systems. An interdepartmental group is vigorously studying this subject to meet very short deadlines established by the Congress. The Office of Telecommunications has performed intensive research to establish the relationships between the existing prototype system and other electronic systems which potentially limit its effectivness—a critical issue in the planning for this safety service.

The National Severe Storms Laboratory has conducted studies to improve aircraft flight safety in the vicinity of thunderstorms. As part of this program, a dual-Doppler radar network is being constructed to map the horizontal wind within thunderstorms. Direct observations of thunderstorm turbulence obtained by aircraft have been correlated with measurements made indirectly by Doppler radar. Satellite data are used in these studies to correlate radar echoes and weather characteristics, to identify cloud and storm systems in their incipient phases, and to estimate the role of meteorological parameters in storm development.

The National Weather Service continued to provide a wide variety of services essential to safe and efficient aircraft operations. Observations, forecasts, warnings, pilot briefings, and in-flight advisory services were provided to domestc and international aviation interests.

Aeronautical Charts.—Evaluation of remote sensors for use in cartography was begun by the NOS. Emphasis was on small-scale aeronautical charts for use under visual flight rules. Two new series of charts were issued. One depicts the Standard Terminal Arrival Route (STAR) procedures, previously published in textual form in the Airman's Information Manual (AIM); the other, Airport Taxi Charts (published for selected airports), provides details on items such as airport buildings, service areas, runways, and taxi ramps.

The World Aeronautical Chart series covering the contiguous United States and Alaska was completed. These charts meet the Inter-Agency Air Cartographic Committee specifications for common use by civil and military aviation.

Support to Environmental Programs.—Techniques for obtaining measurements of the water equivalent of snow by remote sensing from aircraft have been developed and refined over the past three years. Operational testing of the technique in suport of flood forecasting was initiated in the north-central plains region and around Lake Ontario, the latter in support of the International Field Year of the Great Lakes.

Environmental Data Programs

NOAA's Environmental Data Service, (EDS) working with the National Environmental Satellite Service, established a program to provide NASA earth resources data to users. Photographic products acquired by NASA from airborne and spaceborne platforms in the NASA Earth Resources Survey Program are available for purchase through the EDS National Climatic Center (NCC), Asheville, N.C. As part of

this effort the NESS established an Earth Resources Survey (ERS) Data Center at Suitland, Md. The ERS Data Center has distributed more than 7,000 photographic products to government and non-government scientific investigators since the launch of ERTS I on July 23. EDS coordinated the establishment of earth resources imagery "browse files" for local users at 22 NOAA locations throughout the United States.

High altitude meteorological data received from cooperating foreign countries, the Meteorological Rocket Network, and the Inter-American Meteorological Rocket Network were processed and published. Data for March 1970 through March 1971 were published in the *High Altitude Meteorological Data* series.

Monitoring-type solar-terrestrial data recorded by satellites and space probes are archived by the National Geophysical and Solar-Terrestrial Data Center (NGSDC). NGSDC is the primary sources for the ionograms taken by the topside ionosonde satellites. Solar parameters (protons, X-rays, and solar wind) measured by satellites and space probes are published monthly in *Solar-Geophysical Data*—a primary reference for the international scientific and technical community. During 1972, new data on interplanetary electric- and magnetic-field measurements obtained by the PIONEER space probes were added. Similar monitoring-type solar-terrestrial data recorded by satellites and space probes are included in the Special Data Compilations in the World Data Center A for Solar-Terrestrial Physics UAG-Report series.

During 1972, the National Oceanographic Data Center continued to process aircraft expendable bathythermograms, and prepared to assess sea surface temperature data remotely sensed by aircraft and satellites.

Climatological applicatons of meteorological satellite data were explored by the Laboratory for Environmental Data Research. Monthly cloud cover amounts were estimated from meteorological satellite data for tropical areas of the Pacific and Atlantic Oceans. Long period variations in cloud amount in these ocean areas, and interocean cloud cover variations, are being studied because the amount of cloud cover is closely related to characteristics of the general atmospheric circulation.

XII United States Information Agency

Introduction

Although activities related to Apollo 16 and 17 highlighted the U.S. Information Agency's space programming in 1972, the Mariner and Pioneer planetary probes, Earth Resources Technology Satellite and future U.S. space projects all received considerable attention. As NASA's public information arm overseas, USIA devoted substantial programming to Skylab and the space shuttle, the practical benefits of space research and international cooperation in outer space. Foreign audiences maintained a high level of interest in U.S. space activities, and the Agency enjoyed the cooperation of NASA and the Smithsonian Institution in a number of successful projects. The Agency provided three multilingual escort officers for the NASA International Youth Science Tour in December, and USIA officers at Cape Kennedy assisted the foreign press covering the launches of Apollo 16 and 17.

USIA initiated a Presidential good-will visit to Poland and Yugoslavia by the Apollo 15 crew in January. Focusing on scientific results of their mission, the astronauts held round-table discussions with scientists from the disciplines supporting lunar exploration in Warsaw and Torun, the birthplace of Copernicus, in Poland and in Belgrade, Zagreb, and Ljubljana in Yugoslavia. The crew also addressed university audiences, held press conferences and appeared on television in both countries. The highly successful visit opened doors to increased exchange of space information with East European scientists.

Radio

The Voice of America broadcast detailed reports of Apollo 16 and 17 in 35 languages around the world. Coverage included interviews with the astronauts and key members of mission control, and extensive follow-up on the scientific achievements of the missions. Special broadcasts in English, Chinese, Russian, Span-

ish, French, and Portuguese reported live on flight progress along with on-the-scene news from VOA's multilingual correspondent teams at Cape Kennedy and Houston.

In addition to coverage of the two Apollo flights during 1972, VOA carried a constant flow of news reports on other U.S. space projects and developments. These included reports on Skylab, the space shuttle, the Mariner 9 and Pioneer 10 planetary probes, the Earth Resources Technology Satellite, Viking and the U.S./U.S.S.R. joint docking mission planned for 1975. VOA reporters interviewed scientists involved in the projects in English and the vernaculars, promoted space exhibits overseas and good-will visits of the astronauts and stressed the scientific gains of American space efforts. The U.S.S.R. division gave special attention to developments in United States-Soviet space cooperation.

Press and Publications

Continuing a service on which foreign editors, science writers and radio and television space specialists have come to rely, USIA produced special Apollo 16 and 17 feature packets of articles on the scientific importance of the missions, backgrounders on the astronauts, explanations of new scientific experiments and appropriate photographs and drawings. During the flights USIA reporters filed daily wireless stories from Cape Kennedy and Houston and followed up with analyses of data obtained by the missions.

Another space story receiving special attention from the Agency's press and publications service was the Earth Resources Technology Satellite, which was the subject of a series of four special wireless articles. Mariner 9, Pioneer 10, and the Orbiting Astronomical Observatory were covered in wire stories and mailed features. Several feature articles on the increasing space cooperation between the United States and the Soviet Union were sent to all posts. Major photo subjects were Apollo, Mariner, Skylab, and the space shuttle.

USIA's magazine in Russian and Polish, *America Illustrated,* carried a variety of articles and photographs on space, including, "Orbiting the Red Planet," "What's New in Space?," "What the Moon Is Telling Us," "The Computer and Space" and "Soviet-U.S. Space Docking Test."

Topic, the Agency's magazine for readers in Africa, featured stories on satellite communications, lunar geology and the space shuttle. The Arabic-language magazine *Al Majal* carried articles on the benefits of space research, the U.S./U.S.S.R. joint docking mission and a feature on Egyptian-born lunar geologist Farouk El Baz.

Motion Pictures and Television

The number of prints and foreign language versions of space films ordered by USIS posts was evidence of continuing interest in space by viewers abroad. When the Agency's motion picture and television service announced the availability of NASA's color documentary "Promise of the Moon: Apollo 16," 93 posts ordered 269 prints in 14 language versions. USIA's own television program "Windfall From Space," which contains new information on the benefits space exploration has brought to other activities of mankind, received an equally favorable response—200 prints ordered in 12 languages. Five language versions and 121 prints of the NASA documentary "A Man's Reach Should Exceed His Grasp," covering aeronautical and space history from the Wright Brothers to Apollo 11, were ordered, and four prints of the NASA feature documentary "Moonwalk One" were acquired for theatrical distribution in Yugoslavia. USIA's Science Report, sent monthly to 70 countries for use on television and in schools, featured Mariner 9, the Third Lunar Science Conference, Apollo 16 and 17 and Skylab.

Excellent usage reports were also received on USIA space news clips, especially during the flights of Apollo 16 and 17, and older space documentaries are reused repeatedly. An estimated 150 countries have some USIA space films or television programs, which during 1972 were seen by millions of people. Of the 10 films most used in direct projection during the year, four were NASA color documentaries and one was USIA's feature documentary "The Infinite Journey," released in 1971 to commemorate the first landing on the moon.

Satellite television programming included the visits of Presidents Tito of Yugoslavia and Medici of Brazil, a program inaugurating color telecasting in Brazil, and American participation in the opening of satellite ground receiving stations in Jordan, Israel, and Ecuador.

Representatives of the Agency's motion picture and television service assisted and arranged interviews for foreign television producers at Cape Kennedy during Apollo 16 and 17. Foreign correspondent's one-to-two minute reports were filmed at the launch site and sped by air to their home stations for telecast. USIA provided special coverage of the launch of the Orbiting Astronomical Satellite "Copernicus" for use by Polish television.

Information Centers and Exhibits

Fascination with U.S. space achievements was evident in visitor reaction to space exhibits and artifacts included in major U.S. exhibitions overseas. The Apollo 10 Command Module, which accompanied the

large "Research and Development—USA" exhibition on a six-city tour of the Soviet Union was one of the chief attractions for the approximately 2 million visitors. A full-scale mock-up of the Skylab living quarters, with its many examples of how ingenious scientists and designers had solved the problems of living and working in space, intrigued 386,000 Polish visitors to the U.S. exhibition on "Industrial Design at the Poznan International Trade Fair. The model later drew an estimated one million visitors in a tour of several Japanese cities.

Another highly successful space exhibition was the "Moonrock Express," which began a series of showings in the Netherlands in 1971, and continued in West Germany throughout most of 1972. This educational exhibit traveled from city-to-city by train and truck, featuring a lunar rock sample and various space artifacts, all with explanatory captions and textual materials. In a year and a half some 5 million viewers visited the exhibition in the two countries.

Sixteen other traveling space exhibits toured East and West Europe, Latin America, Africa, and Australia. Among them was an unusually interesting collection of space artifacts including Astronaut Bean's spacesuit and helmet, "Buzz" Aldrin's glove, a Hasselblad space camera, a space sextant and an Apollo 11 navigational star chart displayed in Zagreb, Yugoslavia, and Warsaw to large, receptive crowds.

The six moon rocks on loan to the Agency from NASA were displayed in 16 countries. The most unusual exhibit was in Mecca, Islam's holiest city, which is closed to non-Muslims. Here the rock was viewed by 1,800 university students, city administrators, educators and the judiciary during a space film and lecture program at the College of Education. Some Meccans doubted the authenticity of the rock and of the manned lunar landings. A professor of Islamic jurisprudence, overhearing the whispers of disbelievers, gave a brief impromput speech asserting as fact that man had landed on the Moon and that nothing in Koranic teachings contradicted that fact. USIS Jidda called the event a historic first and an auspicious precedent for future cooperative programs with Islamic educators.

USIA published translations of five books on space in Thai, Arabic, Korean, Chinese, and Burmese for a total of 39,000 copies and sent numerous documents and pamphlets on space to USIS libraries throughout the world for reference use.

Summary

Using all effective communications media at its disposal, the U.S. Information Agency told the story of U.S. space accomplishments during 1972 to foreign audiences around the world. While Apollo 16 and 17 were the highlights of the year in space, considerable coverage was also given to ERTS, Mariner and Pioneer, Skylab and the space shuttle, as well as the U.S./U.S.S.R. joint docking mission planned for 1975 and the benefits of space research. Major exhibits included a six-city tour of the Apollo 10 Command Module in the Soviet Union and a full-scale mock-up of the Skylab living quarters in Poznan, Poland. A historic first was achieved when a moon rock was displayed in Mecca, Islam's holy city. The Agency initiated a highly successful Presidential good-will tour to Poland and Yugoslavia by the Apollo 15 crew in January, which opened the doors to increased exchange of space information with East European scientists.

XIII National Science Foundation

Introduction

As an independent agency established to promote the progress of science, the National Science Foundation supports scientific research in all fields of science. Research related to aeronautics and space science can be found throughout many of the Foundation's programs. Most of the research project support is provided to investigators based at colleges and universities. An important segment of this support is provided through a number of national research centers administered by contract for the National Science Foundation.

Astronomy.—A variety of theoretical investigations focusing on understanding the sources of celestial X-rays were pursued at universities. Many of the X-ray sources in our Milky Way are binary stars with one of the components suspected of being a black hole. The

extremely strong gravitational field of the black hole may suck clouds from the more ordinary member of the pair onto the surface of the very condensed, dark companion. X-rays are given off as the infalling material accelerates and impacts onto the black hole. Cosmic X-rays are also generated in hot gas filling the space between galaxies in some of the rich clusters. The gas is very rarified but may be as hot as tens of millions of degrees. Theoretical studies are in progress to determine the source, extent, and heating mechanism for this gas.

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. and one at Kitt Peak, Ariz. Two new receivers were developed during fiscal year 1972, a dual-channel, cooled 1350–1430 MHz receiver for the 140- and 300-foot telescopes and a 33–50 GHz mixer receiver for the 36-foot telescope. The 140-foot telescope drive and control system was modernized and placed under computer control. During the year, radio radiation was discovered from the eclipsing binary star Algol, and the spectacular radio explosion in the X-ray source Cygnus X–3 was monitored by all telescopes at Green Bank. Initial funding was received for the Very Large Array project and a site for the array was chosen in the Plains of San Augustin, 50 miles west of Socorro, N. Mex.

Kitt Peak National Observatory (Arizona).—The national center for optical astronomy provides frontier research support facilities for American astronomers. More than 200 visiting astronomers used the KPNO facilities during 1972 and represented more than 50 different institutions active in astronomical research. The year 1972 marked the tenth anniversary of the McMath Solar Telescope, the most powerful and versatile solar instrument in existence. This 63-inch aperture telescope has provided fundamental data on the solar magnetic and velocity fields, and on the chemical composition and physical condition of the solar atmosphere. Six other stellar telescopes were also in operation; the largest of these is the 84-inch telescope which was used this year for a number of exciting studies of the quasars and peculiar galaxies, old and young stars of our Milky Way System, and the tenuous stratum of dust and gas lying between the stars of our galaxy. Kitt Peak National Observatory has maintained a small sounding rocket program in support of astronomical and aeronomical studies. Two groups of visitors flew experiments on KPNO rockets during 1972, one payload was an ultraviolet spectrometer which obtained excellent data on the X-ray source Sco X–1. The second flight carried infrared detectors which surveyed the central regions of our galaxy.

Cerro Tololo Inter-American Observatory (Chile).—The Cerro Tololo Inter-American Observatory, with its administrative headquarters in the city of La Serena, is located at a superb site in the Chilean Andes. The facilities include six stellar telescopes which provide unique opportunities for American astronomers to study celestial objects visible from the Southern Hemisphere. Excellent observing conditions prevail at both infrared and visible wavelengths. More than 70 astronomers from 35 institutions made observations at CTIO during 1972. During the year, several new pieces of auxiliary instrumentation were introduced into use with the CTIO telescopes. These included a photoelectric scanner operated under computer control with the CTIO data system. A faint star photometer is also now in use. This instrument promises to be especially valuable for research programs in the Magellanic Clouds. Recent studies by CTIO astronomers have led to the identification of many pulsating variable stars in the Magellanic Clouds and these objects will enable astronomers to learn more about the distance, age, and evolution of these neighboring galaxies.

National Astronomy and Ionosphere Center (Puerto Rico).—This unique facility makes available to scientists and students throughout the United States a 1,000-foot-diameter radio telescope, by far the largest of its kind in the world. The observatory has contributed to space science through its radar studies of the moon and planets, providing orbital information necessary for the successful guidance of spacecraft, topographical information, and the terrain elevations which are essential to the success of the Viking landers on Mars. Through conventional radio astronomy techniques, information on the radiation belts and temperatures in the lower atmospheres of the planets have been obtained.

Solar Terrestrial Research Program.—The role of photosynthesis in the biosphere is well known. Less well known is the solar influence in determining the physical nature of the Earth's outermost environment. The Earth actually resides in the upper atmosphere of the Sun, an incessant stream of hot plasma carrying along with it magnetic fields rooted at the Sun. As this "solar wind" sweeps past Earth it interacts strongly with the terrestrial magnetic field, and this interaction is responsible for the structure and dynamics of the charged-particle populations trapped therein. The presence of solar plasma and fields in interplanetary space also affects the intensity of galactic cosmic rays reaching earth, and the sun itself occasionally emits large number of particles of cosmic ray energy. This program supports a wide variety of observational and theoretical projects concerned with understanding the solar atmosphere and how it determines the behavior

of particles and fields in interplanetary space and at earth and the nearby planets. A major accomplishment of the past year has been the progress made in learning how the large-scale electric fields and the associated plasma motions within the magnetosphere depend on solar-interplanetary parameters.

Aeronomy Program.—The Aeronomy Program encompasses the physics and chemistry of the atmosphere from the stratosphere to the magnetosphere of the earth and the other planets. Laboratory investigations of reaction rates and cross sections of both neutral and ionized atmospheric constituents provide vital information to the modeling efforts carried out by theorists. These models, which represent our understanding of the high atmosphere, must in turn be checked by observation. Incoherent scatter radar continues to be the premier tool for field observations. During 1972, studies of the auroral region ionosphere with the incoherent scatter radar at Chatanika began to bear fruit. First results were obtained on the relationship of the spatial distribution of ionospheric ionization to the position of the aurora. Incoherent scatter radar measurements at several latitudes have revealed a need for information on neutral winds at high altitudes. Such winds are now being inferred from a combination of radar and optical studies of the behavior of the ionosphere both at Arecibo, Puerto Rico and at Chatanika, Alaska. All of these observations are important to the understanding of the ionosphere for its use in radio communication. Recently, it has been shown that the neutral stratosphere can be studied with the incoherent scatter radar at Jicamarca, Peru. This opens another method of stratospheric investigation to scientists from the United States.

Meteorology Program.—The National Science Foundation supports a wide range of meteorological investigations of importance to aeronautics, including the dynamics and energetics of extra-tropical storm systems, the modeling of isolated cloud systems, the role of gravity waves in transferring momentum and energy from the lower atmosphere to the upper atmosphere, fundamental studies of the behavior of rotating convecting fluids which form the basis of all dynamical understanding of the motion of planetary atmospheres and the development of Raman scattering techniques for the measurement of atmospheric water vapor concentration. Fund transfers by the Department of Transportation to the National Science Foundation supported work on modeling of radiative effects using a general circulation model at the National Center for Atmospheric Research, the construction of airborne sensing equipment to measure the constituents of the stratospheric atmosphere, modeling studies of stratospheric photochemistry, laboratory studies of the formation of stratospheric aerosol, and balloon measurements of nitric acid in the stratosphere.

National Center for Atmospheric Research.—During 1972, the National Center for Atmospheric Research (NCAR) High Altitude Observatory (HAO) has developed some new concepts concerning relationships between periodic changes in the terrestrial upper atmosphere and the Sun's 27-day rotation period. These magnetic disturbances have been widely attributed either to particles from long-lived solar sources, or to solar activity regions. By combining detailed theoretical models of the solar wind in the presence of coronal magnetic fields, spiral beam paths deduced from particle speeds, and the magnetic characteristics of the beam, a tentative conclusion has been reached that geomagnetic activity is related to the flowing of coronal plasma and not to solar activity. HAO scientists have also developed a geometrical model to explain how ejecta from a solar flare moves in a distinct "blob" through space. These results help to better define the nature of solar particles, magnetic activity and energy from the Sun which men in space will encounter outside the earth's atmosphere. The Apollo Telescope Mount (ATM) coronograph, developed by HAO, has undergone final testing and has been delivered to NASA. This instrument, which will provide continuous observations of the Sun's corona from changes in the Earth's atmosphere, is to be mounted in the SKYLAB now scheduled for launch in April 1973.

Working with colleagues from the University of Michigan, NCAR scientists, using stellar occultation measurements from the OAO–2 satellite, have determined the nighttime molecular oxygen and ozone number density distribution in the lower thermosphere and mesosphere. Theoretical studies at NCAR have led to the development of an automated meteorological analysis technique which will enable meteorologists to pinpoint locations of probable clear air turbulence, a forecasting technique of importance to commercial airlines. The computer program will be available by the beginning of 1973 for airline meteorologists to use in planning flight paths to avoid major turbulence as well as some other weather hazards.

An instrument to detect and measure clear air turbulence has been designed and is presently being fabricated. Several of these instruments will be flown on commercial 747 aircraft. Isotopic studies of sulfate and nitric acid vapor in the stratosphere have shown a similar composition in both hemispheres. This tentatively rules out manmade pollution as the prime source of atmospheric sulfur and points to natural phenomena (e.g. volcanoes) as the prime causes for this contamination. Isotopic studies of nitrogen are underway to discover if the source of nitric acid vapor is the photodissociation of molecular nitrogen at very high altitudes or the oxidation of nitrous oxide. These studies

are important in determining the impact of supersonic aircraft on the stratosphere.

Engineering.—The majority of research support in Engineering is provided for the understanding of basic phenomena, including work in such problem areas as unsteady boundary-layers, separation and nonlinear wave propagation. However, organized areas with application to more immediate goals have also received serious attention during the past year. An example of the latter, is wind engineering research where numerical techniques and experimental procedures developed for aerospace related problems are being adopted to study the wind and tornado induced loads on engineered structures. Joint projects were funded where structural and aeronautical engineers jointly examined such diverse but fundamentally related topics as suspension bridge aerodynamics response, surface roughness effects on the wind loading of hyperbolic cooling towers, wind tunnel studies of interference and interaction of adjacent structures and studies on the turbulence structure in the lower reaches of the atmospheric boundary-layer. A feasibility study is underway to examine the design details for a new type of meteorological wind tunnel. This type of facility will be necessary in the simulation of turbulent shear flow found in the lower regions of the atmospheric boundary-layer and would be invaluable to wind engineering activities

Materials Research.—Although much materials research is fundamental and general in character, the results can often be relevant, either directly or indirectly, to materials-related space and aeronautical applications. Three examples of ongoing programs having particular implications for space technology are research on solid state electrolytes and novel cathode structures for all solid state batteries, liquid epitaxial growth of compound semiconductor heterojunctions for potential application to solar energy conversion, and the study of shape-memory effects associated with structural phase transitions in alloys. Research is also carried out on a wide variety of structural materials ranging through metals, alloys, composites, and polymers, as well as on basic phenomena related to the mechanical, processing and environmental properties of such materials. The broad area of electronic and optical materials continues to be one in which there is a clear relationship to aerospace requirements. Significant work is being carried out on the nonlinear optical properties of materials.

Chemistry.—As interest in stratospheric air transport has grown, and as astronomers discover the existence of certain chemical compounds in interstellar space, it has become apparent that understanding the photochemistry and rates of reactions of small molecules and molecular fragments, such as water, ozone, nitrogen oxides and hydroxyl radicals, is a crucial part of the technology of flight. Chemists have long been interested in such reactions. Foundation grantees have worked out theory and experiments which show that the vibrational energy state of the molecules may determine what reactions occur and how fast. It has become clear that simply shining ultraviolet light on moist carbon dioxide vapor generates a complex mixture whose reactions can only be sorted out with a computer. Another reaction with new facets is that between ozone and hydrocarbons. The current mechanism for this reaction is being reexamined.

Mathematics.—A broad spectrum of mathematics research supports aeronautics and space activities. Algebra, analysis, and topology programs provide a base for techniques used to formulate and solve problems arising in applications. Research in dynamical systems, control and optimization, both deterministic and stochastic, are pertinent to these activities. Specific projects in the mathematical theories of dynamics, wave motion, thermodynamics, magneto fluids dynamics, stellar dynamics, coding, mathematical programming and celestial mechanics, all of which may contribute directly to the aeronautics and space program, are under way.

U.S. Polar Research Programs.—The NSF Office of Polar Programs supports a solar-terrestrial research effort using ground-based stations and balloon-borne instrumentation. At several locations unique to the Antarctic, observations are made of auroral events, interactions between solar particles and the earth's magnetosphere and ionosphere, and other upper atmosphere phenomena. An unmanned geophysical observatory (UGO), similar in concept to the Lunar ALSEP, was developed by NSF and placed in operation in Antarctica during 1972. The UGO transmits data from solar terrestrial and meteorological instruments to the United States in real time via an INTELSAT satellite. Data buoys placed in the Arctic Ocean during the Arctic Ice Dynamics Joint Experiment (AIDJEX) in spring 1972 are transmitting meteorological data via Numbus D. Satellite images continue to be used for studies of meteorology and sea ice extent in the remote polar regions. Moreover, recent ERTS–1 images are enabling significant new and varied investigations of sea ice properties.

Educational Activities.—In fiscal year 1972, approximately $1.3 million was obligated by the Foundation's three Education Divisions for activities which were related to the aeronautic and space sciences. The great-

est proportion of these funds supported the training of graduate students through fellowships and traineeships. These funds also provide for upgrading the aeronautic and space sciences subject matter background of teachers in secondary schools, colleges and universities, unusual independent study and research experiences for students and the improvement of instructional programs in these disciplines at all levels of education.

XIV National Academy of Sciences National Academy of Engineering National Research Council

Introduction

The National Academy of Sciences and the National Academy of Engineering are private organizations of scientists and engineers that serve as official advisors to the Federal Government under a Congressional act of incorporation. These advisory services are carried out largely by the National Research Council, which was established by the Academy to act as an operating agency.

Highlights of the work of the Academies-Research Council during 1972 in aeronautics and space include special studies by the Space Science Board in planetary and astronomical research and in space biomedicine; the Aeronautics and Space Engineering Board's counselling on aircraft noise abatement and the space shuttle; establishment of the Space Applications Board and the Climatic Impact Committee; advice on remote sensing programs by the Committee on Remote Sensing Programs for Earth Resource Surveys and on aerospace materials by the National Materials Advisory Board; the Committee on Atmospheric Sciences' review of weather and climate modification; evaluation of the Sanguine communications system by the Committee on Solar-Terrestrial Research; administration of NASA fellowships; and review and advisory work in aeronautics and aerospace science and applications.

Space Science Board

The Space Science Board is a consultative group concerned with shaping the most effective national program in space research. On behalf of the National Academy of Sciences, it advises the Government on scientific aspects of the space program and represents the U.S. scientific community internationally on the Committee on Space Research (COSPAR) of the International Council of Scientific Unions.

The Board met five times during 1972 to discuss outstanding matters in space science with NASA management and senior staff of the President's Science Advisory Committee, National Science Foundation, National Aeronautics and Space Council, and other interested agencies. Close liaison is maintained with the National Academy of Engineering's Aeronautics and Space Engineering Board and its newly established Space Applications Board (see below). As is customary, sessions were scheduled to take into account critical times in budget planning and formulation; thus the Board's views have been available to program planners for consideration. Briefings and discussions gave particular attention to major thrusts in space science for the 1980s, plans for scientific utilization of the space shuttle, scientific and biomedical results of Apollo, increased international cooperation, and Department of Defense space technology programs. In addition, special studies were conducted on planetary quarantine policy, space astronomy, exploration of Venus, and solar cell efficiency.

The Board's ad hoc Committee for Review of Planetary Quarantine Policy met in Denver in February 1972 to review proposed changes in the NASA quarantine policy for the moon and planets. Particular attention was directed to the sterilization procedure for the Viking 1975 spacecraft and its probable effect on preserving the quarantine of the Martian planetary surface and atmosphere. In April, the Board, augmented by six invited astronomers, reviewed the NASA program in space astronomy. The recommendations of the Board's 1970 study, *Venus: Strategy for Exploration,* were reviewed by an ad hoc panel in the light of results from the 1971 Soviet spacecraft Venera 7 and reaffirmed. The conclusions and recommendations of the above studies were transmitted to NASA.

The report of a study conducted by the Board in cooperation with the Academy's Solid State Sciences Committee, *Solar Cells: Outlook for Improved Efficiency,* was published by the Academy in June 1972. The study, made at the request of NASA, concluded

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that, with sufficient effort, increased solar cell efficiencies up to 20 percent (from the present 11 to 16 percent) are probable with reasonable improvement in materials.

The Board has several standing committees which maintain a continuing overview in major fields of space science. Among these are space biology and medicine, international relations, and rocket research. Toward the end of the year, the Board established a new Committee on Space Astronomy to advise on the broad range of astronomical questions and potential missions being considered in the space program. Particular interest in the immediate future will focus on the high energy astronomical observatories and large space telescope.

Space Biology and Medicine.—An ad hoc group of the Committee on Space Biology and Medicine reviewed cardiovascular and metabolic effects of manned spaceflight in December 1971 and January 1972 with special attention to biomedical results of the Apollo 15 mission. The group's recommendations, which centered on the cardiac disturbances experienced in Apollo 15, were implemented in time for the Apollo 16 mission in April 1972. No biomedical difficulties occurred during that flight. The group met again in August to review and advise on medical procedures planned for Apollo 17.

The Committee's Radiobiological Advisory Panel during 1972 conducted a review of NASA's radiobiology program and facilities. The Panel's report, transmitted to the agency in August, offers guidelines for focusing NASA's radiobiological effort onto investigations that will be most likely to fill the anticipated needs of manned spaceflight in this area. Consideration is given to the extensive research in radiobiology supported by other sources. The Panel is currently completing a report responsive to the second area of advice requested by NASA, the biological effects of high-energy heavy (HZE) particles.

Human Factors in Manned Spaceflight, the results of a special Space Science Board study, was published as an Academy report in the spring of 1972. Prepared at the request of NASA, the volume analyzes behavioral, psychological, and medical factors of manned spaceflights of up to two years' duration and recommends research that will be most useful in dealing with problems of long-duration missions.

The final report of the ad hoc Panel on Desynchronosis was forwarded to NASA early in the year. Its charge was to examine the likely effects on man of rapid time zone changes, as in jet air flight, and to offer guidelines for further investigations and research.

International Relations.—The formal international activities of the Space Science Board are centered in the Committee on Space Research (COSPAR). COSPAR, an inter-Union organization of ICSU, fosters fundamental research in space science through the use of space vehicles. Data and significant results are exchanged on a cooperative basis through the World Data Center system. COSPAR accepted the invitation of the Consejo Superior de Investigaciones Cientificas de España to host the 1972 Annual Meeting in Madrid, Spain, May 10–24, 1972. Symposia included: Planetary Atmospheres and Surfaces, Critical Problems of Magnetosphere Physics, and X-Ray and Gamma-Ray Astronomy (nonsolar). As in past years, the Board's Committee on International Relations organized U.S. participation in the meeting, reviewed U.S. contributed papers, and prepared the annual report to COSPAR on U.S. space research during 1971. A preliminary report of the meeting has been completed and distributed.

Aeronautics and Space Engineering Board

The Aeronautics and Space Engineering Board (ASEB) of the National Academy of Engineering provides advisory services to government agencies interested in aeronautical and space engineering.

In aeronautics the ASEB continued its review of current and proposed NASA research and development programs. Special emphasis was placed on studying the relative merits of conventional, short, and vertical take-off-and-landing aircraft (CTOL, STOL, and VTOL, respectively) for use during the 1980's and beyond. A recent Board meeting was held at the Lewis Research Center where problems of aircraft noise in the airport community are being studied in some detail; the on-going and planned programs at Lewis for aircraft engine noise abatement and related projects were reviewed. Other problems associated with the future of Civil Aviation Research and Development (CARD), as identified by the Joint NASA-DOT Policy Study Group on the subject, remained high on the Board's agenda of matters requiring and receiving continual engineering consideration.

In space engineering the ASEB has continued its review of progress and future plans in the NASA space shuttle program. Ways and means of reducing costs of future spaceflight and experimentation are under study. It is anticipated that this work will increase in volume and intensity.

The Board's conclusions and recommendations have been transmitted informally by its Chairman to the Administrator of NASA. Emphasis was placed on those areas of research and development which the Board believed should receive special attention during in the years ahead.

Space Applications Board

The National Academy of Engineering is establishing a Space Applications Board whose function will be to

provide advice and recommendations from a national viewpoint to all elements of the Federal Government, including Congress, on the application of space techniques and capabilities to benefit the nation and mankind. Through continuing review and analysis of the need and capabilities of present and projected space applications programs, the SAB will stimulate active collaboration among the various components of the government and industrial communities whose combined interests and resources will be required to meet the needs of and achieve the maximum benefits from space applications. By broad dissemination of its findings through multiple mechanisms, the SAB will assist in informing industrial segments of new space applications that offer potential benefits to industry and the public welfare.

In view of the broad range of activities to which space systems may be applied, it was anticipated that a wide variety of expertise, drawn mainly from the industrial and academic communities, would be needed on the SAB. Therefore, the NAE elected to approach the organization of the Board through an initial six-month planning activity which was scheduled for completion early in 1973. The Organizing Committee's report to the President of the NAE will recommend a charter for the Board, suggest a mode of operation for consideration by the Board for the initial phases of its work, and recommend candidates for its chairman and members. The Board is to begin functioning early in 1973.

Division of Behavioral Sciences

Committee on Vision.—During 1972, a working group on Visual Elements in Flight Simulation surveyed research activities and technical developments at a number of government and private laboratories around the country. A final report summarizing the group's findings will soon be published.

A working group on Effects of Drugs on Vision has listed tests of visual function that it considers most likely to show drug effects. Another working group on Air-to-Air and Air-to-Ground Visual Detection has made a preliminary analysis of visual tests that are most likely to predict superior search performance and has outlined the types of information needed by a visual scientist for research that will yield results valid for a particular search task.

The Committee's general meeting in 1972 featured review papers on pattern recognition, eye movements, and effects of drugs on vision.

Division of Earth Sciences

Committee on Remote Sensing Programs for Earth Resource Survey (CORSPERS).—In recognition of the broad spectrum of potential users of remotely sensed data from both spacecraft and aircraft platforms, the Committee on Space Programs for Earth Observations, Advisory to the Department of the Interior, was re-named as the Committee on Remote Sensing Programs for Earth Resource Surveys and was reorganized to include both aircraft and spacecraft platforms in its range of interests. It was also made advisory to all Federal agencies having a potential user interest in remotely sensed data. This includes the Departments of the Interior (USGS), Commerce (NOAA), Agriculture, Navy, Army (Civil Works, U.S. Army Engineers), and the Environmental Protection Agency. In order to cover this range of interests, the CORPSERS organized itself into seven standing application panels: Geology: Mineral and Land Resources; Geography: Land Use; Nydrology: Water Resources; Oceanography: Marine Resources; Cartography: Mapping and Charting; Biology: Agriculture, Forestry, Range, and Wildlife; and Environmental Measurements. In addition, CORSPERS may establish ad hoc panels to conduct specific one-time interdisciplinary studies of interest to the remote sensing program. Such an ad hoc panel was convened during the year to review the information management considerations of the Earth Resource Survey Program.

The Committee has initiated a broad review of the usefulness of remotely sensed data based on the experimental results obtained by the ERTS–1 experiments. This review, with conclusions and recommendations, should assist federal agencies in formulating a responsive national program in remote sensing.

Division of Engineering

National Materials Advisory Board.—The National Materials Advisory Board (NMAB) is composed of about 25 specialists in the science and technology of materials, chosen from industry, universities, research institutes, and government. The general purposes of the Board is to foster the advancement of materials science and engineering in the national interest. Since aeronautical and space projects require the most advanced materials technology, NMAB devotes a significant part of its activities to defining technical problems in aerospace materials and furnishing advice to the government, and indirectly to industry and academe, on research and development in aerospace materials.

Several studies completed in 1972 relate to materials in aerospace applications. An NMAB ad hoc committee has made a selective survey of the needs for new and improved accelerated testing techniques and predictive methods for forecasting the performance of materials in structures and components under combined stresses in service. The Committee's report (NMAB–288) provides suggestions for establishing a policy for government/industry interaction and recommends mechanisms for implementing this policy. In the area of nonstructural materials, the report "Materials and

Processes for Electron Devices" (NMAB–289) identifies needs and deficiencies in electronic materials and suggests technical approaches for alleviating these deficiencies. A study on high-power infrared laser windows (NMAB–292) assesses loss mechanisms associated with the transmission of high-power infrared laser energy through solid materials. It makes recommendations on experimental methods to evaluate these effects and on classes of solid material that have potential as high-power laser windows.

Several studies in aerospace materials initiated in 1971 and 1972 are continuing. Among them are: a study of materials for radiation detection; a study to define the technical potential of high-performance castings and the problems of producing them in both ferrous and nonferrous materials; a study of problems involved in producing high-temperature-resisting metallic composites by directional solidification and, specifically, a survey of adhesives for structural use in aeronautical and space vehicles, with the objective of accelerating applications where advantage would accrue in performance or economy.

Division of Physical Sciences

Astronomy Survey Committee.—Volume I of the report of the Astronomy Survey Committee, *Astronomy and Astrophysics for the 1970's*, was published by the Academy in midyear. The comprehensive survey outlines a 10-year program for gound- and space-based research. In its major space-related recommendation, the Committee calls for a series of high-energy astronomical observatories to be launched in the latter half of this decade. The compilation of the reports of the Committee's specialized panels will be published early in 1973.

Climatic Impact Committee.—The Climatic Impact Committee was established under the National Academy of Sciences and the National Academy of Engineering in 1972. Its purpose is to advise the Department of Transportation (DOT) and other interested government agencies on the planning of, and the interpretation of results from, a research program to assess the climatic impact of high-altitude aircraft, including the supersonic transport, and of other activities of man which can affect the atmosphere and particularly the stratosphere.

For several years scientists in various countries have been studying the composition, chemistry, and dynamics of the stratosphere and have greatly increased man's knowledge of the role of the stratosphere in atmospheric processes. Recently, however, discussions of the potential atmospheric effects from the large-scale operation of supersonic transports (SST) in the stratosphere have delineated specific areas where uncertainties exist in present knowledge. For example, the natural concentrations, variability in time and space, sources, sinks, and removal rates of such gases as NO_x, H_2O, and CO suggest that these substances may influence ozone depletion processes. There are, as yet, inadequate data on the ambient concentrations of these constituents or on the injection rates from high-altitude aircraft. In 1971 a Climatic Impact Assessment Program (CIAP) was initiated by DOT to support research in meteorology, climatology, chemistry, biology, engineering, medicine, economics, and related areas. In response to the DOT request to the Academies, the multidisciplinary Climatic Impact Committee will carry out the following tasks: (1) advise on research priorities; (2) follow the progress of research sponsored by CIAP, and others as it may bear on the CIAP, review the results, and advise on the significance of the investigations; and (3) consider a possible summer study in 1974 that would assess the state of knowledge developed by the CIAP, as well as the other knowledge available at that time, and arrive at a set of conclusions regarding the likely effects of a fleet of SST's on the earth's climate and the biosphere.

Committee on Atmospheric Sciences.—The Committee reviews in broad perspective the current status of research activities, education, and exchange of information as they may affect progress in the atmospheric sciences. The Committee encourages those activities that will foster a balanced national scientific program and seeks to stimulate U.S. participation in pertinent international programs.

The review by the Committee's Panel on Weather and Climate Modification has been completed and is to be published in 1973. It points out progress made in the United States since the Committee's earlier study in 1965 and the continuing problems that exist in this field.

It is becoming possible to specify those atmospheric circumstances during which seeding may produce no significant changes or may result in a decrease of precipitation. The Committee recommends that a national goal in this field should be to specify by the year 1980 the meteorological conditions under which precipitation can be increased, decreased, or redistributed in representative meteorological regimes. The development within the next decade of the technology to mitigate the effects of severe weather hazards is advanced as an additional goal for a national program in weather modification. The polar-orbiting and geostionary satellites of NOAA and NASA are foreseen by the Committee as major components for monitoring atmospheric concentrations of trace gases and particulates. Using a variety of remote sensing techniques, these platforms can provide basic and continuing observations on water vapor, ozone, CO_2, and SO_2, and can measure atmospheric cloud cover, albedo, and heat budgets. These capabilities, in conjunction with

ground-based remote sensing devices such as acoustic and optical radar, should be exploited as part of a national monitoring system to investigate the effect of man's activities on the composition of the atmosphere and on climate.

A similar conclusion has been reached by an additional study by the Committee on current activities in atmospheric chemistry. This study notes that present knowledge of the causes of climate and climatic change is incomplete. The sources, transport, and sink of trace atmospheric constituents must be monitored on a continuing basis to develop a physical explanation for the variation in climate, and to evaluate the impact man is now having, or is likely to have, on short- and long-term variations in climate.

With man's continuing need for natural resources to meet the growing requirements for energy and for the production of adequate supplies of food, regional and global climate and climatic change must be a priority environmental problem whose physical processes must be fully understood well in advance of the development of significant climatic trends.

U.S. Committee for the Global Atmospheric Research Program.—The Global Atmospheric Research Program (GARP) is an international scientific and technical program having as its primary objectives the improvement of knowledge of the dynamic processes of the general circulation and the development of a physical basis for understanding climate and climatic change. This undertaking is being developed by many cooperating nations working through the International Council of Scientific Unions (ICSU) and the World Meteorological Organization (WMO). The U.S. Committee for GARP is the principal scientific mechanism for development of the United States program and its coordination with international activities.

The first major field experiment to be undertaken by GARP is the GARP Atlantic Tropical Experiment (GATE) to be conducted in June–September 1974. Designed to study the interaction of atmospheric motions with the general circulations, the experiment will mount coordinated observations of the tropical atmosphere from ships, satellites, aircraft, buoys, balloons, and land stations.

The First GARP Global Experiment (FGGE) will be undertaken in 1977 and last for a year. In addition to observations from land stations, ships, buoys, and aircraft in both hemispheres, primary observational data will be secured from five geostationary satellites to be launched and operated by the U.S.S.R., Japan, Europe (ESRO), and the United States (2). Complementary programs to the FGGE that are presently under consideration and being planned are: the Air Mass Transformation Experiment (AMTEX); the Monsoon Experiment (MONEX); the Radiation Subprogram, and the Polar Experiment (POLEX). In addition, proposals have been made for regional programs in the Mediterranean and Saharan areas.

Committee on Solar-Terrestrial Research.—The Committee on Solar-Terrestrial Research (CSTR) of the Geophysics Research Board is the National Academy of Sciences' affiliate to the ICSU Inter-Union Commission on Solar-Terrestrial Physics (IUCSTP), which has recently been converted to an ICSU Special Committee. The Committee reviews the status of U.S. research in solar-terrestrial problems, assists in coordinating this research with that of other countries, and provides advisory services to the Federal government.

The Committee's studies, although dealing principally with ground-based research, are directly relevant to the space program because these ground-based observations are used in support of, and in some cases in lieu of, observations with space vehicles. An ad hoc Panel convened to consider current and future requirements for ground-based cosmic ray observations using neutron monitors transmitted its findings to the National Science Foundation in March 1972. At the request of the Department of the Navy, a study panel was appointed in 1971 to evaluate the technical feasibility of an ELF communications system known as Sanguine. This system is based on propagating signals from a buried antenna to submerged submarines via a spherical "duct" defined by the ionosphere and the earth's surface. The panel's report was issued in May.

A part of the IUCSTP program is the International Magnetospheric Study 1976–1978, which is aimed at international coordination of long-term magnetospheric experiments including space, ground-based, balloon and rocket measurements. CSTR is to conduct in January 1973, in cooperation with the Space Science Board, a study to identify the fundamental unanswered scientific questions regarding the earth's magnetosphere and to appraise opportunities for U.S. participation in the IMS.

Committee on Radio Frequencies.—The Committees on Radio Frequencies (CORF) and its subcommittee on Space Science, Radio Astronomy, and Earth and Life Sciences, serve as a channel for coordinating the knowledge and views of the U.S. scientific and engineering communities regarding the radio frequencies needed for research. CORF is currently concerned about the possible interference by broadcast satellites in the 2500–2690-MHz band to radio astronomy observations in the 2690–2700-MHz band. Working with representatives of Federal agencies, CORF has arranged for tests using transmissions in the 2500–2690-MHz band from the ATS satellites to determine what measures can be taken to protect the radio astronomy ob-

servatories from interference in frequency bands allocated to radio astronomy.

Office of Scientific Personnel

Two postgraduate programs are administered for NASA by the Office of Scientific Personnel. The NASA International University Fellowships in Space Science provide opportunities to young scientists from other countries for study and research at 39 leading universities in the United States. During 1972, 85 Fellows were on tenure. From the start of the program in 1961 through 1972, 354 graduate and postdoctoral Fellows from 20 countries have held appointments at 34 U.S. universities. This fellowship program, which is a part of NASA's international cooperative effort, is jointly financed by NASA and the space agencies or other scientific organizations of the cooperating countries.

The NRC–NASA Resident Research Associateship program (postdoctoral and senior postdoctoral) provides research opportunities in space-related sciences to investigators of unusual competence from the United States and other countries. By their presence at NASA Centers, the Associates provide a powerful impulse to important research in the United States. In addition, the program provides a method for dissemination of space knowledge from NASA laboratories to universities and other research centers throughout the world. There were 195 Associates on tenure on August 31, 1972. Of these 100 were from the United States, and 95 were from 17 other countries.

XV The Smithsonian Institution

Introduction

The Smithsonian Institution continues to play an active role in national aeronautics and space programs through the activities of its bureaus: The Smithsonian Astrophysical Observatory (SAO), the National Museum of Natural History (NMNH), and the National Air and Space Museum (NASM); and its Center for Short-Lived Phenomena, a facility of the Office of Environmental Sciences.

In the past year, geophysical and astrophysical data were gathered by Smithsonian observing stations around the world, while Smithsonian experiments, including high-altitude balloons, observed other energy sources normally screened from ground-based facilities by the earth's atmosphere. At Smithsonian laboratories, both in Washington and in Cambridge, Mass., scientists analyzed lunar material returned by the Apollo astronauts and meteoritical material recovered on Earth. While these laboratory investigations were designed to provide new knowledge about the creation and evolution of the solar system, the Smithsonian's museums attempted to increase man's understanding of these new discoveries through exhibits, displays, and special programs.

Smithsonian Astrophysical Observatory

The space research of the Smithsonian Astrophysical Observatory (SAO) continues to make fundamental contributions to man's understanding of the solar system and the universe beyond. Its programs include satellite tracking for earth-physics research and other purposes, study of extraterrestrial material, and active participation in balloon and space missions.

Earth Dynamics.—Both nationally and internationally, the Observatory's satellite-tracking program has made substantial progress this year. The SAO–organized Earth Physics Satellite Observing Campaign (EPSOC) continues, with participating camera and laser stations located in 25 countries.

At the same time, data previously gathered by the International Geodetic Satellite Experiment (ISAGEX), coordinated by France, have been used to compute the *Smithsonian Standard Earth* (III), which represents a considerable refinement of the earth's figure and gravity field. For this calculation, SAO greatly extended those computer programs treating lunar and solar perturbations, air drag and radiation pressure, and other effects.

Satellite-tracking data are also used by the Observatory to develop models of the earth's atmosphere. The most important recent result is the finding of a variation, as a function of solar activity, in the coefficients relating the 27-day variation in the atmosphere to those in the decimetric solar flux.

During the year, the Observatory also expended considerable effort on the development of investigation

techniques designed to support planned national earth- and ocean-physics applications programs. For example, laser ranging to artificial satellites offers the prospect of precision far beyond that from photographic tracking. Indeed, one SAO goal is to obtain satellite range observations to an accuracy of ±2 cm and orbits to an accuray of ±5 cm. Already five of the SAO stations are equipped with laser ranging systems, and SAO scientists have been investigating sources of errors in laser ranging to satellites for very high-accuracy orbit determination.

Extraterrestrial Materials.—The Observatory continues its analysis of lunar samples and of meteors and meteorites.

One group conducted petrographic surveys of samples returned by both the Apollo and the Soviet Luna missions, singling out for special study several materials, including types of rock found at considerable depth under the lunar terrae; a variety of green glass containing quenched crystallites of a type not yet identified among other lunar rock fragments; and a heretofore unrecognized iron-rich basalt that apparently forms in the final stages of crystallization of certain lunar magmas. A second group is making isotopic analyses of lunar samples to learn about recent and ancient solar flares. Solar flares occurring within months of the Apollo missions were determined from the 35-day Ar^{37} activity, and the values agree with satellite measures. Solar flares averaged over the past thousand years were determined from the 300-year Ar^{39} activity. A third group is studying the distribution of gases in lunar samples to gain an understanding of how, when, and why these constituents were implanted in the surface layers.

By applying similar analysis techniques to meteorites, the presence of microscopic diamond material was detected in thin sections of the Haverö meteorite, a ureilite that fell in Finland in August 1971.

Statistical studies of fireball trajectories done in collaboration with the Ondřejov Observatory in Czechoslovakia and based on data obtained by SAO's Prairie Network have led to better observational distinctions between ordinary stony meteorites and other types that seldom, if ever, survive atmospheric entry. As a result of these studies, it now seems likely that at least three, and possibly five, types of material are represented in the fireballs, with each type differing in both ablation rate and orbit.

Space Observations.—SAO is compiling and analyzing data from several satellite experiments, flying an infrared telescope in a balloon, and designing and constructing a rocket experiment to provide a new test of the theory of relativity.

The results from SAO's Celescope experiment aboard the Orbiting Astronomical Observatory (OAO–2) were published as the *Celescope Catalog of Ultraviolet Stellar Observations.* The catalog is based on more than 8,000 ultraviolet television pictures taken by Special Uvicon cameras and represents observations of approximately 10 percent of the entire sky, including 20 percent of the region near the Milky Way, where the majority of ultraviolet stars are found. The final catalog lists for each of 5068 stars the magnitude, position, spectral type, and other statistical information, including cross references to ground-based catalogs.

A companion volume, *Blanketed Model Atmospheres for Early-Type Stars,* representing an analysis of the Celescope data as applied to stellar theory, is in publication as well. Both volumes are milestones in space science and should become valuable reference works for observational astronomers as well as for theoreticians.

The Celescope experiment—launched December 7, 1968—has proved to be remarkably durable. It was turned on better than two years after it had last been operated, in an attempt to observe the pulsating X-ray source Centaurus X–3. The equipment worked perfectly, and a number of frames of the area containing the pulsar were obtained. Although the X-ray source was not detected, the ultraviolet fluxes of a number of stars in the area were measured.

Using OSO data, SAO scientists showed that solar flares have in the EUV an impulsive component correlated with hard X-rays and microwave bursts, both in chromospheric and in coronal lines, followed by a slower component that parallels the soft X-ray component of flares. A study of the chromospheric Lyman-continuum emission of the quiet sun was also completed, resulting in an improved model of the chromosphere and a thorough investigation of variations in chromospheric density from equator to pole.

In collaboration with Harvard University and the University of Arizona, SAO built a 40-inch-aperture balloon-borne telescope, designed to obtain far-infrared (100 micron) data from altitudes high above the obscuring effect of the earth's atmosphere. The resultant data are expected to give new insights into the structure and energetics of our own Milky Way Galaxy, the processes of birth of stars and planetary systems, and the structure of planetary atmospheres. During the first engineering flight in October 1972, the telescope was successfully floated at 95,000 feet for 10 hours; a second flight, scheduled for year's end, was expected to produce the first scientific data.

Work has begun on an experiment to test the equivalence principle—the cornerstone of Einstein's General Theory of Relativity—by employing a maser clock

in a rocket probe. This 3.5-hour experiment will use the stability of the hydrogen maser to measure the expected gravitational redshift to an accuracy of about 20 parts per million. The NASA supported experiment employs a two-way doppler cancellation system that may be useful for further experiments of this type. Studies of the application of this technique to a probe approaching the sun have begun, with an expectation of redshift measurement to an accuracy of 1 part in 10 million—in other words, to the level of second-order contributions of the gravitational potential difference between the Earth and the solar probe.

Using imagery of the African rift system provided by the Earth Resources Technology Satellite (ERTS), one scientist has detected new structural features as well as new properties of known features not previously observed by ground-based surveys. These features, particularly along the Red Sea margin of Yemen and the northern end of the Western Rift and in the Nandi Fault of Western Kenya, indicate there is a direct relation between the degree of obliquity in the pattern of recent faulting and the older and underlying Precambrian structures. These results could have important implications for mining interests throughout East Africa.

National Museum of Natural History

During the past year the National Museum of Natural History has continued its program of research on returned lunar samples, especially their chemical and mineralogical composition. Much evidence has been derived bearing on the origin and evolution of the Moon, and the importance of meteorite impact in affecting surface topography and the composition of the lunar soil. Comparative studies on different types of meteorites have further supported the belief that meteorites, while having some compositional analogies with lunar rocks, cannot have come from the Moon, but must have a different source in the Solar System, probably the asteroidal belt between Mars and Jupiter. Field studies of Gosse's Bluff (Australia), Lonar Crater (India), and Bukkaros (Southwest Africa) have added significantly to our knowledge of large meteorite impacts on Earth. The work at Lonar Crater was conducted in cooperation with the Geological Survey of India.

National Air and Space Museum

The Smithsonian Institution's cluster of museums on the Mall in Washington attracted nearly 15 million visitors in 1972, with the artifacts of manned space flight continuing as a prime attraction.

Construction began this fall on the latest addition to this museum group—the building to house the National Air and Space Museum. The new museum is scheduled to open July 4, 1976, as a national center for education about the science and technology of space flight and its social, cultural, and political meaning.

The $40-million facility, designed by St. Louis architect Gyo Obata, will include an auditorium/film theater and a 350-seat "Spacearium" that can be used both to project conventional planetarium star shows and to serve as a showcase for unusual audiovisual presentations of air and space flight.

The Smithsonian Center for Short-Lived Phenomena

The Smithsonian Center for Short-Lived Phenomena of the Office of Environmental Sciences serves as an international alert system for the rapid receipt and dissemination of information concerning transient geophysical, biological ,and astrophysical events of major scientific importance.

The Center's participation in astrophysical events during 1972 included the investigation reports of six large fireballs seen over various parts of the world. In one such event, the widely observed Alberta Fireball of August, the Smithsonian Astrophysical Observatory assisted the Center in its efforts to obtain visual and photographic documentation, including rare motion-picture footage, of the meteor's trajectory. In addition, the Air Force assisted SAO by dispatching aircraft on flights through the meteor's suspected path to collect airborne samples of ablation products remaining in the upper atmosphere.

In another joint project, SAO scientists coordinated efforts by the Center to provide "ground truth" data concerning large-scale events observable from the Earth Resources Technology Satellite launched by the National Aeronautics and Space Administration in August.

Center personnel also participated in the planning of similar observation programs to be conducted by astronauts aboard the orbiting Skylab.

XVI Office of Telecommunications Policy

Introduction

The Office of Telecommunications Policy (OTP) carries out delegated functions on behalf of the President relating to oversight and facilitation of the development of communication services via satellite. OTP's authority is set forth in Reorganization Plan No. 1 of 1970 and Executive Order No. 11556, September 4, 1970. Participating in interagency and government/industry telecommunications activities, OTP works primarily on programs involving space communications applications rather than research and development of space techniques.

Aerosat

The Office of Telecommunications Policy has concentrated on developing a U.S. Government position toward arrangements with Europe to evaluate the use of satellite communications in improving air traffic control over the high seas. Negotiations with the European Space Research Organization on a coordinated evaluation program continued during 1972. It is expected that the satellite channels required for the evaluation will be provided by a new entity to be owned jointly by ESRO and a private U.S. company. The State Department, FCC and DOT/FAA have closely coordinated their interests in this area with OTP throughout this year.

Marsat

The Office of Telecommunications Policy has actively participated in intra-governmental policy discussions aimed at providing satellite communications to civilian ships on the high seas. Current international discussion of this subject is taking place in the International Maritime Consultative Organization. The U.S. Government is participating in the necessary preparatory work of defining the maritime requirements for satellite services without prejudging operational or organizational aspects of how the required services will be provided. Coordination with all agencies interested in this field is continuing.

Direct Broadcast Satellites

In coordination with the State Department, USIA, FCC, and other agencies concerned, OTP has participated in the formulation and presentation in international forums of U.S. Government positions on the use and regulation of satellites for broadcasting. Activities at the United Nations and in UNESCO have increased on this subject during 1972, and new international legal regimes have been proposed. Study of these proposals continues.

XVII Federal Communications Commission

Introduction

During 1972 considerable progress in the development of satellite communications took place. Membership in INTELSAT increased to 83 countries, and two INTELSAT IV satellites were launched, one for service over the Pacific and one over the Indian Ocean. The Commission issued its Second Report and Order on domestic satellite facilities on June 16, 1972, setting forth the guidelines upon which it will consider applications for the ownership and operation of domestic communications satellites. During 1972, the Commission also released its Notice of Proposed Rule Making relating to the availability of frequency bands

for domestic satellite use, these bands having been previously agreed upon at the World Administrative Radio Conference for Space Tele-communications (WARC–ST).

Communications Satellites

During 1972, with the inclusion of Barbados, INTEL SAT membership has grown to a total of 83 countries. On January 22, 1972, the first INTELSAT IV satellite for service in the Pacific was launched and on February 14, 1972 it became operational. The first INTELSAT IV for Indian Ocean commercial service was launched on June 13, 1972 and became operational on July 30, 1972. Another INTELSAT IV satellite, an operational spare for the Pacific INTELSAT IV, will be launched in early 1973 and is planned to become operational shortly thereafter. After this launch the operational configuration of the INTEL SAT IV space segment will consist of two INTELSAT IV satellites in both the Atlantic and the Pacific Ocean regions, and one INTELSAT IV in the Indian Ocean region.

At the end of 1972, 78 Earth stations with 86 antennas operating in 54 countries were providing satellite communications in the INTELSAT system. The eight U.S. Earth stations are located at Andover, Maine; Cayey, P.R.; Etam, W. Va.; Brewster Flat, Wash.; Bartlett, Alaska; Paumalu, Hawaii; Jamesburg, Calif.; and Guam. Two standard communications antennas are operating at the Paumalu earth station. In addition a U.S. Earth station in the Antarctic Region received approval to operate for the collection of scientific data via the Pacific Region INTELSAT satellites.

In June 1972, the Commission adopted its Second Report and Order concerning the establishment of domestic communications-satellite facilities by non-governmental entities. The Commission indicated that all qualified applicants, acting either independently or in coalitions, will be authorized to operate domestic satellites and that it will place special restrictions on some of the applicants. Service from the U.S. mainland to Hawaii, Alaska and Puerto Rico is to be integrated into the domestic satellite system and the Commission indicated that distinctions with respect to the level of charges and rate patterns applicable to such service should be eliminated. Because of a requested reconsideration of the Commission domestic satellite decision final resolution of the matter has been delayed until early 1973.

International Telecommunication Union

The International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR) are permanent organs of the International Telecommunication Union (ITU), conducted under Article 14 of the International Telecommunication Convention (Montreux, 1965) to study technical and operating questions on telegraphy and telephony, and radio, respectively, and to issue recommendations on such questions. Many of these questions deal directly or indirectly with space communications.

The World Plan Committee is a joint CCITT/CCIR study group administered by the CCITT and is the parent body of the four Regional Plan Committees for Africa, Asia and Oceania, Europe and the Mediterranean Basin, and Latin America.

The work of the Plan Committees involves the development of telecommunications traffic and circuit forecasts, the compilation of data on major arteries and routing, and deals with technical and economic matters of interest regarding telecommunications.

During 1972, several Commission engineering experts participated in an interim CCIR meeting in Geneva on matters relating to space communication and broadcasting. In addition, several FCC members in December attended the Fifth Plenary Session of the CCITT. Preparations are under way for the ITU Plenipotentiary Conference to be held in September 1973 in Spain.

New international Radio Regulations, which were adopted in 1971 by the ITU World Administrative Radio Conference on Space Telecommunications (WARC–ST), were signed by the President and ratified with the advice and consent of the Senate in July 1972. To provide frequency bands for domestic use in accord with these new international regulations, the Commission, on July 26, 1972 released its Notice of Proposed Rule Making in Docket 19547. The provisions of the regulations adopted by the WARC–ST are scheduled to become effective on January 1, 1973.

The implementation of frequency bands for domestic use is a two-step process in which frequency allocations are first listed in Part 2 of the Commission's Rules and Regulations and then listed as being available for assignment in the various radio services. Frequency bands will be allocated by the Commission to the Amateur-satellite, Broadcasting-satellite, Fixed-satellite, Aeronautical-satellite, Maritime Mobile-satellite and Radio Navigation-satellite services.

Aeronautical Services

The Commission staff is developing amendments to the FCC rules which will provide expanded and more suitable frequencies for allocation to satellite systems designed to serve aeronautical requirements with the aim of satisfying short-term needs through the decade of the 1970's. Newly allocated frequencies will make it possible to pursue more satisfactory and comprehensive system development.

In this regard, the Commission staff has continued to work with the Federal Aviation Administration (FAA) and the Office of Telecommunications Policy (OTP) in current program planning, particularly regarding the use of frequencies in the 1535–1660-MHz band. Further programs involving the 1535–1660-MHz band include studies of the feasibility of joint aviation and marine use. The Commission staff is presently studying the comparative requirements in that band for air traffic control and marine operational control purposes.

The Commission is continuing studies of presently developing systems designed to solve other airspace problems which may be solved by means other than the use of satellites. These systems include aircraft midair collision and terrain avoidance equipment. While the Commission has outstanding developmental authorizations for the systems, it has not yet determined which system can be authorized on a regular basis. Further study as well as further development of candidate systems is required.

Normal Commission rulemaking procedures are being implemented to provide additional channels for aircraft operational control purposes by means of channel splitting of the available band.

Maritime Mobile Service

The Commission staff is continuing to work both nationally and internationally in forums which are planning for the development of satellite systems which will be used by the Maritime Mobile Service. Activity toward the development of such systems is being pursued by the Martime Administration nationally and the IMCO internationally. Normal rulemaking will provide, in the Commission's Rules, the newly allocated frequencies previously approved by the ITU WARC–ST for maritime satellite service.

The staff continues to place emphasis on the safety and search and rescue features of satellite systems used for maritime mobile purposes.

Amateur Radio Service

On October 15, 1972, the OSCAR 6 satellite, sixth in the "Orbiting Satellite Carrying Amateur Radio" series, was placed into a 900-mile polar orbit by a NASA Delta vehicle launched from the Western Test Range, as a secondary payload. Designed and built by amateur radio operators, this satellite represents several innovations in space telecommunications. A two-to-ten meter linear translator for multichannel communications by amateur radio operators anywhere in the world is in operation for the first time. It is also the first time telemetry has been transmitted from a satellite in Morse code enabling any amateur radio operator to receive and interpret the data.

It is the first time a beacon has operated in space in the seventy-centimeter band allocated to the Amateur Satellite Service at the 1971 ITU World Administrative Radio Conference for Space Telecommunications. Moreover, OSCAR 6 has a digital memory system capable of store-and-forward of Morse code and teleprinter communication. It also has a twenty-one function command system operated by amateur radio stations. OSCAR 6 is expected to be operational for at least one year. It is being used by amateur radio operators world-wide in conducting multiple-access communication experiments, in educational instructional programs to demonstrate physical concepts, in providing communication with remote areas and for emergency communication. In addition to voice and telegraphy messages, slow-scan television pictures have been successfully transmitted through OSCAR 6 by amateur radio operators. In addition, experiments for the exchange of medical data are being planned.

Another OSCAR satellite is under construction, looking toward launch soon after the end of life for OSCAR 6.

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	1966	95	12	5	[1] 1
1958	5	8	0	4	1967	77	4	10	0
1959	9	9	1	2	1968	61	15	3	0
1960	16	12	1	2	1969	58	1	8	1
1961	35	12	0	0	1970	36	1	3	0
1962	54	12	4	1	1971	45	2	8	1
1963	60	11	0	0	1972	32	2	8	0
1964	69	8	4	0					
1965	94	8	3	0	Total	746	118	58	12

[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 attainment of earth orbit or earth escape rather than a judgment of mission success.

This tabulation includes spacecraft from cooperating countries which were launched by U.S. launch vehicles.

APPENDIX A–2

World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond

Year	United States	U.S.S.R.	France	Italy	Japan	Chinese Peoples Republic	Australia	United Kingdom
1957		2						
1958	5	1						
1959	10	3						
1960	16	3						
1961	29	6						
1962	52	20						
1963	38	17						
1964	57	30						
1965	63	48	1					
1966	73	44	1					
1967	57	66	2	1			1	
1968	45	74						
1969	40	70						
1970	28	81	2	[1] 1	1	1		
1971	30	83	1	[1] 2	2	1		1
1972	30	74		[1] 1	1			
Total	573	622	7	5	4	2	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—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Jan. 20 Defense 2A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	211 93 89. 3 96. 9	Decayed Feb. 29, 1972.
Jan. 20 Defense 2D Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	342 292 94. 8 96. 5	Still in orbit.
Jan. 23 Intelsat IV (F–4) 3A Atlas-Centaur	Objective: To provide equivalent of 3,000 to 9,000 telephone circuits simultaneously or 12 color TV channels or a combination of telephone, TV, and other forms of communications traffic. Spacecraft: Cylindrical 93.7-in. diameter and 17.3-ft. high; spin stabilized; 12 communications repeaters (transponders); 6 antennas; 45,012 solar cells. Weight after apogee motor fire: 1,587 lbs.	22, 238 22, 137 1, 432. 0 0. 7	Launched by NASA for Comsat Corp., manager of Intelsat. Third satellite in improved Intelsat IV series. Stationed at 174° east longitude over Pacific. Used during President Nixon's China trip. Spacecraft operating normally.
Jan. 31 HEOS 2 5A Thorad-Delta	Objective: To investigate interplanetary space and high latitude magnetosphere and its boundary in the region around the northern neutral point. Spacecraft: 16-sided cylindrical polyhedron 51, 2-in. diameter and 27, 6-in. high, having a 24-in. axial tripod-type boom and an experiment BLF loop antenna at the top. Overall length is 94.3-in. About 70 percent of outer surface covered with solar cells. A central octagonal tube holds most of the spacecraft's experiment instrumentation, electronic controls, batteries, telemetry, and command equipment. Contains seven experiments. Weight: 257 lbs.	154, 207 273 7,835. 4 90. 2	ESRO-built satellite launched into highly eccentric orbit by NASA. All experiments turned on and spacecraft fully operational.
Mar. 1 Defense 10A Titan IIIC	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	22, 347 22, 008 1, 429. 9 0. 2	Still in orbit.
Mar. 3 Pioneer 10 12A Atlas-Centaur	Objective: To obtain, during the 1972 Jovian opportunity, precursory scientific information beyond the orbit of Mars with the following emphasis: (a) investigation of the interplanetary medium; (b) investigation of the nature of the asteroid belt; (c) exploration of Jupiter and its environment. Spacecraft: Hexagon-shaped spacecraft with an auxiliary offset hexagonal compartment for scientific instruments and 9-ft. dia. parabolic antenna reflector; four radioisotope thermoelectric generators (RTG) on trusses 120° apart extend 1.9-ft. radially beyond periphery of antenna reflector. A four-segment folding magnetometer boom extends radially 5.2-ft. beyond the reflector and 120° from the RTG's; from the top of the high-gain antenna feed to the bottom of the low-gain antenna, measures 3.2-ft. Eleven scientific instruments will measure magnetic fields, plasma, cosmic rays and charged particles, the electromagnetic radiation in the ultraviolet, visible and infrared ranges, and the asteroid/meteoroid population. Six thrusters; spin stabilized. Weight: 569 lbs.	Heliocentric, later to become solar escape trajectory.	First of a new generation Pioneer series. Reached highest launch velocity ever attained (32,000 mph) with first use of Atlas-Centaur as a 3-stage vehicle. First NASA spacecraft powered entirely by nuclear energy and first intended to ultimately escape solar system into interstellar space. By Oct. 31, 1972, spacecraft had crossed half of the Asteroid Belt without incident and was 270 million miles from the Sun. Jupiter encounter planned Dec. 3, 1973. Spacecraft operating normally and all instruments functioning properly.

Successful U.S. Launches—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Mar. 12 TD-1A 14A Thorad-Delta	Objective: To make UV spectrometer measurements of the celestial sphere on an approximate 180 day cycle. Spacecraft: Box-like structure, 38.6-in. by 85-in., resembles a large refrigerator. Divided into two sections, the smaller bottom section contains all of the spacecraft electronics and other subsystems, and the top section contains the experiment complement. Two large solar panels attached to the sides deploy when orbit is achieved. Fixed to the bottom of the spacecraft is a 106.3-in. omindirectional antenna which deploys after orbital insertion. Spacecraft is 3-axis stabilized and contains seven experiments. Weight: 1,038 lbs.	339 327 95. 3 97. 5	ESRO-built satellite launched into sun-synchronous orbit by NASA. Largest and most advanced scientific satellite ever built in Western Europe. Spacecraft 3-axis stabilized and fully operational; all experiments turned on.
Mar. 17 Defense 16A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	246 88 89. 8 110. 9	Decayed April 11, 1972.
Mar. 24 Defense 18A Thor-Burner 2	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	549 498 101. 7 98. 7	Still in orbit.
Apr. 16 Apollo 16 (CSM-113) 31A Saturn V	Objective: To perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Descartes region; to emplace and activate surface experiments; to conduct in-flight experiments and photographic tasks. Spacecraft: Carried full lunar landing configuration, including command module, service module, and lunar module; also lunar roving vehicle, added lunar module consumables, and Scientific Instrument Module (subsatellite) for extensive lunar-orbital scientific investigation. Total weight at initial Earth orbit insertion: 308,750 lbs; at translunar injection: 144,500 lbs; CSM: 66,858 lbs; 34-ft. long, 12.8-ft. diameter.	N. A.	Crew consisted of John W. Young, commander; Thomas K. Mattingly, command module pilot; Charles M. Duke, Jr., lunar module pilot. Fifth successful lunar landing mission. Extensive geology traverses with lunar roving vehicle. Lunar module landed at 02:23 (G.m.t.) on Apr. 21 and lifted off at 01:26 (G.m.t.) on Apr. 25. Total lunar stay time 71 hours, 14 minutes. Three dual EVA's totaling 20 hours, 15 minutes. Total flight time 265 hours, 51 minutes.
Apr. 16 Saturn IVB (SA-511) 31B 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, 14, and 15 ALSEP instruments. Spacecraft: A cylinder about 62.3-ft. long by 21.7-ft. in diameter;. Total weight at impact, about 30,805 lbs.	Lunar strike.	Impacted Moon April 19, 1972.
Apr. 16 Lunar Excursion Module (LM-11) 31C 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 36,241 lbs.	N. A.	Lunar ascent module abandoned in lunar orbit after rendezvous and docking with CSM.
Apr. 16 Subsatellite 31D Saturn V	Objective: To pursue extensive, continuing lunar scientific studies from lunar orbit. Spacecraft: Hexagonal 31-in. long and 14-in. diameter with three 5-ft. booms extended; carried magnetometer and charged particle sensor. Weight: 80 lbs.	Lunar orbit. 81 57 119. 0 169. 3	Shaping burn to optimize orbit not performed because of problems with CM engine. Subsatellite lifetime decreased, and impacted the moon May 29, 1972, after 425 revolutions.

Successful U.S. Launches—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Apr. 19 Defense 32A Thorad-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	153 96 88.4 81.4	Decayed May 12, 1972.
May 25 Defense 39A Thorad-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	161 96 89.2 96.4	Decayed June 4, 1972.
June 13 Intelsat IV(F–5) 41A Atlas-Centaur	Objective: To provide equivalent of 3,000 to 9,000 telephone circuits simultaneously or 12 color TV channels or a combination of telephone, TV, and other forms of communications traffic. Spacecraft: Cylindrical 93.7-in. diameter and 17.3-ft. high; spin stabilized; 12 communications repeaters (transponders); 6 antennas; 45,012 solar cells. Weight after apogee motor fire: 1,587 lbs.	22,347 22,232 1440.4 0.4	Launched by NASA for Comsat Corp., manager of Intelsat. Fourth satellite in improved Intelsat IV series. Stationed at 61.4° east longitude over the Indian Ocean. Used during Olympic games held in Munich, West Germany. Spacecraft operating normally.
July 7 Defense 52A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	160 108 88.7 96.8	Decayed Sept. 13, 1972.
July 7 Defense 52C Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	311 310 94.5 96.1	Still in orbit.
July 23 ERTS 1 58A Thorad-Delta	Objective: To acquire synoptic, multispectral repetitive images for a period of three months from which useful data can be obtained for investigations in such disciplines as agriculture and forestry resources, mineral and land resources, land use, water resources, marine resources, mapping and charting, and the environment. Spacecraft: Shares same basic structure and design as Nimbus satellites. 120-in. high and 132-in. wide spacecraft consists of three major elements: 56-in. torus ring forms base; smaller hexagon-shaped housing, connected to ring by truss, houses attitude stabilization and control system; two 3-ft. by 5-ft. canted solar paddles. Active 3-axis stabilization. Carries two multispectral sensors, a multispectral scanner subsystem (MSS), a return beam vidicon (RBV) camera subsystem, a data collection system (DCS), and two wide band video tape recorders (WBVTR). Weight: 2,075 lbs.	569 558 103.1 99.1	Successful launch into polar orbit allows spacecraft to photo nearly entire planet during an 18-day period. Three co-aligned RBV cameras each photo identical scene (13,000 sq. ft.), but each in a different spectral band. Also provides near-real-time environmental information. Spacecraft operating normally and returning over 9,000 pictures a week.
Aug. 13 Explorer 46(MTS) 61A Scout	Objective: To measure the meteoroid penetration rates in a bumper-protected target in the near earth environment in order to evaluate the effectiveness of the bumpers. Spacecraft: Cylindrical spacecraft 10.5-ft. long. Four bumper wings measure 23-ft. tip-to-tip when deployed; wings covered with two thin stainless steel bumper sheets separated by ½-in. Spin stabilized; three scientific experiments; two telemetry systems. Weight: 386 lbs.	504 305 97.7 37.6	Spacecraft launched into proper orbit, but only two of four bumper wings deployed. No data received from secondary experiments, but primary experiment functioning properly and returning good data.

Successful U.S. Launches—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Aug. 21 OAO 3 (Copernicus) 65A Atlas-Centaur	Objective: To obtain high-resolution spectra of a number of stars in the ultraviolet range between 1000 and 3000 Å to investigate the composition, density, and physical state of matter in interstellar space and stellar sources. Spacecraft: eight-sided structure with a central tube which carries astronomical observing equipment; sunbaffle mounted on viewing end of spacecraft; solar cell arrays, containing about 55,500 cells, and inertial balance booms, folded flat against sides during launch, are deployed in orbit. Spacecraft measures 10-ft. long by 7-ft. wide in space; central tube is 4-ft. in diameter. Carries two experiments: Princeton Experiment Package (PEP) is 32-in. dia. reflecting telescope housed in the 10-ft. central tube; University College London (UCL) experiment consists of three small X-ray telescopes and a collimated proportional counter. Attitude control system; two transmitters, four receivers; thermal control system. Weight: 4,900 lbs.	462 457 99. 6 35. 0	Heaviest scientific satellite ever launched by the United States; contains largest telescope ever orbited. Spacecraft fully operational and pointing accuracy three times better than planned; also spacecraft far more stable than expected.
Sep. 1 Defense 68A Titan IIIB–Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	237 88 89. 7 110. 4	Decayed Sep. 30, 1972.
Sep. 2 Triad OI–1 69A Scout	Objective: To correct long term drift of satellite, forcing it to fly a highly predictable orbit; and to test environmental and component quality factors in performance. Also, to provide for general navigation support in the Transit system. Spacecraft: Three gravity-stabilized components separated by 10-foot booms. The Earth-facing body contains the Doppler system, computer system, and directional antenna. The central body contains the DISCOS (disturbance compensation system) for station-keeping. The space-facing body is the radioisotope thermal generator system, experimental solar cells. The spacecraft generates 30 watts of power, transmits on 400 and 150 MHz. Overall length is 24 feet: Weight is 207 lbs.	521 462 100. 6 90. 1	Still in orbit.

Successful U.S. Launches—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Sept. 23 Explorer 47 (IMP) 73A Thorad-Delta	Objective: To perform detailed and near continuous studies of the interplanetary environment for orbital periods comparable to several rotations of active solar regions; and to study particle and field interactions in the distant magnetotail including cross sectional mapping of the tail and neutral sheet. Spacecraft: 16-sided drum-shaped structure 62-in. high and 53-in. diameter. Upper portion of spacecraft contains an aluminum honeycomb shelf which supports experiments and spacecraft electronics. The lower portion has an 18-in. thrust tube to accommodate solid propellant kick motor. Spacecraft structure consists of aluminum honeycomb RF shield panels and three bands of solar panels (16 panels per band) mounted on an aluminum honeycomb substrate. Two diametrically opposed experiment booms (each 10-ft. long) and two attitude control system booms (each 4-ft. long) spaced 90° from experiment booms, are appended to spacecraft exterior and deployed after launch. The spacecraft is fitted with eight equally spaced, RF antennas (four active, four passive turnstile type) which extend radially. Spacecraft is spin stabilized and contains 13 experiments. Weight: 833 lbs.	146, 426 125, 274 17, 702. 1 17. 2	Spacecraft launched into nearly circular earth orbit approximately half the distance to the moon. Spacecraft functioning normally; 12 of 13 experiments operating properly.
Oct. 2 STP 72-1 76A Atlas-Burner 2	Objective: To measure background gamma radiation over whole Earth in 100–300 Kv and over 700 Kv ranges; to measure fluxes and spectra of low altitude charged particles as a function of time and magnetospheric position; to determine effects of space environment on various thermal control coatings; to measure UV radiation which generate and maintain the nighttime ionosphere, and to measure H and He atoms and ions, and to observe extreme and far UV originating in interaction of solar wind with interplanetary medium or from galactic sources. Spacecraft: Gamma ray spectrometer; low altitude particle measuring sensor. Satellite is cylinder 7 ft. long, 4.5 ft. in diameter. Antenna booms extend 9 ft. from each end coincident with the spin axis. Weight: 1,248 lbs.	465 453 99. 5 98. 4	Still in orbit.
Oct. 2 Radcat 76B Atlas-Burner 2	Objective: To provide a passive optical and radar calibration target of about 5 square meters cross section. Spacecraft: Cylinder 10 ft. in length, 4 ft. in diameter. Weight: 485 lbs.	467 453 99. 5 98. 4	Still in orbit.
Oct. 10 Defense 79A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	167 99 88. 7 96. 4	Still in orbit.

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Successful U.S. Launches—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Oct. 15 NOAA 2(ITOS D) 82A Thorad-Delta	Objective: To place spacecraft in a sun-synchronous orbit having a local equator crossing time between 9am and 9:20am, and conduct in-orbit engineering evaluation so that daytime and nighttime meteorological 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. The base of the main body is about 40-in. by 40-in. and the overall height is about 48-in. The total area of the array is 48-sq. ft. with each of the three panels measuring 36.4-in. by 63.8-in. Three-axis stabilized, earth-oriented satellite carries two Very High Resolution Radiometer (VHRR) instruments and two Scanning Radiometer (SR) sensors for daytime and nighttime coverage, and two Vertical Temperature Profile Radiometers (VTPR) which permit determination of the earth's atmospheric vertical temperature profile over every part of the earth's surface at least twice daily. Thermal control system; four antennas. Weight: 760 lbs.	906 902 114.9 101.7	First operational spacecraft to provide temperature soundings of the earth's atmosphere as well as direct readout and globally recorded cloud-cover data. Spacecraft functioning normally and turned over to NOAA Nov. 8, 1972, for operational use.
Oct. 15 Oscar 6 82B Thorad-Delta	Objective: To conduct an experimental program of multiple-access communication techniques using a large number of relatively low-powered earth terminals. Spacecraft: Powered by solar cells and a battery, spacecraft carries a 2- to 10-meter linear translator with a bandwidth of 100 kHz; input frequency is centered on 145.95 MHz and the output centered at 29.5 MHz. Peak power output of transmitter is about one watt; also carries a message storage device. Weight: 41 lbs.	905 902 114.9 101.7	Built by American, Australian, and German amateur groups working through the Radio Amateur Satellite Corporation (AMSAT). Launched by NASA as secondary payload. Spacecraft is functioning normally.
Nov. 9 Defense 89A Thor-Burner 2	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	546 512 101.5 98.6	Still in orbit.
Nov. 10 Anik 1 90A Thorad-Delta	Objective: To provide transmission of television, voice, and other data throughout Canada. Spacecraft: Cylindrical 6-ft. diameter and 11-ft. high; spin stabilized; 60-in. optically transparent antenna weighing 9-lbs. affixed to top of spacecraft remains stationary, pointed toward Canada, as satellite revolves. Provides 10 color TV channels or up to 9,600 telephone circuits; 23,000 solar cells. Weight at launch: 1,200 lbs; in orbit: 600 lbs.	22,241 22,234 1,436.0 0.1	Launched by NASA for Canadian Domestic Communications Satellite System into stationary transfer orbit. Apogee kick motor fired by Canada Nov. 14 and spacecraft placed in stationary equatorial orbit off the west coast of South America. Spacecraft able to "see" and service all of Canada. Western world's first operational domestic communications satellite.

Successful U.S. Launches—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Nov. 15 Explorer 48(SAS) 91A Scout	Objective: To measure the spatial and energy distribution of primary galactic and extra-galactic gamma radiation. Spacecraft: Dome-shaped cylinder 23.2-in. dia and 20.1-in. high. Four solar paddles 10.6-in. wide and wide and 53.2-in. long hinged to outer shell are folded downward against cylinder during launch and upon deployment are canted 30° from the two axis and perpendicular to the cylinder surface; command and telemetry antennas are attached to tips of paddles; spacecraft measures 156-in. tip-to-tip with paddles deployed. Inside spacecraft shell, honeycomb deck contains basic spacecraft systems; nickel-cadmium battery, command receivers and decoders, telemetry system, and spin control system. Spacecraft experiment consists of a 32-level digitized spark chamber gamma-ray telescope which will detect rare celetial gamma rays and determine their intensity, energy, and direction of arrival. Weight: 410 lbs.	392 276 95.4 1.9	NASA-built satellite launched into equatorial orbit from San Marco range by an Italian launch crew.
Nov. 22 ESRO 4 92A Scout	Objective: To investigate and measure several phenomena in the polar ionosphere, a region of high intensity that begins in the upper atmosphere and extends to an indefinite height in space. Spacecraft: Cylindrical spacecraft about 54-in. high and 30-in. in diameter with 6,990 body-mounted solar cells. Three radial booms, hinged at the bottom of the craft, are folded along its sides during launch and deployed in orbit; a fourth boom, mounted on the spacecraft's bottom, is stowed inside the center of the craft during launch and is deployed immediately after the radial booms. The radial booms contain sensors for part of the ionospheric experiment. Spacecraft carries six experiments and is spin stabilized. Weight: 286 lbs.	721 152 98.8 91.1	ESRO-built spacecraft launched successfully by NASA into near-polar elliptical orbit. Still in orbit.
Dec. 7 Apollo 17 (CSM-114) 96A Saturn V	Objective: To perform selenological inspection, survey, and sampling of materials and surface features in a preselected area of the Taurus-Littrow region; to emplace and activate surface experiments; to conduct in-flight experiments and photographic tasks. Spacecraft: Carried full lunar landing configuration, including command module, service module, and lunar module; also lunar roving vehicle, added lunar module consumables, and Scientific Instrument Module (SIM) for extensive lunar orbital scientific investigations. Total weight at initial earth orbit insertion: 311,151 lbs; at translunar injection: 144,929 lbs; CSM: 66,953 lbs, 34-ft long, 12.8-ft diameter.	N.A.	Crew consisted of Eugene A. Cernan, commander; Ronald E. Evans, command module pilot; Harrison H. Schmitt, lunar module pilot. Sixth successful lunar landing mission. Extensive geology traverses with lunar roving vehicle. Lunar module landed at 19:55 (G.m.t.) on December 11 and lifted off at 22:55 (G.m.t.) on December 14. Total lunar stay time 75 hours. Three dual EVA's totaling 22 hours, 5 minutes. Total flight time 301 hours, 52 minutes.
Dec. 7 Saturn IVB (SA-512) 96B 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, 14, 15, and 16 ALSEP instruments. Spacecraft: A cylinder about 62.3-ft. long by 21.7-ft. in diameter. Total weight at impact, about 30,712 lbs.	Lunar strike	Impacted Moon December 10, 1972.

Successful U.S. Launches—1972

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and Perigee (in statute miles)— Period (minutes)— Inclination to Equator (degrees)	Remarks
Dec. 7 Lunar Excursion Module (LM-12) 96C 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 36,278 lbs.	N.A.	Lunar ascent module commanded to impact the moon on December 14, after rendezvous and docking with CSM.
Dec. 11 Nimbus 5 97A Thorad-Delta	Objective: To improve and extend the capability for vertical sounding of temperatures and moisture in the atmosphere, particularly with regard to altitude coverage, and with regard to the interfering effects of clouds, by the acquistion of synoptic data for a period of 10 weeks from either the Infrared Temperature Profile Radiometer (ITPR), or the Nimbus E Microwave Spectrometer (NEMS); to demonstrate improved thermal mapping of the earth by obtaining data for a period of 10 weeks from either the Electrically Scanning Microwave Radiometer (ESMR), or the Surface Composition Mapping Radiometer (SCMR). Spacecraft: Butterfly-shaped spacecraft 10-ft. high and 11-ft. wide consists of three major elements: a 5-ft. diameter torus ring forms the base and houses the major spacecraft electronics; a smaller hexagon-shaped housing; connected to the ring by a truss, houses the attitude stabilization and control system; and two solar paddles about 3-ft. by 8-ft. Active 3-axis stabilization; carries six experiments. Solar cells provide 550 watts of power and eight nickel-cadmium batteries average 277 watts. Weight: 1,695 lbs.	684 677 107.2 99.9	Nimbus 5 attained its planned orbit, and sensors were activated successfully. Still in orbit.
Dec. 16 Aeros 100A Scout	Objective: To measure the main aeronomic parameters of the upper atmosphere and the solar ultraviolet radiation in the wavelength band of main absorption. Spacecraft: Circular cylindrical shell welded to a bottom conical shell to form a structural unit 36-in. in diameter and 28-in. high. Flat honeycomb solar cell array lid is attached to spacecraft cylinder top. Carries five scientific instruments: Mass Spectrometer (MS), Retarding Potential Analyzer (RPA), Impedence Probe (IP), EUV-Spectrometer (EUV), and Neutral Atmosphere Temperature Experiment (NATE). Spinstabilized; four telemetry antennas; two batteries. Weight: 277 lbs.	537 135 95.5 96.9	German-built satellite launched by N.A.S.A.
Dec. 20 Defense 101 A Atlas-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	40,728 31,012 9.7 1440.4	Still in orbit.
Dec. 21 Defense 103A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	243 86 90.0 110.5	Still in orbit.

APPENDIX B

U.S. Applications Satellites 1958–1972

Date	Name	Launch vehicle	Remarks
		GEODESY	
Oct. 31, 1962	Anna 1B	Thor-Able Star	Used 3 independent measuring techniques: Doppler frequency shift, flashing lights, and radio triangulation.
Jan. 11, 1964	Secor I	Thor-Agena D	Uses radio triangulation and trilateration.
Oct. 10, 1964	Beacon-Explorer XXII	Scout	Conducted reflecting-light geodetic measurements.
Mar. 9, 1965	Secor III	Thor-Agena D	
Mar. 11, 1965	Secor II	Thor-Able Star	
Apr. 3, 1965	Secor IV	Atlas-Agena D	
Apr. 29, 1965	Beacon-Explorer XXVII	Scout	
Aug. 10, 1965	Secor V	Scout	
Nov. 6, 1965	GEOS-I Explorer XXIX	Thor-Delta	
June 9, 1966	Secor VI	Atlas-Agena D	
June 23, 1966	Pageos I	Thor-Agena D	Spacecraft is a 100-foot-diameter balloon used as a photographic target to make geodetic measurements.
Aug. 19, 1966	Secor VII	Atlas-Agena D	
Oct. 5, 1966	Secor VIII	Atlas-Agena D	
June 29, 1967	Secor IX	Thor-Burner II	
Jan. 11, 1968	GEOS II	Thor-Delta	
Apr. 14, 1969	Secor XIII	Thor-Agena D	
Apr. 8, 1970	Topo I	Thor-Agena D	

U.S. Applications Satellites 1958–1972—Continued

Date	Name	Launch vehicle	Remarks
		COMMUNICATIONS	
Dec. 18, 1958	Score	Atlas B	First Comsat, carried taped messages.
Aug. 12, 1960	Echo I	Thor-Delta	100-foot ballon 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 ballon, passive Comsat, first joint use by United States and U.S.S.R.
Aug. 19, 1964	Syncom III	Thor-Delta	Synchronous-orbit Comsat; after experimental phase, used operationally by DOD.
Feb. 11, 1965	LES I	Titan IIIA	Experimental payload did not reach intended apogee.
Mar. 9, 1965	Oscar III	Thor-Agena D	
Apr. 6, 1965	Intelsat I (Early Bird)	Thor-Delta	First Intelsat (Comsat Corporation) spacecraft, 240 2-way voice circuits; commercial transatlantic communication service initiated June 28, 1965.
May 6, 1965	LES II	Titan IIIA	All solid state advanced experiment.
Dec. 21, 1965	LES III	Titan IIIC	All solid state, UHF signal generator.
	LES IV		All solid state SHF or X band experiment.
	Oscar IV		
June 16, 1966	IDCSP 1–7	Titan IIIC	Initial defense communication satellites program (IDCSP)-Active-repeater spacecraft in near-synchronous orbit, random spaced.
Oct. 26,1966	Intelsat II–F1	Thor-Delta(TAT)	First in Intelsat II series spacecraft; 240 2-way voice circuits or 1 color TV channel. Orbit achieved not adequate for commercial operation.
Nov. 3, 1966	OV 4–1T	Titan IIIC	Transmitter and receiver for low-power satellite-to-satellite F layer experiments.
	OV 4–IR		
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	Titan IIIC	
	LES V		Tactical military communications tests with aircraft, ships, and mobile land stations from near synchronous orbit.
	DATS		Electronically despun antenna experiment.
	DODGE		Multipurpose, gravity stabilized.
Sept. 27, 1967	Intelsat II–F4	Thor-Delta(TAT)	Positioned to carry commercial transpacific communication traffic.
Nov. 5, 1967	ATS III	Atlas-Agena D	Multipurpose including communications.
June 13, 1968	IDCSP 19–26	Titan IIIC	
Aug. 10, 1968	ATS IV	Atlas-Centaur	Multipurpose; failed to separate from Centaur, did not reach planned orbit.
Sept. 26, 1968	LES 6	Titan IIIC	Continued military tactical communications experiments.
Dec. 18, 1968	Intelsat III (F–2)	Thor-Delta(TAT)	First in Intelsat III series of spacecraft, 1,200 2-way voice circuits or 4 color TV channels. Positioned over Atlantic to carry traffic between North America, South America, Africa, and Europe. Entered commercial service on Dec. 24, 1968.
b. 6, 1969	Intelsat III(F–3)	Thor-Delta (TAT)	Stationed over Pacific to carry commercial traffic between the United States, Far East, and Australia.
. 9, 1969	Tacsat I	Titan IIIC	Demonstrated feasibility of using a spaceborne repeater to satisfy selected communications needs of DOD mobile forces.

U.S. Applications Satellites 1958–1972—Continued

Date	Name	Launch vehicle	Remarks
		COMMUNICATIONS—Continued	
May 22, 1969	Intelstat III(F–4)	Thor-Delta(TAT)	Stationed over Pacific to replace F–3 which was moved westwrad to the Indian Ocean. Completes global coverage.
July 26, 1969	Intelsat III(F–5)	Thor-Delta(TAT)	Spacecraft failed to achieve the proper orbit. Not usable.
August 12, 1969	ATS V	Atlas Centaur	Multipurpose; for millimeter and L band communications; entered flat spin.
Nov. 22, 1969	Skynet I (IDCSP–A)	Thor-Delta(TAT	Launched for the United Kingdom in response to an agreement to augment the IDCSP program.
Jan. 15, 1970	Intelsat III(F–6)	Thor-Delta(TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, Latin America, and the Middle East.
Jan. 23, 1970	Oscar V (Australis)	Thor-Delta(TAT)	Ham radio satellite built by amateur radio operators at Melbourne University, Melbourne, Australia.
Mar. 20, 1970	NATOSAT–I (NATO–A)	Thor-Delta (TAT)	First NATO satellite, stationed over Atlantic to carry military traffic between the United States and other NATO countries.
Apr. 23, 1970	Intelsat III (F–7)	Thor-Delta (TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, North Africa, and the Middle East.
Jul. 23, 1970	Intelsat III (F–8)	Thor-Delta (TAT)	Spacecraft failed to achieve the proper orbit. Nor usable. Last launch of Intelsat III series.
Aug. 22, 1970	Skynet II (IDCSP–B)	Thor-Delta (TAT)	Launched for the United Kingdom in response to an agreement to augment the IDCSP program. Spacecraft failed to achieve the proper orbit.
Jan. 26, 1971	Intelsat IV (F–2)	Atlas-Centaur	First in Intelsat IV series of spacecraft; 3–9,000 2-way voice circuits or 12 color TV channels. Positioned over the Atlantic.
Feb. 3, 1971	NATOSAT–II (NATO–B)	Thor-Delta (TAT)	Second NATO satellite, stationed over the Atlantic to carry military traffic.
Nov. 3, 1971	DSCS 2–1, 2	Titan IIIC	Operational defense communications satellites launched as a pair to 24-hour synchronous orbits to provide high capacity voice, digital, and secure voice communications for military networks.
Dec. 19, 1971	Intelsat IV (F–3)	Atlas Centaur	Second in new high-capacity series.
Jan. 22, 1972	Intelsat IV (F–4)	Atlas Centaur	Third in new high capacity series.
June 13, 1972	Intelsat IV (F–5)	Atlas Centaur	Fourth in new high capacity series.
		NAVIGATION	
Apr. 13, 1960	Transit 1B	Thor-Able Star	First navigation satellite. Used Doppler frequency shift for position determination.
June 22, 1960	Transit 2A	Thor-Able Star	
Feb. 21, 1961	Transit 3B	Thor-Able Star	
June 29, 1961	Transit 4A	Thor-Able Star	Used the first spacecraft nuclear SNAP–3 as a secondary power supply.
Nov. 15, 1961	Transit 4B	Thor-Able Star	
Dec. 18, 1962	Transit 5A	Scout	Operational prototype, power failed during first day.
June 15, 1963	NavSat	Scout	Used gravity-gradient stabilization system.
Sept. 28, 1963	NavSat	Thor-Able Star	Used first nuclear SNAP–9A as primary power supply.
Dec. 5, 1963	NavSat	Thor-Able Star	
June 4, 1964	NavSat	Scout	
Oct. 6, 1964	NavSat	Thor-Able Star	
Dec. 13, 1964	NavSat	Thor-Able Star	
Mar. 11, 1965	NavSat	Thor-Able Star	
June 24, 1965	NavSat	Thor-Able Star	
Aug. 13, 1965	NavSat	Thor-Able Star	
Dec. 22, 1965	NavSat	Scout	
Jan. 28, 1966	NavSat	Scout	
Mar. 25, 1966	NavSat	Scout	
May 19, 1966	NavSat	Scout	
Aug. 18, 1966	NavSat	Scout	
Apr. 13, 1967	NavSat	Scout	
May 18, 1967	NavSat	Scout	
Sept. 25, 1967	NavSat	Scout	
Mar. 1, 1968	NavSat	Scout	
Aug. 27, 1970	NavSat	Scout	
Sept. 2, 1972	Triad OI–1	Scout	First experimental station keeping Transit navigation satellite.

U.S. Applications Satellites 1958–1972—Continued

Date	Name	Launch vehicle	Remarks
		WEATHER OBSERVATION	
Apr. 1, 1960	Tiros I	Thor-Able	First weather satellite providing cloud-cover photography.
Nov. 23, 1960	Tiros II	Thor-Delta	
July 12, 1961	Tiros III	Thor-Delta	
Feb. 8, 1962	Tiros IV	Thor-Delta	
June 19, 1962	Tiros V	Thor-Delta	
Sept. 18, 1962	Tiros VI	Thor-Delta	
June 19, 1963	Tiros VII	Thor-Delta	
Dec. 21, 1963	Tiros VIII	Thor-Delta	First weather satellite designed to transmit continuously local cloud conditions to ground stations equipped with APT receivers.
Aug. 28, 1964	Nimbus I	Thor-Agena B	Carried advanced videcon camera system, APT, and a high resolution infrared radiometer for night pictures.
Jan. 22, 1965	Tiros IX	Thor-Delta	First weather satellite in a sun-synchronous orbit.
July 2, 1965	Tiros X	Thor-Delta	
Feb. 3, 1966	ESSA 1	Thor-Delta	First operational weather satellite; carried 2 wide-angle TV camera systems.
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	Odd-number ESSA spacecraft carry 2 advanced videcon camera systems. Even-numbered spacecraft carry 2 automatic picture transmission camera systems.
Dec. 6, 1966	ATS–1	Atlas-Agena D	Provided continuous black-and-white cloud-cover pictures from a synchronous orbit, using a Suomi camera system.
Jan. 26, 1967	ESSA 4	Thora-Delta	
Apr. 20, 1967	ESSA 5	Thor-Delta	
Nov. 5, 1967	ATS–3	Atlas-Agena	Provided continuous color cloud-cover pictures from a synchronous orbit, using 3 Suomi camera systems.
Nov. 10, 1967	ESSA 6	Thor-Delta	
Aug. 16, 1968	ESSA 7	Thor-Delta	
Dec. 15, 1968	ESSA 8	Thor-Delta	
Feb. 26, 1969	ESSA 9	Thor-Delta	
Apr. 14, 1969	Nimbus III	Thor-Agena	Provided first vertical temperature profile on a global basis of the atmosphere from the spacecraft to the Earth's surface.
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.
Aug. 16, 1971	Eole (CAS–1)	Scout	French satellite to gather data from constant density surface ballons relaying meteorological data for the study of the characteristics and movements of air masses. New balloons are released daily from three sites in Argentian, for this cooperative French/U.S. project.
Oct. 15, 1972	NOAA–2 (ITOS D)	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. 35 mins.	Longest-duration manned flight.
Gemini 6–A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	25 hrs. 51 mins.	Rendezvous within 1 foot of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	10 hrs. 41 mins.	First docking of 2 orbiting space craft (Gemini 8 with Agena target rocket).
Gemini 9–A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	72 hrs. 21 mins.	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	70 hrs. 47 mins.	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	71 hrs. 17 mins.	First initial-orbit rendezvous; first tethered flight; highest Earth-orbit altitude (853 miles).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	94 hrs. 35 mins.	Longest extravehicular activity (Aldrin, 5 hours 37 minutes).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	26 hrs. 37 mins.	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	260 hrs. 9 mins.	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgi Beregovoy	94 hrs. 51 mins.	Maneuvered near unmanned Soyuz 2.

History of U.S. and Soviet Manned Space Flights—Continued

Spacecraft	Launch date	Crew	Flight time	Highlights
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	147 hrs. 1 min.	First manned orbit(s) of moon; first manned departure from earth's sphere of influence; highest speed ever attained in manned flight.
Soyuz 4	Jan. 14, 1969	Vladimir Shatalov	71 hrs, 23 mins.	Soyuz 4 and 5 docked and transferred 2 Cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris Volynov Alecksey Yeliscyev Yevgeniv Khrunov	72 hrs. 56 mins.	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	241 hrs. 1 min.	Successfully simulated in earth orbit operation of lunar module to landing and takeoff from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	192 hrs. 3 mins.	Successfully demonstrated complete system including lunar module descent to 47,000 ft. from the lunar surface.
Apollo 11	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	195 hrs. 19 mins.	First manned landing on lunar surface and safe return to earth. First return of rock and soil samples to earth, and manned deployment of experiments on lunar surface.
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy Kubasov	118 hrs. 42 mins.	Soyuz 6, 7 and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and earth and celestial observations.
Soyuz 7	Oct. 12, 1969	Anatoliy Filipchencko Vladislav Volkov Viktor Gorbatko	118 hrs. 41 mins.	
Soyuz 8	Oct. 13, 1969	Vladimir Shatalov Aleksey Yeliseyev	118 hrs. 50 mins.	
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	244 hrs. 36 mins.	Second manned lunar landing. Continued manned exploration and retrieved parts of Surveyor III spacecraft which landed in Ocean of Storms on Apr. 19, 1967.
Apollo 13	Apr. 11, 1970	James A. Lovell, Jr. Fred W. Haise, Jr. John L. Swigert, Jr.	142 hrs. 55 mins.	Mission aborted due to explosion in the service module. Ship circled moon, with crew using LEM as "lifeboat" until just prior to reentry.
Soyuz 9	June 1, 1970	Andrian G. Nikolayev Vitaliy I. Sevastianov	424 hrs. 59 mins.	Longest manned space flight lasting 17 days 16 hrs. 59 mins.
Apollo 14	Jan. 31, 1971	Alan B. Shepard Stuart A. Roosa Edgar D. Mitchell	216 hrs. 42 mins.	Third manned lunar landing. Mission demonstrated pin-point landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir Shatalov Aleksey Yeliseyev Nikolai Rukavishnikov	47 hrs. 46 mins.	Docked with Salyut 1, but crew did not board space station launched April 19. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Georgiy Timofeyevich Dobrovolskiy Vladislov Nikolayevich Volkov Viktor Ivanovich Patsayev	570 hrs. 22 mins.	Docked with Salyut 1 and Soyuz 11 crew occupied space station for 22 days. Crew perished during final phase of Soyuz 11 capsule recovery on June 30, 1971.
Apollo 15	July 26, 1971	David R. Scott Alfred M. Worden James Bensen Irwin	295 hrs. 11 mins. 53 secs.	Fourth manned lunar landing and first Apollo "J" series mission which carry the Lunar Roving Vehicle. Worden's in-flight EVA of 38 min. 12 secs. was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charles M. Duke, Jr. Thomas K. Mattingly, II	265 hrs. 51 mins.	Fifth manned lunar landing, with lunar roving vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	301 hrs. 52 mins.	Sixth and final Apollo manned lunar landing, with roving vehicle.

APPENDIX D

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant [4]	Thrust (in thousands of pounds)	Max. dia. (feet)	Height [3] (feet)	Payload (pounds) [5] 100 NM orbit	Payload (pounds) [5] Escape	Payload (pounds) [5] First launch
Scout	1. Algol (IIB)	Solid	100.9	3.3	68.3	520	50	[1] 1965(60)
	2. Castor II	Solid	60.7					
	3. Antares II	Solid	20.9					
	4. Altair III or FW4.	Solid	5.9					
Thrust-augmented Thor-Delta.	1. Thor (SLV–2J) plus:	LOX/RP	205	11	95	4,650	1,150	1972(60)
	nine TX 354–5	Solid	[2] 57.3					
	2. Delta (DSV–3)	N_2O_4/Aerozine	9.2					
	3. TE 364	Solid	15					
Thrust-augmented Thor-Agena.	1. Thor (SLV–2H) plus.	LOX/RP	170	11	110	3,500	.....	1966(60)
	three TX 354–5	Solid	[2] 52					
	2. Agena	IRFNA/UDMH	16					
Atlas-Burner II	1. Atlas booster and sustainer (SLV–3A).	LOX/RP	400	10	86	7,000	700	1968
	2. Burner II	Solid	10					
Atlas-Agena	1. Atlas booster and sustainer (SLV–3A).	LOX/RP	400	10	100	8,500	1,430	1968(60)
	2. Agena	IRFNA/UDMH	16					
Titan IIIB-Agena	1. LR–87	N_2O_4/Aerozine	464	10	119	9,950	1,975	1966
	2. LR–91	N_2O_4/Aerozine	102					
	3. Agena	IRFN/UDMH	16					
Titan IIIC	1. Two 5-segment 120″ diameter.	Solid	2,400	10x30	108	29,000	6,000	1965
	2. LR–87	N_2O_4/Aerozine	523					
	3. LR–91	N_2O_4/Aerozine	102					
	4. Transtage	N_2O_4/Aerozine	16					
Titan IIID	1. Two 5-segment 120″ diameter.	Solid	2,400	10x30	95	30,000	.....	1971
	2. LR–87	N_2O_4/Aerozine	523					
	3. LR–91	N_2O_4/Aerozine	102					
Titan IIID-Centaur	1. Two 5-segment 120″ diameter.	Solid	2,400	10x30	128	34,000	12,000	1974(est.)
	2. LR–87	N_2O_4/Aerozine	523					
	3. LR–91	N_2O_4/Aerozine	102					
	4. Centaur (Two RL–10).	LOX/LH	30					
Atlas-Centaur	1. Atlas booster and sustainer.	LOX/RP	400	10	103	11,650	2,700	1967(62)
	2. Centaur (Two RL–10).	LOX/LH	30					
Saturn IB	1. S–IB (Eight H–1)	LOX/RP	1,640	21.6	142	40,000	.....	1966
	2. S–IVB (One J–2)	LOX/LH	230					
Saturn V	1. S–IC (Five F–1)	LOX/RP	7,570	33	281	285,000	103,000	1967
	2. S–II (Five J–2)	LOX/LH	1,150					
	3. S–IVB (One J–2)	LOX/LH	230					

[1] The date of first launch applies to this latest modification with a date in parentheses for the initial version.

[2] Each motor.

[3] Height to spacecraft interface.

[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—IRFN/UDMH; Nitrogen Tetroxide and 50% UDMH and 50% Hydrazine (N_2H_4)—N_2O_4/Aerozine; Liquid Oxygen and Liquid Hydrogen—LOX/LH.

[5] Due East Launch.

APPENDIX E

Nuclear Power Systems for Space Application

Designation	Application	Status
SNAP–3	Navigation satellites (DOD)	Units launched in June and November 1961. Unit still operating at reduced power levels.
SNAP–9A	Navigation satellites (DOD)	Units launched in September and December 1963. Units still operating at reduced power level. Third satellite failed to orbit in April 1964.
SNAP–19	Nimbus B weather satellite (NASA)	First Nimbus B launch aborted; Pu-238 fuel recovered from offshore waters. Replacement unit launched in April 1969 and has operated continuously at gradually reducing power levels since that time.
SNAP–27	Apollo lunar surface experiment package (NASA)	First SNAP–27 placed on lunar surface by Apollo 12 astronaut in November 1969. System is supplying total power for ALSEPS of Apollo 14 & 15.
SNAP–10A	Unmanned missions	Tested in orbit in 1965.
Transit	Navigation satellites (DOD)	Development program underway.
Pioneer	Jupiter flyby mission (NASA)	Modified SNAP–19 generator system.
Viking [1]	Mars unmanned lander mission (NASA)	Modified SNAP–19 generator system.
Multi-Hundred Watt [1]	Outer planet missions (NASA)	Development program underway.

[1] Planned missions.

APPENDIX F–1

Space Activities of the U.S. Government

15-YEAR BUDGET SUMMARY—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			3.2	6,999.8
1967	4,967.6	4,862.2	1,663.6	183.6	29.3			2.8	6,741.5
1968	4,588.8	4,452.5	1,921.8	145.1	28.1	0.2	0.5	3.2	6,551.4
1969	3,990.9	3,822.0	2,013.0	118.0	20.0	0.2	0.7	1.9	5,975.8
1970	3,745.8	3,547.0	1,678.4	102.8	8.0	1.1	0.8	2.4	5,340.5
1971	3,311.2	3,101.3	1,512.3	94.8	27.4	1.9	0.8	2.4	4,740.9
1972	3,306.6	3,071.0	1,407.0	55.2	31.3	5.8	1.6	2.8	4,574.7
1973	3,406.5	3,092.6	1,623.0	58.9	39.7	10.0	2.3	2.8	4,829.3
1974	3,015.0	2,734.2	1,827.0	41.3	54.4	8.4	3.0	2.5	4,670.8

[1] Excludes amounts for aviation technology.

Source: Office of Management and Budget.

APPENDIX F–2

Space Activities Budget

[In millions of dollars]

	New obligational authority			Expenditures		
	1972 actual	1973 actual	1974 estimate	1972 actual	1973 actual	1974 estimate
Federal space programs:						
NASA [1]	3,071.0	3,092.6	2,734.2	3,194.9	2,811.6	2,865.6
Defense	1,407.0	1,623.0	1,827.0	1,470.0	1,557.0	1,767.0
AEC	55.2	58.9	41.3	59.6	54.1	38.5
Commerce	31.3	39.7	54.4	37.4	29.4	37.6
Interior	5.8	10.0	8.4	5.8	10.0	8.4
NSF	2.8	2.8	2.5	2.5	2.5	2.2
Agriculture	1.6	2.3	3.0	1.6	2.3	3.0
Total	4,574.7	4,829.3	4,670.8	4,771.8	4,466.9	4,722.3
NASA:						
Manned space flight	1,639.3	1,520.8	1,385.1	1,740.3	1,416.9	1,449.7
Space science and applications	900.4	1,098.3	898.9	889.8	942.7	965.5
Space technology	213.1	161.0	122.3	228.5	156.1	138.7
Aviation technology	235.6	313.9	280.8	226.8	249.4	269.4
Supporting activities	331.3	323.5	328.9	349.4	306.9	312.7
Less receipts	−13.1	−11.0	−1.0	−13.1	−11.0	−1.0
Total NASA	3,306.6	3,406.5	3,015.0	3,421.7	3,061.0	3,135.0

[1] Excludes amounts for aviation technology.

Source: Office of Management and Budget.

Aeronautics Budget

[In millions of dollars]

	New obligational authority		
	1972 actual	1973 actual	1974 estimate
Federal aeronautics programs:			
NASA [1]	235.6	313.9	280.8
Department of Defense [2]	1,964.0	1,802.0	1,780.3
Department of Transportation [3]	94.8	86.3	88.0
Total	2,294.4	2,202.2	2,149.1

[1] R. & D., R. & P.M., C. of F.
[2] R.D.T. & E. aircraft and related equipment.
[3] Office of Sec. of Trans. and FAA.
Source: Office of Management and Budget.

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