

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

*1976 Activities*

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# Aeronautics and Space Report of the President

*1976 Activities*



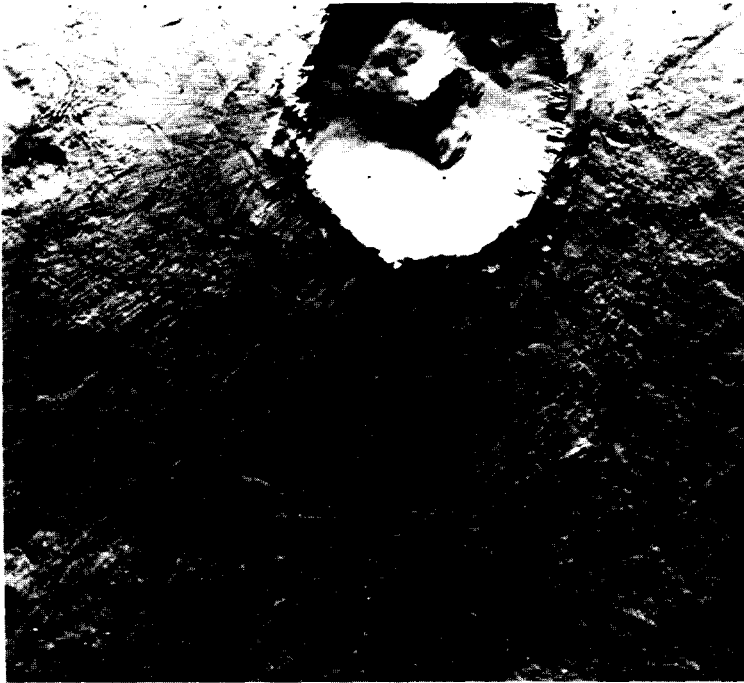
**National Aeronautics and Space Administration  
Washington, D.C. 20546**

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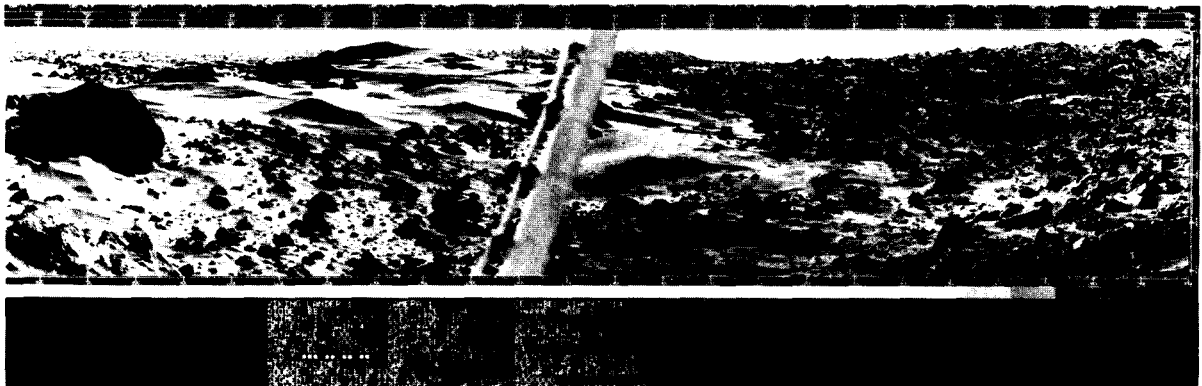
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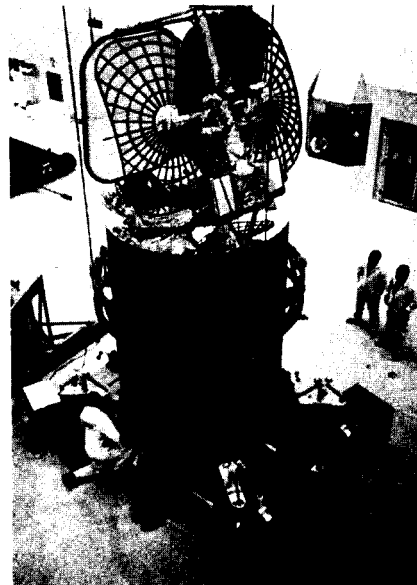
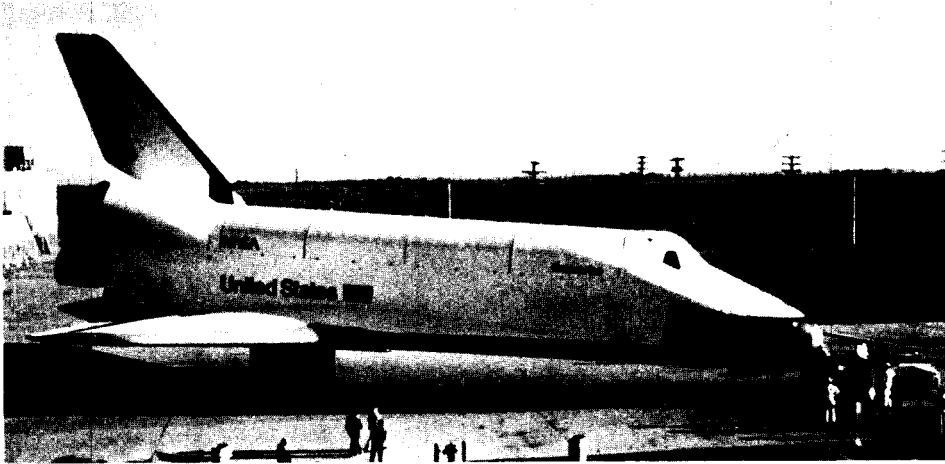
## Aerospace Events in the Bicentennial Year

The United States in 1976 orbited spacecraft around Mars and landed and operated spacecraft on its surface, showed the first Space Shuttle Orbiter, launched a number of communications satellites, flight-tested research aircraft, and opened the new National Air and Space Museum.

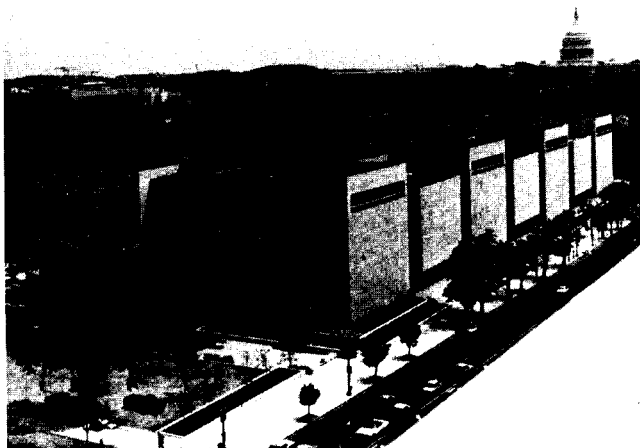


From an altitude of 1857 kilometers, the Viking 1 orbiter photographed the meteorite crater Arandas on Mars (above) in July. Twenty-five kilometers in diameter and with a typical clearly defined rim and conical peak at the bottom, Arandas and some other craters on Mars have one surprising feature: the ejecta layer around it appears to have flowed out of the crater rather than having been blasted out by the impact of the meteorite. Similar results have been seen in experimental cratering of waterlogged ground. A closer look at the Martian landscape was afforded by the lander spacecraft. The panorama below was photographed early on an August morning by the Viking 1 lander. The wind-sculpted sand dunes look much like parts of Mexico and California. The large boulder at left, about 8 meters away, measures about 1 by 3 meters.





Enterprise (top), first of five Space Shuttle Orbiters for the Space Transportation System, was rolled out of the factory at Palmdale, California, on September 17. The joint NASA/Army experimental Tilt Rotor Research Helicopter (above) was delivered and began flight tests in 1976. At right, the Comstar 2 domestic communications satellite was being readied for mating with its launch vehicle prior to launch in July. And below, a view of the Independence Avenue side of the Smithsonian's new National Air and Space Museum which opened July 1.





# Summary of United States Aeronautics and Space Activities in 1976

## Introduction

This bicentennial year has been one of major achievements in space and aeronautics. In space, the most significant accomplishments were the highly successful Viking orbiter and lander missions to Mars and the rollout of the first of the Space Shuttle orbiters. These highly visible milestones were balanced by the growing maturity of the world's space communications systems and the continuing exploitation and evaluation of data from Earth resources and weather satellites. In aeronautics, there was promising research on aircraft technology that could lead to better fuel economy, higher performance with quieter engines, and increased safety both at cruising altitudes and in terminal areas. New automated equipment was placed into operation on the nation's airways, improving the safety and efficiency of the current system. This chapter briefly summarizes and highlights the more detailed contents of the agency chapters that follow.

## Space

The United States had 26 launches into orbit in 1976. A total of 34 spacecraft were orbited. NASA orbited 15 satellites on 15 successful launches; the Department of Defense orbited 19 payloads on 11 successful launches. Of NASA's total, 9 were industry or government communications satellites—1 for INTELSAT, 5 for Comsat Corporation, 1 for RCA, 1 for the U.S. Navy, and 1 communications research satellite for the U.S. Air Force; 1 was an operational weather satellite for the National Oceanic and Atmospheric Administration (NOAA); and 4 were international satellites—1 a joint launch with Canada, 1 launched for West Germany, 1 for NATO, and 1 for Indonesia. Three of the international launches were also communications satellites. Launches for NASA's own program included a laser geodynamic satellite and a suborbital gravity probe (the latter not counted in the orbital launch figures). Among the DOD payloads were 2 communications research satellites and 3 scientific satellites.

## Earth Applications

*Communications.* In August the ATS 6 experimental communications satellite completed its year-long experiment with India, where it had transmitted educational and agricultural instruction programs, prepared by the Government of India, to inexpensive receiving antennas in some 2400 Indian villages. As it was moved back toward the U.S., it participated in a NASA-Agency for International Development program known as Aidsat, beaming programs to 24 Asian and African countries on the potential uses of satellite technology in developing nations.

On the other side of the world, the joint Canadian-U.S. experimental communications satellite was launched in January. The most powerful communications satellite to date, Communications Technology Satellite (CTS) 1 used its higher transmission power and higher frequencies to transmit to small, inexpensive antennas in remote communities.

Operational communications satellite systems continued to grow in 1976. The international INTEL-SAT system acquired additional capacity in January when NASA launched Intelsat IV-A F2 as a backup for the first of this updated series. Satellite technology helped Indonesia meet a national need for better communications with the July launch by NASA of Indonesia's Palapa 1 communications satellite. When it began transmitting from synchronous orbit in August, it was the first time the thousands of inhabited islands in the archipelago were linked by direct communication. In the U.S., the number of operational domestic communications satellites doubled during 1976 with the launches of RCA-Satcom 2 and Comstars 1 and 2. A new special purpose communications satellite system also came into being with the launches of Marisat 1, 2, and 3.

*Weather.* The network of U.S. weather satellites maintained its operational status with the launch of the polar-orbiting NOAA 5, allowing NOAA 3 to be deactivated. NOAA was developing a system for SMS satellite monitoring of the data-sparse Gulf

of Mexico for potential severe storm conditions and was experimenting with 3-minute-interval images from the Goes 1 satellite of low-level cumulus clouds to study their potential to become hurricanes.

*Earth Resources.* Work continued to define and refine the uses and techniques of exploiting satellite sensors for gathering wide-area information on the character, conditions, and changes of land areas. A cooperative project of NASA, Department of Agriculture, and NOAA, LACIE (Large Area Crop Inventory Experiment) continued in its second phase. The second phase will extend measurements of wheat production to areas outside North America as part of the overall LACIE effort to examine the feasibility of a space-based global crop inventory system.

ICEWARN, the NOAA project that tracks ice formation in the Great Lakes, had a second successful winter season, enabling uninterrupted shipping throughout the winter of 1975–1976. The Coast Guard has extended the technique to the coastal waters of Alaska.

A number of established and new demonstration projects used Landsat satellite data to inventory forest, water, wildland, and range resources, as well as deriving contemporary, wide-area data on urban development. These demonstration projects are sponsored by a number of agencies, including NASA and the Departments of Agriculture, Interior, and Commerce.

*Monitoring Air and Water Quality.* An intensified program of stratospheric monitoring established more accurate measurements of the effect of aerosols and other man-generated gases on the upper atmosphere, including the effect of emissions from forthcoming flights of the Space Shuttle. Several agencies, including NASA, NOAA, the National Academy of Sciences, the National Science Foundation, and the Smithsonian Institution, are cooperating in the examination of this complex problem.

In the lower atmosphere, the utility of satellites and aircraft for measuring and establishing baselines of air pollution and experimenting with long-term techniques for monitoring changes in the baselines was actively explored by the Environmental Protection Agency (EPA), supported by NASA, NOAA, U.S. Geological Survey, and other agencies. For example, EPA was testing an aircraft-mounted differential-absorption LIDAR (light-detecting and ranging) system that constructs a vertical profile of relative particle density, showing the horizontal and vertical travel of smokestack emissions.

Similarly techniques for monitoring sea and lake pollution, currents, and circulation patterns were

studied and measured by several agencies including EPA, NASA, and NOAA. An example is EPA's testing of an aircraft-mounted laser fluorosensor that identifies organics, including specific oils, on surface water, offering a means of detecting and assessing industrial pollution.

### *Planetary Exploration*

*Mars.* The most significant event in space during 1976 was the successful Viking mission to Mars. During the summer both spacecraft reached the planet, were slowed down, and put into orbit. Careful study of the photos taken by the orbiting spacecraft and of the radar returns from NSF's upgraded radar telescope at Arecibo, Puerto Rico, narrowed the search for safe landing sites. On July 20 and September 3 the lander vehicles separated from the orbiters and made successful landings on the Martian surface. The orbiters continued photographing the planet, depicting mountains and canyons larger than any on Earth and widespread evidence of water and steam erosion in Mars's geologic past. The orbiters also measured the water vapor in the atmosphere and on the surface, discovering large amounts of water locked in the frozen polar caps. The landers photographed the detail of the surface around their landing sites, confirming the red color of the surface and the pinkness of the lower atmosphere; monitored the Martian weather, which to the end of the year remained much the same from day to day; and scooped up soil and processed it in a series of biochemical tests in an effort to determine whether microbial life exists on Mars. Such evidence of life is still unclear at the year's end. In November the intensive phase of the missions ended, and NASA began the extended missions, a lower phase of activity that would continue observing seasonal changes until about September 1978.

*Venus.* In addition to using its big radar telescope to assist NASA in determining the roughness of proposed Viking landing sites on Mars, NSF also used the instrument to penetrate the murky atmosphere of Venus. There it found a 1,500,000-square-kilometer flat area similar to the lunar "seas". Another discovery was a series of parallel canyons and ridges extending unbroken for hundreds of kilometers and unlike any formations on Earth.

*Saturn.* Pioneer 11, having flown past Jupiter in 1974, was still using the gravitational acceleration imparted to it by that huge planet to cross the solar system toward Saturn. It is due to fly by Saturn in 1979.

### *Sun and Sun-Earth Interactions*

Ever since the Skylab missions of 1973–1974, scientists have been studying the 171,000 photographs



of the Sun taken by the 10 instruments in the Apollo Telescope Mount. Since Skylab, OSO 8 has been orbited for solar study, as well as the two West German Helios satellites, which have traveled closer to the Sun than any other man-made object. Only a preliminary analysis has been possible of these more recent data, but those results were combined with Skylab data in a Skylab Solar Workshop held in 1976. Important findings resulted, not only for understanding of the Sun itself, but for those functions of the Sun that control the solar wind that blows upon the outer fringes of Earth's atmosphere and affects our weather and communications. Coronal holes, the wellspring of the solar wind, were studied closely: temperatures at various levels were measured, locations pinned down, the nature of movements identified. Larger convectional trends on the Sun's surface were tracked and better understood. Because of certain anomalies in the data, future satellite missions, most importantly the Solar Maximum Mission, were set in motion in an attempt to fill gaps in the data.

### *The Universe*

The search for understanding of the origins of the Universe, its dynamics, and future has been a target of the space program since its inception and continued in 1976. The OAO 3 satellite (also called Copernicus) has been operational since 1972. New techniques, developed since the spacecraft was launched, have extended its observational sensitivity to objects one-sixth the brightness that it could originally perceive and extended its range in the near ultraviolet.

NSF, in studies of the relative movement of galaxies in the Universe, discovered that our galaxy and nearby galaxies are traveling at higher speeds than previous theory had predicted.

A NASA suborbital probe, Gravity Probe A, was launched in 1976 to test an important part of Einstein's general theory of relativity—the concept that a clock beyond the influence of Earth's gravity field would run faster than its counterpart on Earth. Extremely accurate maser clocks developed by the Smithsonian Institution were used in the 2-hour flight that reached an altitude of 10,000 kilometers; the results generally confirm that portion of the Einstein theory.

Studies continued of the proposal for a space telescope, intended to be an international facility launched and maintained by Space Shuttle missions and to provide data to be analyzed by scientists worldwide.

### *Space Transportation*

The Space Transportation System represents a major turning point in the national space program.

Intended to put manned and unmanned space flight on a more routine basis and to reduce the cost of putting each pound of cargo in orbit, the system has been designed around the concept of maximum reusability of major components and regular operational performance. The principal element in the system is the Space Shuttle; looking somewhat like a transport aircraft, the Shuttle will be powered by three high-pressure rocket engines burning liquid hydrogen and liquid oxygen. Its cockpit area will contain the flight controls and the flight crew of three astronauts. Behind the cabin will be a cargo bay, 19 meters long and 5 meters wide, that will contain cargoes weighing as much as 29,250 kilograms. Though the cargo bay itself is unpressurized, it will be fitted with the Spacelab, a sophisticated set of modular units that can permit a crew of as many as four experimenters to operate the instruments in the payload.

At launch the three Shuttle engines will be augmented by two solid-fueled rocket boosters strapped to the fuselage on either side of a large, external liquid-fuel tank. When the Shuttle has risen above the atmosphere, the boosters will drop off and parachute down to an ocean landing, to be recovered and reused. The external fuel tank is subsequently jettisoned. The Shuttle engines will carry the vehicle into low Earth orbit (some 320 kilometers), where it can remain as long as 30 days. In addition to the wide variety of experiments that can be performed from the Spacelab, the Shuttle can use an arm-like remote manipulator to lift satellites out of the cargo bay and place them in orbit, or to pick up satellites already in orbit and place them in the cargo bay, where they can be repaired or returned to Earth for refurbishment. For missions where a high-energy orbit is needed, the expendable Interim Upper Stage, which has rocket motors, can be attached to the payload. In returning to Earth, the Shuttle will descend through the atmosphere more gradually than previous space vehicles, using the aerodynamic lift of its wings, and will flare out and land on a 5-kilometer-long runway at Kennedy Space Center, Florida, or Vandenberg Air Force Base, California.

Since presidential approval in 1972, the Space Transportation System has been under research, development, and most recently fabrication. A major event took place on September 17, when the first Space Shuttle orbiter was rolled out in Palmdale, California. In mid-1977 the orbiter will begin approach and landing tests at Dryden Flight Research Center. In 1979 the second Space Shuttle will begin orbital test flights, preliminary to inauguration of operations in 1980. When the full five-Orbiter fleet is in operation, the Space Transportation System will replace most of the present

stable of expendable launch vehicles for NASA, DoD, international, and commercial missions.

### *International Cooperation*

*Space Transportation System.* International participation in the forthcoming Space Transportation System continued to grow during 1976. Spacelab, the major Space Shuttle system being developed by the European Space Agency, passed its preliminary design review in December. The first flight unit is to be delivered in 1979, a year before its first mission. In addition to this \$500 million European investment, Canada began development this year of the remote manipulator system, a commitment involving tens of millions of dollars.

Potential government, industry, and university users of the Space Transportation System from Europe, Canada, and Japan were briefed on capabilities, payload accommodations, and probable terms and conditions of use. NASA and the European Space Agency completed preliminary studies of the first Spacelab payload. For the Orbital Flight test phase that will begin in 1979, invitations were sent out internationally for proposals of experiments.

*Communication Satellite Experiments.* The ATS 6 experimental communications satellite completed its one-year experiment of transmitting Indian educational programming to small receivers in some 2400 villages in India. Though the results are still being evaluated, the practicality of such broadcasting was clearly demonstrated.

In August ATS 6 began its return journey toward the U.S. On the way it served as Aidsat, making demonstration broadcasts to 24 developing nations and regional organizations on the possible uses of space technology for national development, and transmitting live, two-way conversations between local and U.S. officials and experts.

Canada's Communications Technology Satellite (CTS) was launched by NASA in January, and the two countries began sharing its broadcast time for experiments in using higher power signals to transmit health care, education, and special service messages to remote, relatively inexpensive receivers.

Other events of the year were the three launches by NASA of international satellites, four agreements for instrumentation on future NASA satellites, and 173 proposals for experiments from 15 countries and agencies for 14 flight opportunities on future NASA satellites and Space Shuttle flights.

### *Defense*

In space operational systems, as well as research and development, the Department of Defense moved ahead in 1976.

The NAVSTAR Global Positioning System, a worldwide, precision, three-dimensional navigation system based on satellites, conducted ground tests of prototype hardware, preliminary to the launch of the first six satellites in 1977. Until NAVSTAR is fully operational, the TRANSIT satellite system will continue to provide two-dimensional navigation.

Communication satellite systems have become more and more important to DoD both for worldwide command and control and for operational communications. In 1976 the Defense Satellite Communications System, the command and control system, continued operations through its satellite over the Pacific and shared use of the NATO satellite over the Atlantic and the U.K.'s Skynet satellite over the Indian Ocean. The Navy Fleet Satellite Communications System was preparing its Earth terminals for the launch of its first satellite in 1977. Production of terminals began for the Air Force Satellite Communications System.

DoD intensified its preparations for use of the Space Shuttle, which will have a major effect on the nature and cost of space operations. In addition to mission planning and coordination with NASA, the Air Force initiated development of the Interim Upper Stage, to be used with the Space Shuttle when high-energy missions are required. Contracts were let for defining the Space Shuttle ground facilities to be constructed at Vandenberg Air Force Base.

### **Aeronautics**

The broad purposes of U.S. aeronautical research and development are to improve the performance, efficiency, and safety of current commercial and general aviation aircraft and the airways on which they fly; to provide the technology base for future aircraft; and to maintain the competitive performance of current and future military aircraft.

In recent years increasing concern over environmental problems and oil resources has focused much of the research on quieter aircraft with lower fuel consumption and emission rates.

### *Improving Current and Future Aircraft*

The Aircraft Energy Efficiency program was established by NASA in 1976. It seeks technology that will reduce fuel consumption of future commercial transport aircraft by 50 percent, as compared to current aircraft. Research will principally center in three areas: (1) redesign of components in large turbofan engines to reduce specific fuel consumption; (2) combining new aerodynamic technology, such as the supercritical wing and winglets, with

active flight controls that allow significant reduction of structural weight; and (3) substituting composite materials in place of metal in certain structures, for a weight savings of some 30 percent.

Other research on improving future aircraft included a NASA contract to build a Quiet Short-Haul Airplane, wind-tunnel testing of a supersonic transport model that promised a 30 percent improvement in supersonic lift-over-drag ratio over the 1971 U.S. supersonic transport design, and providing design information for a second low-speed airfoil of improved lift and drag characteristics for general aviation aircraft.

### *Improving the Operational Environment*

Aircraft noise and particle emissions from engines were the principal subjects of this research. A computer program has been constructed that can predict the takeoff and landing noise generated by current and conceptual aircraft. Further validation will refine this program. Comprehensive studies of community response to aircraft noise are identifying the types and levels of aircraft noise that cause most concern in communities near airports.

In emission control, NASA's Experimental Clean Combustor program for gas turbine engines reached the hardware demonstration phase. Preliminary results from ground tests of complete engines suggest major reductions in emissions during takeoff and landing and significant reduction in nitrogen oxide emission at high-altitude cruise.

Another major area of research is in improving the efficiency and safety of terminal and airways operations. NASA worked with the Federal Aviation Administration (FAA) on reducing wake vortices that trail behind large aircraft, on defining the conditions likely to cause low-altitude wind shear near airports, and on improved safety reporting. The two agencies also demonstrated to the International Civil Aviation Organization the first application of all-digital controls in a commercial transport aircraft. A number of hands-off landings were made with the system controlling approach and the landing flare. The FAA also inaugurated a long-term project to automate and streamline their nationwide network of Flight Service Stations.

### *Defense*

In 1976 DoD improved the combat aircraft inventory, continued research and testing on next-generation aircraft and components, and worked with NASA on several research aircraft.

The first F-16 air combat fighter, being produced in concert with five European nations, was delivered; the F-15 fighter reached full production; and F-14As were arriving aboard carriers.

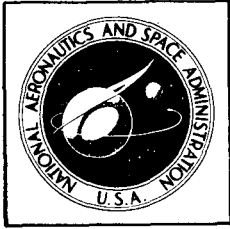
In research and development, the F-18 fighter entered full development, and the B-1 bomber neared the end of flight testing. All three services increased the number of aircraft components that were being studied or tested for use of composites in place of metal to reduce structural weight. The Laser Obstacle Terrain Avoidance Warning System was flight-tested and found sensitive enough to detect obstacles as slender as a small wire. Simulator development continued for helicopter flight characteristics under instrument flight conditions for the CH-47 and AH-1 aircraft.

In joint DoD-NASA programs the two agencies completed design of the joint Highly Maneuverable Aircraft and began fabrication of two remotely piloted research aircraft. In both joint experimental helicopter programs—the Rotor Systems Research Aircraft and the Tilt Rotor Research Aircraft—aircraft were delivered for flight testing.

Details of the events summarized will be found in the succeeding chapters.

### **The Heritage**

This bicentennial year, which witnessed the beginning of a new chapter in the history of flight with the Viking landings on Mars and the rollout of the Space Shuttle Orbiter, also became the year of commemoration of the past history of flight. On July 1, the Smithsonian Institution opened the new National Air and Space Museum. Situated on the Mall in Washington, the museum displays the actual craft that made flight history, from the Wright Brothers' airplane to the Apollo 11 spacecraft that carried men to the first landing on the Moon. Exhibits in 23 bays tell the story of the technology, science, and history of flight. Public response was immediate; more than five million persons visited the museum in the first six months.



# National Aeronautics and Space Administration

## Introduction

The National Aeronautics and Space Administration (NASA) is the civilian agency of the United States government charged with planning, direction, and conducting research and development activities related to civilian space and aeronautics programs. In carrying out these responsibilities, the agency works with many other civilian Federal agencies that have research or operational interest in these fields and also interacts with and provides research and development assistance to the Department of Defense, which conducts the military space and aeronautics program.

In its space program, NASA has since its inception in 1958 pursued several broad goals: development of technology for space operations, demonstration of practical applications of space systems and technology, and discovery of new scientific knowledge about the origin, evolution, and processes of the universe, our solar system, near space, and the complexities of the Earth's atmosphere. While emphasis has fluctuated from time to time, the broad intent has remained constant.

In our bicentennial year of 1976, NASA made significant advances toward these objectives. In space, a combination of space research and operations produced a NASA launch total of 16 satellites and probes, 14 of which supported new or existing commercial, national, and international systems, while 2 supported NASA R&D initiatives.

Two major milestones in NASA's R&D program were the successful landings and long-duration operations of the Viking 1 and 2 spacecraft on Mars and the rollout of the first Space Shuttle Orbiter. Meanwhile a large network of previously launched satellites and instruments continued to operate successfully—from Earth-focused satellites returning data on crops, population distribution, sea state, weather warnings; to greatly increased information about the planets of the solar system, the Sun, and the new discoveries in the galaxies—pulsars, quasars, black holes. In aeronautics, research continued on improvement of current commercial aircraft, of future higher performance aircraft, and of the safety and performance of current airway systems.

## Applications to Earth

The applications program continued in 1976 to make significant strides in attaining its goals and objectives through the application of space technology in communications, environmental research, weather forecasting, and improving man's understanding of the Earth. Satellites continued to improve our ability to locate, inventory, and manage our planet's resources. Efforts to improve the technology transfer process also continued.

### *Communications*

*Applications Technology Satellite 6 (ATS 6).* The ATS 6 satellite completed two years of successful orbital operations on May 30, 1976. India's Satellite Instructional Television Experiment (SITE), completed on August 1, 1976, was conducted by the Indian Government to provide instructional television via the ATS 6 satellite to about 2400 villages, reaching some 3 million viewers regularly. Areas of instruction included family planning, health and hygiene, agriculture, and national development. In August 1976, ATS 6 started moving slowly back to the U.S. for an experimental program in the societal, communications, and technological disciplines. En route, ATS 6 supported the U.S. Agency for International Development in a project to demonstrate application of communications and remote sensing technology to developing countries, via direct satellite broadcasting to more than two dozen countries.

*Communications Technology Satellite (CTS-1).* The CTS-1 satellite, a cooperative program with Canada, was launched on January 17, 1976, to experiment with technology for satellite communications to low-cost ground stations at the 12 GHz frequency, allocated specifically for satellite broadcasting without power limitations. By December 1976, eleven of eighteen experiments had started operations over a wide range of educational, health, social services, and information-exchange investigations.

*Advanced Communications Research and Technical Consultation.* Research was expanded on the higher regions of the radio frequency spectrum.

Studies continued on frequency allocations, bandwidth and orbit requirements, and the opening of new regions of the communications spectrum for future missions. Research to improve space communications components and technologies continued, and new capabilities were demonstrated using experimental hardware for voice, data, and educational television. The objective was more efficient use of the available spectrum through new bandwidth-compression techniques.

Technical consultation to the Federal Communications Commission on satellite systems evaluations and design reviews was completed as new commercial applications for satellite services were filed. A special effort was the preparation for the 1977 World Administrative Radio Conference (WARC) on Broadcast and Fixed Satellite Services. NASA also increased its support to the Department of State, Federal Communications Commission, and the Office of Telecommunications Policy in preparation for the 1979 WARC.

#### *Data Collection via Satellite*

The Corps of Engineers continued to use data collection platforms reporting through Landsat 1 and 2 to collect hydrologic data in New England. Also a joint NASA-California Division of Forestry prototype-operational demonstration began in July 1976 to test a satellite-aided automated fire-weather data system as an aid to predicting the onset and location of forest fires. Wind velocity, air temperature and humidity, solar radiation, and the moisture of the ground fuel were measured by 24 instrumented platforms at remote California sites and the data regularly sent via the Goes 1 spacecraft to the Division of Forestry in Sacramento for analysis and decision making.

*Satellite-Aided Search and Rescue.* NASA studies continued on a space concept to detect and locate endangered aircraft and ships equipped with Emergency Locator Transmitters. Satellite-aided search and rescue feasibility experiments employing the Oscar VII (Amateur Radio) spacecraft have demonstrated that emergency signals can be relayed through a satellite to ground stations hundreds of miles away and provide useful positions information.

#### *Earth Resources*

Satellites contribute important information to the search for necessary resources and the preservation of the environment.

During 1976, the Landsat 1 and 2 satellites continued to operate satisfactorily, providing almost total global coverage every 9 days. A portable

ground station was installed in Pakistan to obtain data from that part of the world without placing undue demands on the one operable tape recorder on Landsat 2. Development of Landsat-C and its sensors progressed on schedule to meet a projected late 1977 launch date.

During 1976, good progress was made in the ongoing Applications Systems Verification and Transfer projects and five new ones were initiated. The purpose of these projects is to develop, demonstrate, and transfer technology to managers and planners in the public and private sectors. In addition, interest and participation by the public and private sectors steadily increased, in many cases independently of NASA and without Federal funding.

The Large Area Crop Inventory Experiment operated during its second wheat-growing season, and measurements were extended to more areas outside North America. The ICEWARN project, which provided information on ice conditions in the Great Lakes for the second straight year, was an important factor in having uninterrupted shipping on the lakes through the winter of 1975-1976. The technique was also used by the Coast Guard along the north coast of Alaska. A project in the western U.S. gave indications of potential benefits resulting from use of Landsat data for snow mapping. The Corps of Engineers examined the feasibility of producing computer-generated land cover classification maps for the entire nation, based on Landsat data and using NASA-developed techniques. The Pacific Northwest Regional Land Inventory Project achieved positive results in all the discipline areas (urban, land use, agriculture, water resources, forestry, and range).

New Applications Systems Verification and Transfer projects initiated in 1976 were:

- a Water Management and Control project in cooperation with the Corps of Engineers to use Landsat data to predict water run-off in flood-prone areas.
- a Census-Urbanized Area project in collaboration with the Census Bureau to monitor urban and suburban growth.
- a Forest Resource Inventory System in collaboration with the St. Regis Paper Company to quantify forest resources, using Landsat data.
- a Wildland Vegetation Inventory project in cooperation with the Bureau of Land Management to develop techniques by which the Bureau can classify and inventory the 1,918,000 square kilometers of land in Federal ownership.
- a Land Cover Change Detection Survey, in cooperation with the U.S. Geological Survey, to develop a capability for using Landsat data

in the Bureau of Land Management's Land Use and Data Analysis program.

### *Weather and Climate*

The Weather and Climate Program is directed toward research on the detection and monitoring of severe storms, the development of improved operational satellite systems in support of the National Weather Service, and continued support of the international Global Atmospheric Research Program (GARP).

Applying the unique capability of geostationary weather satellites to monitor most of the North American continent and its bordering oceans, the NASA-developed Synchronous Meteorological Satellite, SMS-2, and Geostationary Operational Environmental Satellite, Goes 1 (launched in October 1975), have been used by NOAA to detect the presence and predict the movement of severe storms such as hurricanes. The NASA-developed NOAA 5 satellite was launched on July 29, 1976, into polar orbit and it is providing global quantitative atmospheric and sea data. The Atmospheric and Oceanographic Information Processing System has been completed and placed into operation at the Goddard Space Flight Center.

In preparation for the First GARP Global Experiment (FGGE) to be conducted in 1978-1979, unique global weather data sets have been obtained during both summer and winter data systems tests. FGGE research is designed to improve the reliability and length of time over which weather forecasts can be made.

At the Goddard Space Flight Center, a processing project has been established to process and distribute Nimbus 4 global ozone data to scientific users.

### *Environmental Quality Monitoring*

The Environmental Quality Monitoring program concentrates on developing and demonstrating the technology for measuring and monitoring those environmental parameters which affect the quality of the Earth's atmosphere and water.

For the upper atmosphere, emphasis is on developing a space-based capability for monitoring stratospheric ozone, trace gases, and aerosols. The Stratospheric Aerosol Measurement (SAM), flown in 1975 on the U.S./U.S.S.R. Apollo-Soyuz mission, demonstrated the usefulness of the solar occultation technique for measuring aerosols from orbital distance. Advanced versions of the SAM instrument will be flown on the Nimbus G satellite and the Applications Explorer Mission-B/Stratospheric Aerosol and Gas Experiment scheduled for launch in 1978 and 1979, respectively. During the past year,

aircraft, rocket, and balloon measurements have contributed to understanding the seasonal and geographical variations of ozone, aerosols, and nitric oxide (a by-product of high-altitude aircraft operations). Advanced techniques have been developed and demonstrated for the measurement of other important trace gases, including nitrogen dioxide, nitric acid, and the hydroxyl radical. These techniques will provide new tools for regulatory agencies such as the Environmental Protection Agency (EPA) and state environmental agencies. The NASA water quality program attacks four general problem areas: ocean dumping, red tide detection, lake water quality classification, and the definition of off-shore ocean and Great Lakes water quality indicators. NASA and EPA executed an interagency agreement which provided the framework for more extensive cooperative projects between NASA and EPA. A joint working group was then formed to help focus NASA technology development in response to EPA monitoring requirements.

### *Earth Dynamics Monitoring and Forecasting*

The objectives of the Earth Dynamics and Forecasting Program are to demonstrate the use of space technology for gravity and magnetic field mapping, for resource assessment, for geodetic surveying including the monitoring of subsidence, for detection of crustal motions in faulted regions, and for improved determination of polar motion and Earth rotation.

Analysis of satellite-to-satellite tracking data acquired during the Apollo-Soyuz Test Project was used to further define the large gravity anomaly in the Indian Ocean. Work continued on the development of accurate global geoids using satellite tracking data and ocean geoid data acquired with the Geos 3 altimeter.

In response to a need for global magnetic field data for updating field models and magnetic field charts for navigation and resource assessment, NASA and the U.S. Geological Service have undertaken the development of a Magnetic Field Satellite (Magsat) for launch in late 1979. The data acquired with Magsat, in combinations with gravity field data and imagery acquired by Geos and Landsat, should make it possible to develop a map of potentially interesting areas for resource exploration.

The Laser Geodynamic Satellite (Lageos) was launched in May 1976. Lageos is intended for use as a nearly permanent reference point in space for laser ranging from Earth. Observations have verified the stability of its orbit; its predicted orbital position does not vary more than a few meters over many weeks.

This year, as in 1972 and 1974, mobile lasers were deployed on either side of the San Andreas fault to determine any motion of the tectonic plates which form the fault boundaries.

### *Ocean Condition Monitoring and Forecasting*

The Ocean Condition Monitoring and Forecasting program supports research and experimentation associated with the use of space techniques for monitoring and forecasting sea state conditions, ocean currents and circulation patterns, accurate measurement of the sea surface topography, and the incorporation of data on the energy exchange at the air/sea interface into short and long range global weather forecasting.

Data acquired with Geos 3 have been used to demonstrate the acquisition of sea state information and have shown that ocean currents can be detected by the change in radar reflectivity of the moving water and a small depression (about one meter) of the height of mean sea level.

Seasat-A, the first experimental ocean satellite designed to provide the global data needed to validate the use of remotely sensed ocean data, continued under development and is scheduled for flight in mid-1978. Seasat-A will carry both active and passive microwave instruments and an optical radiometer. Data from these instruments will provide information on wave height and direction, ocean surface temperature, sea surface topography, and sea ice. NASA and the U.S. Navy's Fleet Numerical Weather Central have entered into an agreement for the Navy to process and use Seasat data in its ocean forecasting programs. Cooperative agreements were being developed with other agencies and with commercial interests. Work also progressed on the definition of experiments to demonstrate the use of Seasat data for routing of commercial shipping, large-scale fishing, various other off-shore activities, and coastal fishing surveillance.

### *Materials Processing in Space*

The goals of this program are to develop and demonstrate the use of the space environment for activities in materials science and technology and to encourage privately funded efforts in these areas. Previous experience with Skylab and ASTP experiments and analytic studies identified a number of organic and inorganic products that appear to be feasible to produce in space, either at lower cost than now possible on Earth or with substantially improved characteristics. It is also evident that the low-gravity, high-vacuum environment of space presents a unique opportunity for materials research.

During 1976 definition studies of materials research payloads for the early missions of the Space Shuttle and Spacelab were completed and facilities were identified for the initial Shuttle missions involving space processing; these are planned for 1980-1981. Pending the availability of the Shuttle, space processing experiments have been continued using sounding rockets under the Space Processing Applications Rocket program. These rocket flights can carry 6 to 10 experiments each and provide about five minutes of weightlessness. The first two flights were conducted in 1976; three flights are planned for 1977.

Ground-based studies were also conducted on a variety of potential applications, including separation of white blood cells for medical purposes, growth of electronic crystals in special shapes, production of high-power-laser glass, and manufacture of low-cost solar cells.

### *Technology Applications*

A one-million-gallon-per-day pilot plant, using the NASA/JPL-developed Activated Carbon Treatment System for wastewater, was completed in Orange County, California. Initial operation of the plant verified the technical and economic feasibility of converting sewage sludge into activated carbon by means of pyrolysis and using the resulting carbon to treat incoming wastewater.

Another wastewater treatment system being developed uses water hyacinths to absorb large quantities of nutrients, heavy metals, and other pollutants as the final filtration agent in sewage treatment lagoons. This past year produced experience with an operational system in Mississippi. When used appropriately, this Vascular Aquatic Water Treatment System has proven to be an effective, low-cost means of meeting EPA water quality standards.

A means of determining conformance with EPA water quality standards was also being developed by NASA. This automated Water Monitoring System, which evolved from research on life support systems for long-duration manned flights, monitors water quality parameters in near-real time. The system would be field tested in FY 1977 in cooperation with the Gulf Coast Waste Disposal Authority.

NASA was also developing the Agro-Environmental System, which ties pertinent environmental measurements at a number of Virginia Agriculture Experiment Stations into the computer system of the Virginia Polytechnic Institute and State University. This information would be used to optimize the time of application and amounts of pesticides, herbicides, fertilizer, and irrigation water to maximize yield and minimize cost. Two of the projected eight stations of the system were instrumented to

verify the crop management models which are key elements of the system.

## Science

### *Study of the Earth's Upper Atmosphere*

During 1976 the Upper Atmospheric Research Office of NASA pursued its program to acquire a sufficient understanding of the chemical and physical processes occurring in the Earth's atmosphere so that (1) perturbations in the stratosphere caused by man's activities can be accurately assessed, and (2) associated changes in the transmission of solar radiation through the stratosphere to the surface can be determined. A program plan was published which emphasized the development of a long-term basic science program involving field measurements, laboratory experiments, and theoretical studies, but focused in the near-term on assessing the stratospheric impacts of (1) Space Shuttle operations, (2) aircraft operations, and (3) chlorofluoromethanes (CFMs). The institutional base for this program was drawn from an evolving combination of NASA field centers and the university and industrial communities.

*Basic Science Program.* Implementation during 1976 of the basic science elements of field measurements, laboratory experiments, and theoretical studies led to a number of positive results. The first measurements of atomic chlorine (Cl) and chlorine monoxide (ClO), providing direct evidence of the reaction of Cl with ozone in the stratosphere, were made, using a resonance fluorescence instrument on a high-altitude balloon. Measurements of CFM concentrations at various locations and altitudes established their present levels. Altitude profile measurements of hydrogen chloride, an important element in stratospheric chlorine chemistry, were made over different seasons and latitudes. Continuing measurements of these and other important stratospheric constituents, as well as the development of new and improved measurement techniques, were being emphasized.

Laboratory experiments addressed the need for improved measurements of photochemical parameters and reaction rates of vital stratospheric reactions, particularly those reactions involving chemical radicals. Rates for a number of chemical reactions involving OH, Cl, and ClO were measured during 1976. These new and improved data were necessary for theoretical studies that emphasized the development and verification of one-, two-, and three-dimensional models for simulation of the stratosphere. The models, which incorporated both chemical and dynamical processes in varying degrees of complexity, were being continually improved. With

inputs and verification from laboratory experiments and field measurements, these models were central to efforts aimed at assessing potential stratospheric changes caused by man's activities.

*Assessment Activities.* During the past year, efforts directed at assessing the potential impact of Space Shuttle exhaust emissions of stratospheric ozone culminated in a Space Shuttle environmental workshop on stratospheric effects. The major conclusion of this workshop held that a Space Shuttle system with 60 launches per year could be expected to result in an ozone depletion of only 0.2 percent. Program activities in the formal assessment procedures, as well as in the basic science elements required as inputs, were under way for the assessments of aircraft operations and CFM releases. For example, NASA convened an international conference on the stratosphere and related problems in September 1976 to review and update scientific findings related to stratospheric perturbations and to focus on the social and political implications of stratospheric pollution.

*Life Sciences.* A major effort in Life Sciences in 1976 was the work on Life Sciences payloads for Spacelab and on medical standards for the Shuttle crew. This is discussed in the section on Space Transportation.

The biological experiments provided to the U.S.S.R. for flight on the Kosmos 782 satellite were recovered successfully last December after 19.5 days in orbit. A joint U.S.-U.S.S.R. scientific report from the flight experimenters was in final preparation. Plans were being formulated for similar cooperative programs to fly experiments on the U.S.S.R. biosatellite scheduled to be flown the last quarter of 1977.

The biological experiments flown as part of the Viking Mars mission were providing data in support of continuing search for life forms beyond the Earth's atmosphere. Initial results of data analysis indicated apparently new chemical systems but were not conclusive as to existence of life on Mars.

### *Study of the Moon and Planets*

An intensive synthesis of data from various sources in the last few years has led to a greatly improved understanding of the solar system. Photogeologic techniques have been used to obtain relative ages of features on Mercury and Mars, and these were combined with ages computed from samples of meteorites and terrestrial and lunar rocks to develop a chronology of the evolution of the solar system. In this chronology the planets formed approximately 4.8 billion years ago and the larger bodies underwent differentiation which was completed some 4.4 billion years ago. They swept up the larger



meteorites during the period 3.5–4.0 billion years ago and have been proceeding on their independent evolutionary paths since then.

*The Moon.* The Moon has been shown to have only a small, partially molten core—if it has any at all. Remanent magnetic fields found in the lunar samples, however, indicate that at one time the Moon's core was sufficiently active to generate a magnetic field. Sample ages have shown that the Moon produced lava flows during the period 3.1–3.8 billion years ago. At present the explanation is that the low volatile content of the Moon gave its interior a higher melting point than that of the Earth and that the radioactive elements present were unable to produce enough energy to create and maintain a molten core.

*The Planets.* Mercury, which is very similar in appearance to the Moon, has a very large magnetic field. Since we have little compositional information, it is not yet possible to explain this difference.

The atmosphere of Mars has eroded some of the craters created by ancient meteor strikes, although not as severely as they have been on the Earth. It is clear from the Viking photographs that water erosion has also taken place on Mars, but probably 3 billion years ago. The large volcanoes on Mars show that interior melting took place, but the energy was not sufficient to create the tectonic plate motion that exists on the Earth. Studies of the Martian surface composition and atmospheric dynamics are just beginning, and similar studies of Venus and the Gallilean satellites have yet to be started.

*Viking Visits Mars.* Two Viking spacecraft, each consisting of an orbiter and a lander, were launched late in the summer of 1975 on Titan-Centaur launch vehicles. After traveling some 11 months, each spacecraft reached Mars and was injected into an orbit about the planet. The two Viking landers successfully descended to the surface on July 20 and September 3, 1976.

To date the Viking flights have produced a large volume of new data on the structure and composition of the Mars atmosphere and on the physical and chemical nature of the surface. The 4000 pictures obtained from the orbiters revealed extensive details of the effects of tectonic activity and weathering in shaping the surface. Other instruments on the orbiters have furnished data on the thermal gradients on the surface and water vapor distribution in the atmosphere. These measurements indicate that very large amounts of water are stored in the polar ice caps, to the extent that in proportion there may be as much water on Mars as on Earth. Hundreds of black and white, color, and stereo pictures have been obtained on the surface. These show

a very rocky surface and confirm that the planet is truly a reddish color.

Evidence from the instruments on the orbiters and landers, to the extent that it has been studied thus far, portrays a Mars that at some time in its past was in several ways more like the Earth than it is now. Orbiter photographs reveal massive volcanic mountains and canyons deeper than any on Earth; the now-quiescent Mars once was the scene of major seismic events, and running liquid—probably water—eroded the deep canyons. Near the Viking 1 lander sites are evidences of several episodes of flooding that markedly shaped the landscape. Unlike the craters on the Moon and Mercury, a number of large Martian craters are surrounded by an unusual lobate apron of ejecta. Whereas the debris from Moon and Mercury craters was thrown out ballistically in a circle, on Mars there seems to have been action by a lubricating agent that made the material flow out from the craters like a fluid, as if the soil were soft and wet when the meteor struck.

If water existed as a liquid on Mars, the atmospheric pressure must have been notably higher than it is now. The gases that Viking instruments have identified in the atmosphere—nitrogen, oxygen, argon, krypton, and xenon—indicate that a much denser atmosphere did indeed once exist.

All this adds up to an intriguing question: what combination of circumstances caused changes of this magnitude to occur on Mars?

The weather stations on the landers show the weather has been very repetitious day-to-day since the landings. No storms have been encountered as yet. No significant seismic events have been observed. The biological and organic analysis experiments, while having already yielded large amounts of significant data, still had some critical tests to complete before any conclusions can be drawn from them.

The basic mission ended in November 1976, at which time all program objectives were completed. NASA is conducting an extended mission to observe seasonal changes, at a much reduced level of effort. The extended mission will end about September 1978.

*Future Planetary Missions.* Mariner Jupiter/Saturn 1977 (MJS77) Mission. The proof test model (PTM) spacecraft was assembled and system tests, including vibration and thermal/vacuum testing, were completed at the Jet Propulsion Laboratory. After additional testing at the Kennedy Space Center and Eastern Test Range, the PTM hardware will be refurbished and used for flight spares. The assembly and test of the first flight spacecraft began in November 1976.

Detailed development of science observation sequences was performed along with the development

of navigation and maneuver design. Flight trajectories were selected and the associated launch strategy was developed for each day of the August/September 1977 launch period. Most of the software was completed for both test and operations and for the flight subsystem hardware. Development of capabilities for flight mission operations emphasized launch and early mission activities and ground data systems required for launch.

The Mariner Jupiter/Saturn 1977 mission consists of two spacecraft that will reach Jupiter in 1979 and Saturn in late 1980 and 1981. In addition to video observations, scientific studies will be made of both planets, their moons, and the rings of Saturn, as well as of interplanetary and interstellar space.

The second spacecraft to arrive at Saturn will either make a science-intensive flyby or it may continue to Uranus. The decision will depend on the scientific data returned by the first spacecraft to reach Saturn, the operational status of the second craft, and the adequacy of its attitude-control fuel for the additional four-plus years flight from Saturn to Uranus.

Pioneer 10 and 11. The first flyby of Jupiter, accomplished by Pioneer 10 in December 1973, provided excellent data. Rather than repeat the mission, Pioneer 11, trailing one year behind Pioneer 10, was placed on a different trajectory to provide new information. The new track had an additional feature; as Pioneer 11 passed Jupiter, the massive planet altered the spacecraft's trajectory to one that would send the craft to a flyby of Saturn in 1979.

Both spacecraft continue to work well. At the end of 1976 Pioneer 10 was 11 Astronomical Units from the Sun on its way out of the solar system; Pioneer 11 was well on its way to Saturn.

Pioneer/Venus. The primary objective of the Pioneer-Venus program is to study the Venusian atmosphere using four entry probes and an orbiting spacecraft. The probes will enter at the same time, but at widely separate locations. Because the atmosphere of Venus is much hotter and denser than Earth's and because Venus rotates very slowly, atmospheric dynamics should be very different and the results could help scientists understand the atmosphere of Earth.

The program started in FY 1975 and development testing is almost completed. Much of the flight hardware is being built. Two similar spacecraft are planned, one to carry the probes, the other to perform the orbit mission. Launch will be by Atlas-Centaur vehicles in 1978.

### *Study of the Sun and Sun-Earth Relationships*

The NASA physics and astronomy program is directed toward the investigation of the Earth, the Sun and the solar system, galactic and extragalactic phenomena, and how they interrelate. The techniques and tools used include theoretical and laboratory research, aircraft, balloons, sounding rockets, small Explorer spacecraft, large automated observatories, and manned spacecraft. Research teams are located at NASA field centers, other government laboratories, universities, and industrial laboratories. NASA also conducts a number of cooperative projects with foreign countries.

Significant accomplishments during 1976 included the launches of the Helios 2 mission and the Gravity Probe-A mission. The Helios 2 mission is part of a cooperative program between the Federal Republic of Germany and the United States for obtaining increased understanding of fundamental solar processes and solar-terrestrial relationships. The objective of the Gravity Probe-A mission was to confirm with improved accuracy the gravitational red shift predicted by Einstein's theory of relativity. In addition to these launches, several discoveries were made as a result of observations with the 90-centimeter telescope carried on the NASA Airborne Observatory. The sounding rocket and balloon programs also made important scientific contributions.

*Studies of the Sun.* Orbiting Solar Observatories (OSO). After over a year in orbit, all nine experiments in the OSO 8 satellite continue to work well. Both high-resolution ultraviolet spectrometers housed in the OSO 8 sail reached stable operating plateaus after experiencing some initial reduction in sensitivity. The spatial resolution capabilities of these instruments remain extremely good and both are still measuring material motions and oscillations in a variety of solar features.

Despite continuing emphasis on mission operations, some preliminary data analysis is under way. A comparison between OSO 8 and sounding rocket data showed that while the outflow of material from coronal holes can be detected in coronal emission lines, no sign of any such motion is observed in ultraviolet spectra from lower-lying levels. A range of altitudes in which this outflow commences has thus been identified.

Another interesting finding is that a general downflow of material is frequently observed throughout the solar height range observable by OSO 8 (from the photosphere through the low transition region). These downflows are heterogeneous and occur preferentially in regions of high magnetic field strength located at the boundaries of the supergranulation network. Flow speeds of the order of 2-3 kilometers per second have been detected.

Some evidence of upward flow inside the supergranulation cell has also been reported. This identification of the general circulation through the chromospheric network is important for understanding convection in the solar atmosphere.

A result that is proving difficult to interpret is the apparent detection of a persistent horizontal flow in the transition region. This is seen as a relatively constant shift in the position of selected spectral lines which appears always in the same direction, indicative of a flow of material continuously directed towards the observer. It is possible that some mechanism other than motion is producing this effect but its nature is currently unknown. Small-scale, high-speed motions in the vicinity of sunspots have definitely been observed by both the ultraviolet instruments.

One of the prime purposes for OSO 8 was the investigation of atmospheric heating mechanisms. To date, both spectrometers have successfully measured the 5-minute photospheric oscillations both as intensity and as velocity fluctuations in a variety of spectral lines. Shorter period fluctuations (3 and 1.5 minutes) have also been detected in lines formed in the chromosphere and low transition region. Periodicities of 35 seconds and 15 minutes, which appear in the data, are now believed to be spacecraft disturbances.

It is interesting to note that at the highest levels observable from OSO 8 the 3- and 5-minute periodicities are still detectable in the strength of the lines emitted from these regions, but there is little or no evidence of velocity variations.

The widths of the lines may, however, contain important information on the broad-band spectrum of random fluctuations which will also be important in determining the chromospheric and coronal energy transport and heating processes. This possibility will be analyzed during the coming months.

Apollo Telescope Mount (ATM). After three years of intensive activity in the reduction and analysis of the 171,000 photographs and the 2292 hours of photoelectric data collected during the manned Skylab program (1973–1974), the impact of this program on solar physics is becoming visible. The recently completed Skylab Solar Workshop, which brought together ATM scientists, ground based observers, solar experimenters, and theoreticians in a comprehensive attack on the problem of coronal holes, advanced our understanding of the Sun-solar wind interface and, hence, of the effect that coronal holes have on the terrestrial environment.

Among the more exciting results of the study has been the discovery that polar holes can be connected to equatorial solar latitudes by virtue of their highly divergent, open magnetic fields and can hence affect

the structure of the solar wind impinging on the Earth.

This field divergence, which is a general property of all coronal holes, has also been shown to produce supersonic (100 kilometers per second) wind velocities at only 1 to 2 solar radii above the solar surface—a concept completely new to solar wind theorists.

There is also, now, evidence that the one-million K temperature which is observed low in the corona within coronal holes may not be the maximum temperature attained. Both theory and experiment point to the possible existence of a temperature maximum of the order of 3 to 5 million K situated at a height of several solar radii above the surface. Additional experimental and theoretical studies are required.

Another solar phenomenon receiving considerable attention in the analysis of ATM data is flares. The ATM experimenters are in general agreement that the hottest portions of a flare are within one or two small, low-lying loops within an active region. Typical dimensions of these loops are on the order of a few arc seconds (approximately 4100 kilometers) and their height is somewhere in the range 1800–5000 kilometers above the solar surface. The temperature reached by the heated plasma varies from flare to flare and is on the order of 20 million K or more.

These observations indicate the presence of a variety of different magnetohydrodynamic instabilities which are considered to be the source of the flare. Some experimenters think the cause to be instabilities within the loops, while others favor instabilities in the “neutral sheets” between neighboring loops. Both explanations may be correct.

A major disagreement now exists between the ATM scientists, who are constrained to study the “thermal phase” of a flare, and experimenters observing the high energy x-ray and gamma ray emissions originating from the flare-induced beams of high energy particles that are accelerated by the disruption of the magnetic field. The x-ray and gamma ray experimenters generally favor a primary field disturbance high in the corona, while the ATM scientists are convinced that the main flare occurs at lower levels in the solar atmosphere. An attempt to reconcile the two viewpoints will be made at the second Skylab Workshop. It may be, however, that opinion will remain divided until the Solar Maximum Mission, when the high energy and “thermal” emissions from flares can be studied simultaneously.

Out-of-Ecliptic Mission. The growing acceptance of the link between some solar parameter and terrestrial weather and climate has further stimulated research in the nature and variability of solar wind

and in the Sun-wind interface. A great deal of progress has been made in the latter area as a result of the recent Skylab Coronal Hole Workshop. A number of attractive new theories have been devised linking coronal holes with high velocity streams and explaining the observed variations of these streams as a function of the solar cycle. Verification of these theories, which involve the influence of in-ecliptic wind streams by high-latitude coronal holes, requires direct measurement of wind conditions at high solar latitudes. Plans are, therefore, under way for an Out-of-Ecliptic Mission, the prime objective of which will be to measure the properties of the solar wind, magnetic fields, and particle ejecta as a function of solar latitude from the solar equator to the polar regions.

The mission, which involves two Pioneer-class spacecraft, is a joint venture of the European Space Agency and NASA. During 1976 some preliminary definition studies were undertaken by both agencies and a scientific working group was formed to define in detail the payload required to achieve the mission's primary objectives. More detailed studies are planned for Fiscal Year 1978, prior to an official new start for hardware in Fiscal 1979. The two spacecraft will be launched by a four-stage Space Shuttle in February 1983 and will use the gravity of Jupiter to propel them to high solar latitudes.

Solar Maximum Mission. During the past year work has continued on the definition of the basic spacecraft and the experiment package that together form the Solar Maximum Mission (SMM). The seven major flare instruments were selected early in 1976. By observing the entire flare spectrum, from gamma rays to white light emission, using SMM and complementary ground-based instrumentation, the various physical processes that combine to produce flares will be studied. Of particular interest will be the determination of the temporal and spatial relationships between the hard x-rays, produced when beams of particles are accelerated as a result of magnetic field instabilities early in the event, and the soft x-rays and extreme ultraviolet emission, which are thought to be produced when the beams of particles impinge on the relatively cool chromosphere, causing it to evaporate and heat. Some new theories concerning flares, which are being formulated by Apollo Telescope Mount experimenters, require that the two types of radiation originate from the same low-lying region in the solar atmosphere. Scientists specializing in the higher energy aspects of the flare event would favor a higher-level source of the flare's hard x-ray emissions. SMM should resolve this disagreement.

In addition to investigating the flare process, SMM will study the effects of the flare ejecta on the terrestrial environment by conducting a collab-

orative program of flare radiation and particle measurements with the International Sun-Earth Explorer-C spacecraft. The SMM Solar-Terrestrial Program will also include measurements of the long-term variability of total solar emission (the "solar constant") and of the full Sun ultraviolet spectrum. Instruments are currently being selected for this purpose.

Helios. Helios is a cooperative space project between the Federal Republic of Germany and the United States designed to provide increased understanding of fundamental solar processes and solar-terrestrial relationships. Both Helios 1, launched in December 1974, and Helios 2, launched in January 1976, are still operational. These spacecraft will travel closer to the Sun than any previous spacecraft. Germany built the spacecraft and seven of the experiments; and the United States provided three experiments and the launch vehicles, as well as technical, launch, and flight operations support. Although analysis of the data is still under way, two of the interesting results so far from Helios indicate that (1) high-speed solar wind streams are associated with coronal holes which are usually at high solar latitudes rather than with hot spots near the equator, and (2) the acceleration of the high-energy streams which has been observed for some time, but not understood, appears to be associated with large amplitude ion-acoustic waves that were measured by Helios in a region between two high-speed solar wind streams.

### *Studies of the Universe*

*Orbiting Astronomical Observatory.* The Orbiting Astronomical Observatory-3 (OAO 3, also named Copernicus), launched in August 1972, remained operational through 1976, providing accurately stabilized automated facilities for observing celestial objects and interstellar space in the spectral range from the x-ray through the ultraviolet and into the visible region. As a result of new techniques, the usefulness of this satellite has been expanded: objects one-sixth as brilliant as those that could be observed after launch can now be observed, and the useful spectral range has been extended in the near ultraviolet. Many new classes of objects can now be studied by OAO 3.

*Small Astronomy Satellite.* The last of the Small Astronomy Satellites, SAS-C, launched in May 1975, is still operational. With its complement of four x-ray instruments, this spacecraft is the most powerful x-ray mission yet flown. The most exciting accomplishments of this satellite have been the detailed studies of bursters and other transient x-ray sources, leading to their optical identification and

to an increased understanding of the extraordinary physical conditions producing them.

*High Energy Astronomy Observatory.* The basic scientific objective of the High Energy Astronomy Observatory (HEAO) program is to explore the previously inaccessible regions of celestial x-ray and gamma-ray sources and cosmic ray flux. This program should increase our understanding of newly discovered energy processes, of the creation of matter, and of phenomena such as quasars, pulsars, novae, supernovae, and black holes. The first phase of the program consists of three observatories to be launched on Atlas-Centaur rockets; larger observatories are being studied by NASA as possible payloads to be launched by the Space Shuttle. Considerable progress was made during 1976 in the development and fabrication of the first three spacecraft and experiments, with primary emphasis on the HEAO-A mission, scheduled for launch in 1977.

### *International Cooperative Satellites*

Work continued on the International Ultraviolet Explorer (IUE), a joint project involving NASA, the United Kingdom, and the European Space Agency (ESA), planned for launch in 1977. Procurement of hardware and subsystem fabrication was completed during 1976 and systems integration and testing started.

Progress also continued on the International Sun-Earth Explorers (ISEE), a joint project between NASA and ESA. Three spacecraft, two provided by NASA and one by ESA, with a combination of instruments provided by both parties, will be used. ISEE goals include study of the Earth's magnetosphere, effects of the solar wind on the magnetosphere, and interaction of cosmic rays with the solar wind and magnetosphere. Emphasis during 1976 was on fabrication of spacecraft and experiments for the ISEE-A and B missions scheduled for launch in 1977.

### *Space Telescope*

The Space Telescope reached an advanced state of design as a result of work conducted during 1976. The major objective of the Space Telescope is to provide a long-term 2.4-meter astronomical observatory in space above the obscuring effects of the Earth's atmosphere, where it will have the capability to observe objects at greater distances than can the largest Earth-based telescopes. The Space Telescope, designed to be placed in a low Earth orbit by the Space Shuttle, would be operated as an international facility, providing continuous coverage in wavelengths from the far ultraviolet to the near infrared. Scientific instruments would explore

the universe and observe both stellar and galactic phenomena. Significant contributions are expected from the study of early stages of star formation and from observations of such highly evolved objects as supernovae remnants and white dwarfs.

### *Sounding Rockets, Balloons, and Aircraft*

Sixty sounding rockets were launched from sites in the United States (Wallops Flight Center; White Sands Missile Range; Poker Flat Research Range, Alaska; and Wauai Range, Hawaii), Canada (Fort Churchill), Sweden, and Norway; some 50 research teams from universities, private industry, foreign governments, NASA field centers, and other U.S. government agencies were involved. A cooperative program between NASA and DoD launched 26 sounding rockets from the Wallops Flight Center in January in support of the Winter D-Region Campaign, a coordinated program to study winter days of "normal" and "anomalous" electron densities in the ionospheric D region.

The NASA balloon program supported the launch of 50 balloons from the United States and Canada, and involved 20 research organizations. One of the most significant events involved the successful flight of a joint NASA/Netherlands ultraviolet payload which obtained new results on stellar chromospheres and evidence of mass loss and hot, high-luminosity stars. Another highly successful flight carried a very sensitive infrared telescope (from the University of Arizona) which detected, for the first time, a continuous band of diffuse emission around the galactic plane. This enabled scientists to measure the energy associated with the dust in the plane of our galaxy and thereby contributed to the understanding of the structure and physical conditions existing in our own galaxy.

The NASA Airborne Science Program employs two aircraft for infrared astronomical research at altitudes above 90 percent of the Earth's atmosphere. A C-141 aircraft carries the Kuiper Airborne Observatory, consisting of a 90-centimeter telescope, while a Lear Jet carries a 30-centimeter telescope. During 1976, the principal scientific investigations were in three areas: emission spectroscopy of the interstellar medium, stellar formation using far-infrared photometers, and planetary atmosphere spectroscopy with high spectral-resolution interferometers.

### **Space Transportation**

Space flight activities provide the transportation and related capabilities necessary to conduct both manned and unmanned operations in space. These

activities include the Space Shuttle program for the development of a reusable manned Earth-to-orbit space vehicle, U.S. participation with the European Space Agency (ESA) in a cooperative program for the European-funded development of a Spacelab to be used in the Shuttle, development and supporting activities for other elements of the Space Transportation System, development of new component and subsystem technology, conceptual studies and research on future space operations, and launch operations and support for expendable launch vehicles for automated space missions.

### *Space Shuttle*

The Space Shuttle is the cornerstone of the Space Transportation System (STS). It will provide routine two-way access to space starting in the 1980s. A major breakthrough in manned space systems, it eliminates the constraints imposed by present modes of space operations. With the Space Shuttle, manned and unmanned experiments can be conducted within a single mission, advanced payloads and satellites can be deployed into orbit, spacecraft can be retrieved for reuse with updating and refurbishing either taking place in space or back on Earth, and laboratories can be launched into Earth orbit. The versatility and reusability of the Space Shuttle will provide great cost benefits for users.

Space Shuttle development continued on plan and within the cost estimates. During 1976, the major milestones of qualification and ground tests, manufacture of test articles, and assembly of the orbiter were met. Progress was highlighted by the rollout of Orbiter No. 1 on September 17, 1976, at Rockwell International's Space Division in Palmdale, California.

The Rocketdyne Division of the Rockwell Corporation progressed in development of the liquid-fueled rocket engines. These engines have an advanced, high-pressure design and provide the main propulsion systems for the Space Shuttle orbiter. Major milestones were reached in development and ground tests. Three test engines have been delivered, installed, and tested over one hundred times at the National Space Technology Laboratories in Mississippi, demonstrating the capability of the main engine.

Manufacture of the external tank, which contains the cryogenic propellants for the orbiter main engine, continued as planned. Major assembly milestones were met and all major welding tools were installed at the Michoud Assembly Facility in Mississippi. After assembly, the ground test tanks will be tested at the Marshall Space Flight Center to provide confidence that they can withstand the

structural requirements of the Space Shuttle missions.

The solid rocket booster will provide the additional thrust necessary during launch by burning in parallel with the main engines. Progress has been satisfactory on all parts of the rocket motor, directional controls, structural components, and the recovery subsystem. The first motor segments for initial development static firings were delivered.

Major milestones met during 1976 at the Kennedy Space Center included completion of the orbiter landing facility, delivery of the initial launch processing systems, and timely progress on a number of other launch and landing facilities.

Orbiter 1 is scheduled for approach and landing tests in 1977. The orbiter is to be carried to test altitude on a Boeing 747 aircraft and released for unpowered approach and landing. Fabrication proceeded on the second orbiter, to be used for the first manned orbital flights in 1979.

### *Space Transportation System Operations*

The Space Transportation System (STS) includes the Space Shuttle, the Spacelab, and an upper stage. It is a standardized yet flexible system, capable of accommodating a wide variety of payloads and mission requirements. Plans for management, operation, and use of the system when it becomes operational in the 1980s are far advanced, taking into account user development, mission planning, payload integration, flight and ground operations, and financial management.

A pilot User Development Program was initiated and a contract was awarded to the Battelle Memorial Institute to define approaches for encouraging and accommodating commercial users of the STS. After the pilot program ends in February 1977, a full-scale user development program will be initiated.

Since NASA's present complement of active pilots and scientist astronauts is insufficient to fly the planned 60 STS flights per year, NASA announced opportunities for additional pilots and mission specialists. Selection and appointment would not be made until 1978.

A number of studies were undertaken to determine STS operating costs and to establish user charges for STS flights. These studies led to a policy in which each class of user will pay equitably for use and service.

### *Spacelab*

The Spacelab Program is a joint venture between NASA and the European Space Agency (ESA) to produce the Spacelab, a reusable space laboratory.

It would be flown to and from Earth orbit in the cargo bay of the Space Shuttle. Participating European nations are paying for the design, development, production, and delivery of the first Spacelab flight unit to NASA. Scheduled to become operational in the 1980s, it would be available to an international community of users.

In 1976, design reviews were completed and development hardware was being manufactured. Integration of the hard mockup was initiated. Manufacture began on the engineering model, which is to be delivered to NASA prior to delivery of the flight unit.

NASA evaluated proposals for a Spacelab integration contract. Part of this contract would cover design, development, and manufacture of most of the Spacelab hardware for which NASA is responsible. A major item of this hardware is the tunnel that will connect the Spacelab to the Shuttle Orbiter. Design of the tunnel is scheduled to begin in 1977.

*Spacelab Life Sciences.* The response to the announcement of flight opportunity for Spacelab 1 continues to reflect the high interest of the Life Sciences community in Space Shuttle/Spacelab missions. Real-time Life Sciences missions, in a mockup of the Spacelab, have been simulated using experiments of the type being selected for Spacelab. The simulation was in support of payload planning, to provide a method by which science, engineering, and operational evaluations could be conducted on the ground to ensure maximum effectiveness in space. The evaluation included payload synthesis, equipment integration, operational concepts, and crew training.

The program to develop a basic complement of flight-qualified medical laboratory equipment for repetitive use on Spacelab flights was initiated in 1976 and procurement began of items requiring long-lead-time development. Primary among these items is the spaceflight-qualified specimen/biological holding units. Another long-lead-time development is the specimen refrigeration compartments capable of maintaining  $-70^{\circ}\text{C}$  temperature for preservation and storage of Life Sciences specimens and tissues. Conceptual design studies of a free-flying Life Sciences satellite for the conduct of long duration, isolated animal experiments also were completed.

Two sets of medical standards were prepared, NASA Class I and II, to be used for establishing the medical fitness of the Shuttle Pilot and Mission Specialist Astronauts, respectively. A third set of standards for payload specialist/scientist passengers was drafted, requiring less restrictive physical conditioning and stress handling abilities than for

astronauts. Ground-based studies were assessing the deconditioning effects of gravitational stress on a population broadly representative of the potential payload specialist group, while other research sought to develop countermeasures for cardiovascular deconditioning and space motion sickness.

Project planning was completed for an experiment in support of research on space motion sickness. The plan called for a self-contained unit to test vestibular reaction of small animals when exposed to zero gravity for periods up to twenty days.

*Spacelab Science Payloads.* In preparation for the Space Shuttle era, possible Spacelab science payloads were studied. Two of the six orbital flight test missions of the Space Shuttle will provide early demonstration and verification of the Space Shuttle's scientific research capabilities. Payloads on these flights will include selected experiments in space astronomy; high energy astrophysics; life sciences; solar physics; and atmospheric, magnetospheric, and plasma physics.

Two Spacelab missions are already scheduled for flight after the Shuttle becomes operational. Spacelab 1 is a joint undertaking by NASA and the European Space Agency (ESA). ESA participation in the Spacelab 2 missions is still under negotiation. The primary objective of both missions is verification of Spacelab performance and capabilities and the measurement of the induced environment. The secondary objective is to obtain valuable scientific, applications, and technology data. Two announcements of opportunity were issued by NASA in 1976 and experiments will be selected for both Spacelabs 1 and 2 in 1977. Detailed studies of instruments for future Spacelab missions are also being carried out, with major emphasis on class experiments by principal investigators.

### *Interim Upper Stage*

The Interim Upper Stage (IUS) will propel payloads to destinations beyond the capability of the Shuttle alone. NASA would use it primarily for lunar and planetary exploration and other high-energy missions. DoD has the responsibility to define and develop the IUS, with NASA defining design and operational requirements that are unique to NASA and other non-DoD missions. A DoD/NASA assessment of five study contracts in 1975 led to the decision to use a multi-stage solid propellant design. Early in 1976 a request for proposal for the IUS validation phase was issued. The Boeing Aerospace Company was awarded that contract in September. The IUS is expected to be operational in mid-year 1980.

### *Spinning Solid Upper Stages*

Complementary to the Interim Upper Stage, Spinning Solid Upper Stages are to be primarily used for the smaller, commercial-user payloads whose missions require synchronous orbits. Mounted on a spin table in the cargo bay of the Space Shuttle flying in low Earth orbit, the stage and its payload would be set spinning; springs would separate it and propel it a safe distance from the Shuttle, where its solid rocket motor would ignite. The spinning stabilizes the stage, so it is unnecessary to have an expensive guidance system. As many as four of the Delta-class or two of the Centaur-class stages can be mounted in the Shuttle cargo bay on a single flight, one of the several economies that will substantially reduce launch costs from the cost of using the present expendable boosters. They will also provide early, easy transition to the Shuttle for existing satellite series now using expendable boosters. Another saving to the government is that McDonnell Douglas Corporation has agreed to develop and build the Delta-class Spinning Stage at its own expense and initiative. Discussions are underway with Boeing and McDonnell Douglas on a similar scheme of industrial development of the Centaur-class stage.

### *Advanced Studies*

The Advanced Studies program defines requirements for future space systems and develops long range plans for advanced space systems concepts. Among the several studies in 1976 was one of a space station to be used as an operating base for erecting large structures. Ways and means of erecting large structures were examined, as was the possibility that these structures could be part of a space solar power experiment. Other studies investigated solar electric propulsion applications, Shuttle improvements, and concepts of space industrialization.

### *Expendable Launch Vehicle Programs*

Expendable launch vehicles continued to provide transportation services to a variety of users and missions. NASA will use these launch vehicles until most or all are replaced by the Shuttle in the 1980s. Most of the 16 launches in 1976 were conducted for activities which reimbursed NASA for launch services and the vehicles:

*Scout.* During 1976 three satellites were successfully launched by the Scout vehicle: an Air Force test communications satellite (USAF P 76-5), the NASA scientific relativity probe, and the Navy's Transit navigation satellite.

*Delta.* The Delta continued to be the most frequently used vehicle. It successfully launched nine satellites in 1976: a cooperative communications satellite for Canada, three maritime communications satellites (Marisat A, B, and C) for the Comsat Corporation, a Laser Geodetic Satellite (Lageos) for NASA, a weather satellite (ITOS-H) for the National Oceanic and Atmospheric Administration, a domestic satellite (RCA-B) for RCA, one communications satellite (NATO-III A) for NATO, and another (Palapa-A) for Indonesia. The Indonesian satellite for the first time connected more than 3000 islands with telephone, telegraph, and teletype services.

*Atlas-Centaur.* This vehicle successfully launched Comstar A and B, domestic communication satellites; and Intelsat IV-A F2, an international communication satellite, for the Comsat Corporation.

*Titan III-Centaur.* This is the largest of NASA's current family of launch vehicles. It successfully launched Helios-B, a cooperative solar probe satellite, for the Federal Republic of Germany in 1976. It was also the Titan III-Centaur which launched Viking 1 and Viking 2 to Mars in 1975.

## **Space Research and Technology**

The NASA Space Research and Technology program seeks to advance the technology used in scientific instruments and in systems that transport, power, control, and communicate with spacecraft. Some of the resulting technology has terrestrial applications as well.

### *Space Propulsion Technology*

NASA space propulsion technology is dedicated to advancing concepts in liquid, solid, and electric propulsion that will enhance future mission capabilities while reducing costs.

*Liquid Propulsion Technology.* Testing of turbomachinery and a regeneratively cooled thrust chamber for a small, reusable, high-performance oxygen-hydrogen engine started in 1976. The purpose is to demonstrate the technology of advanced propulsion systems suitable for future reusable Orbital Transfer Vehicles. A key component, the liquid hydrogen pump, was successfully run for 800 seconds at various test conditions, including speeds up to 91,800 revolutions per minute.

*Solid Propulsion Technology.* Methods were demonstrated for recovering the active ingredients from the scraps and waste that result from production of solid propellants. The active ingredients can be used in subsequent production at considerable cost saving.

*Electric Propulsion Technology.* Both the auxiliary ion thruster (to produce one-half milligram



for stationkeeping of geosynchronous spacecraft) and the primary ion thruster (to produce fourteen milligrams for planetary exploration) progressed during the past year. Engineering model thruster designs of both systems were firmly established and are being fabricated for flight qualification. Thermal vacuum breadboard power processors were fabricated and successfully operated with prototype thrusters.

### *Space Energy Systems Technology*

Spacecraft of the future will require increasing amounts of energy to power more sophisticated experiments and higher data-transmission rates. NASA's technology effort for space energy systems is directed at providing such advanced performance at lower cost. Improvements are sought in generation, storage, conversion, transmission, and management of power.

*Solar Cell Arrays.* During 1976, full-scale system design and critical component tests of a 12.5-kilowatt, lightweight solar array were completed. This array would produce twice the power of a conventionally designed array of similar weight. Tests also demonstrated the feasibility of a high-voltage ion thruster operating directly from a solar array. Such a system would eliminate the need for complex and costly conditioning for major power loads.

*Chemical Energy Conversion and Storage.* Progress was also made in advanced non-gassing nickel-cadmium batteries which, after more than a year of testing, continued to demonstrate improved reliability for space operations.

*Thermomechanical Energy Conversion.* The demonstration of long-lived rotating machinery is an essential prerequisite to dynamic space power. In 1976, after 21,000 hours of failure-free operation, a 2-to-10 kilowatt Brayton-cycle rotating unit was inspected and found free of wear.

*Thermal Conversion Systems.* Preliminary materials tests during 1976 suggested that it may be possible to increase thermionic converter efficiencies by 30 percent, a gain that would reduce the cost and size of thermal energy sources.

### *Guidance, Control, and Information Technology*

NASA's 1976 efforts in guidance, control, and information technology were directed at improving the operational characteristics and data handling efficiency of a wide spectrum of electronics systems while reducing their size, weight, power requirements, and cost.

*Navigation.* An optical navigation system in the Viking Mars spacecraft determined the position of the craft relative to planet/star-field reference with better than twice the accuracy of conventional

radio navigation techniques. Significant fuel savings resulted through fewer, smaller trajectory corrections.

*Data Acquisition.* NASA's charge-coupled sensor permitted the first high-resolution infrared images of the planet Uranus. These images revealed a 7 percent error in previously accepted values for the diameter of that planet.

*Data Storage.* A solid-state data recording system, featuring a magnetic bubble domain memory, was demonstrated. Because this device has no moving parts, it has 10 times the expected life, uses half the power, and weighs half as much as conventional tape recording systems.

### *Materials and Structures Technology*

Advancements in materials and structures have shown great potential for more efficient and lighter space vehicles and orbiting structures for antenna arrays and space platforms. This not only increases mission capabilities per launch, but effectively reduces cost for both the vehicles and their payloads.

*Structures.* A new concept for truss elements permits high packaging densities for transport to space and has greater structural efficiency than the commonly used cylindrical columns. When transported in the Shuttle and assembled in space, the newly developed tapered element could form large truss structures capable of supporting antennas, solar cell arrays, or other large systems.

Advances in non-destructive testing techniques led to the development of the first inexpensive, portable, highly accurate system for applying the correct strain to bolted fabrications. Use of this system would result in higher reliability, lighter weight through less overdesign, and increased safety through properly stressed bolts.

*Materials.* Significant progress was made in spacecraft heat shields. A new protective coating was developed from improved glasses and pigments that permitted reductions in the manufacturing costs for the Space Shuttle heat shields. This new coating exhibits a significant increase in reliability and a doubling of useful lifetime.

### **Tracking and Data Acquisition**

Efficient and reliable tracking, data acquisition and processing, and communications are essential for all NASA flight programs if they are to attain their specific objectives. The main types of support provided are tracking for orbit or trajectory determination, acquisition of engineering and science telemetry data, transmission of commands from the ground to space vehicles, processing of acquired data, and interconnecting voice and telecommunica-

tions links to widely separated ground locations engaged in flight support.

The majority of this support is rendered by two worldwide networks of stations. The Deep Space Network is specialized to handle planetary and interplanetary missions at great distances from Earth. The other network, the Spaceflight Tracking and Data Network, supports Earth-orbital and sub-orbital programs. Both use a complex communications network to tie their distant locations together. Facilities include massive 64-meter-diameter antennas and the large computer complexes necessary for mission control and data processing.

### *Lageos*

The laser tracking system used with the Lageos satellite is the newest development in precision tracking and ranging. To apply the science of plate tectonics to studying continental drift and the processes that create earthquakes, precision measurement of slight Earth crustal movements is required. The very stable orbit of the Lageos satellite provides a reference from which these minute shifts can be determined. Laser tracking is far more precise than conventional high-frequency radio ranging techniques. There are currently four operating ground stations, three of which are mobile. Using these experimentally with earlier satellites refined the laser system to the point where these stations, and the five additional mobile stations under construction, should be able to obtain measurements accurate to within five centimeters.

In addition to providing precision ranging data from Lageos, which will be utilized in studying Earth crustal motion, the mobile equipment will be moved to various locations to calibrate sensitive altimeters on satellites such as Geos and Seasat.

### *Viking*

The most exciting space event of the year, the landing of Viking on Mars, was supported from launch through the continuing return of lander science data by the Deep Space Network. For the first time, a spacecraft on the surface of another planet was successfully commanded, controlled, and interrogated. Another first was the support of four spacecraft at interplanetary distances. The rapid and flexible responses provided by the network made the Viking adaptive mode, in which subsequent operations depend on the results obtained the day before, a success in terms of scientific productivity and rapid solutions to unexpected problems.

In addition to operational support, the large 64-meter antennas of the Deep Space Network were

employed in the radar surveys that were instrumental in selecting the landing site for Viking 1. Since the resolution of the orbiter cameras was not sufficient to detect all terrain features that might have damaged the lander, analysis of the radar echos helped to determine the roughness of the surface area and minimize risk to the mission.

### *Preparation for Future Missions*

Several events of this year point significantly to continued evolution of the network and communications systems to support future flight programs. The telemetry facility at Dryden Flight Research Center has been modified to support the Shuttle approach and landing tests beginning in 1977. Modification of the Deep Space Network 26-meter antennas was initiated to add an X-band capability; this will significantly help avoid the increased crowding at lower frequencies and provide new means to handle long duration, deep space navigation and data retrieval tasks. Improvements to telemetry data processing systems and advances in image processing facilities for satellites such as Landsat round out activities in progress to provide responsive, reliable, and efficient tracking and data acquisition in the future.

### *TDRSS*

Another important step forward in the procurement of the Tracking and Data Relay Satellite System (TDRSS) was the award of a contract to Western Union Space Communications, Inc. The corporation will provide telecommunications services via TDRSS for support of Earth-orbital spacecraft. Under the fixed-price contract, Western Union Space Communications, Inc., will provide TDRSS services to NASA for a ten-year period beginning in 1980 at an annual contract cost of \$79.6 million. The system will involve two satellites in synchronous orbit acting as two-way relay stations between a single ground station and all satellites in low Earth orbit. When TDRSS is operational, many of the present tracking stations will be closed.

### **International Affairs**

The National Aeronautics and Space Act of 1958 provides that the space activities of the United States shall be conducted so as to contribute materially to cooperation by the United States with other nations. Following are examples of the international cooperation achieved in the past year.

### *Space Transportation System*

Increasing emphasis was given in 1976 to future international use of the Shuttle-based Space Trans-

portation System (STS). Potential users—government, industry, and university—in Canada, Europe, and Japan were briefed on capabilities, payload accommodations, and probable terms and conditions of use. Solicitations were distributed internationally for proposals for Shuttle experiments in the Orbital Flight Test Phase, in the first two Spacelab missions, and in a planned free-flying Long Duration Exposure Facility. Preliminary studies for the first Spacelab payload, jointly planned by NASA and the European Space Agency, were completed. Final selection is expected in early 1977.

The development of Spacelab, the European contribution to STS and currently valued at \$500 million, passed the midpoint in 1976. Completion of the preliminary design review in December was a major milestone toward the delivery of the first Spacelab flight unit to NASA in mid-1979, a year before its first mission.

Development was begun this year on the Canadian contribution to STS—the Remote Manipulator System for the Space Shuttle orbiter. That system is valued at several tens of millions of dollars.

### *Broadcast Satellite Experiments*

On July 31, 1976, India completed a one-year Satellite Instructional Television Experiment using NASA's ATS 6 satellite to transmit educational TV programs directly to some 2400 villages. The TV programs, ground transmitting station, and village receivers were all funded and developed by India. Evaluation is under way, but the experiment has already demonstrated the practicality of satellite-based instructional broadcasting for developing countries and has aroused interest throughout the world. Initial reports indicate an increase in school attendance and enthusiastic acceptance of the new instructional tool by village teachers as well as adult audiences. Programs containing practical instruction—in agriculture and animal husbandry, for instance—were particularly popular and apparently effective.

On August 1, ATS 6 began its return passage to the Western Hemisphere. As it passed over Africa and Latin America, NASA and the Agency for International Development conducted a three-month project using ATS 6 for demonstration broadcasts to 24 developing countries and regional organizations. The broadcasts included films on the uses of space technology for development and live, two-way discussions between panels of U.S. officials and experts and local host government officials in receiving countries.

Another project in experimental satellite broadcasting for remote areas began in 1976 with the January launch of the Communications Technology

Satellite (CTS), developed jointly by NASA and the Canadian Department of Communications. A later development than ATS 6, CTS is designed to transmit higher powered signals to small, relatively inexpensive ground terminals at higher frequencies. Its broadcast time, divided equally between U.S. and Canada, is being used for experiments in education, health care, community and special service broadcasting, and communications technology.

### *Stratospheric Research*

NASA's intensified upper atmospheric research program has focused on the possible threat to the Earth's stratospheric ozone shield from fluorocarbon compounds widely used as refrigerants and aerosol propellants. Because of the global implications, NASA made special efforts in 1976 to inform the world scientific community generally and to pursue its stratospheric research activities cooperatively.

For instance, a French infrared absorption spectrometer was among instruments carried on NASA's CV990 aircraft in November 1976 to measure trace constituents and compare stratospheric concentrations in the northern and southern hemispheres. Arrangements were also made to take complementary measurements of ozone and other atmospheric trace constituents from a NASA U-2 aircraft in coordination with flights of instrumented Canadian balloons.

To foster international coordination of stratospheric research and policy planning, NASA co-sponsored an International Conference on the Stratosphere and Related Problems at Utah State University, September 15–17, 1976.

### *New and Ongoing Cooperative Satellite Projects*

Of the 25 international satellites that have so far been launched by NASA on a cooperative (as distinguished from reimbursable) basis, 8 remained active and returning data in 1976. Most significant were the two German Helios solar probes which, in four perihelion passages in 1976, flew closer to the Sun than any other spacecraft—less than one-third the Sun-Earth distance. Measurements by Helios of the solar atmosphere, magnetic fields, and particle emissions have generated new data on solar-terrestrial interactions.

NASA concluded an agreement with Aerospace Research Center of the University of Rome to develop the next generation of San Marco satellites for continued investigations of processes at the interface between space and the upper atmosphere. San Marco D is also expected to contribute importantly to the current study of the Earth's ozone layer.

International interest in contributing experiments to NASA spacecraft continued. Agreements were reached with Germany, the U.K., the Netherlands, and France on instrumentation for the NASA Solar Maximum Mission and the Pioneer Venus Orbiter and Probe.

During 1976, NASA announced 14 opportunities to participate in future space missions and received over 173 proposals from 9 European countries, the European Space Agency, Australia, Canada, India, Japan, and South Africa. The proposals concerned infrared astronomy, space processing, atmospheric cloud physics, lunar surface studies, stratospheric aerosol and gas investigations, interplanetary and planetary physics, and multidisciplinary opportunities planned for future Shuttle and Spacelab flights.

### *Earth Resources*

During 1976 NASA began to charge foreign Landsat station operators an initial token share of the annual cost of operating the satellites. Such stations, receiving data directly from the satellites, were operating in Canada, Brazil, and Italy. Agreements had been reached for stations in Zaire, Iran, and Chile. Still other stations were being negotiated.

This growing interest in direct reception is related to the significant benefits reported by researchers in more than 100 countries currently using Landsat data. Bolivia, for example, recently discovered deposits of lithium and potassium as a result of computer-assisted interpretation of Landsat data. A new iron ore deposit was discovered recently in Egypt using Landsat data.

### *Reimbursable International Launches*

The following reimbursable (as distinguished from cooperative) launchings took place from the Eastern Test Range in 1976:

- Intelsat IV-A F2, an international communications satellite, Atlas-Centaur vehicle, January 29
- NATO IIIA, an operational communications satellite, Thor-Delta vehicle, April 22
- Palapa-A, the first Indonesian domestic communications satellite, Thor-Delta vehicle, July 8

A reimbursable launching contract was concluded with the Science Research Council of the U.K. for a Scout launch of UK-6 scientific satellite in early 1978. Contracts to use the Thor-Delta vehicle were signed with the European Space Agency for launch of OTS, a geostationary communications test satellite, in mid-1977 and Marots, a geostationary maritime test satellite, in 1978. Launch service contract negotiations were begun with EMBRATEL of Brazil for launch of two domestic communications satellites in 1979; with NASDA of Japan for a

backup launch in 1978 or 1979; with TELESAT of Canada for launch of the fourth Canadian domestic communications satellite in 1978; and with the Federal Aviation Administration for two launches of the international aeronautical satellite, Aerosat, in 1979 and 1980.

### *Overseas Tracking Facilities*

During 1976, the agreement providing for NASA's use of Canada's Churchill Range upper atmosphere research facilities was extended until June 1979. Agreement was also reached with the Government of Pakistan for temporary placement of a NASA portable Landsat receiver station near Rawalpindi. An agreement between CNES (the French space agency) and NASA for reimbursable tracking support was extended until December 1977. Reimbursable tracking arrangements with Japan were also concluded, providing telemetry and tracking support for Japanese launchings by the University of Tokyo and NASDA (the Japanese space agency).

### *U.S./U.S.S.R. Cooperation in Space Science and Applications*

Cooperative work in space science and applications proceeded under the 1971 Bilateral Agreement (incorporated by reference in the 1972 Summit Agreement).

In planetary explorations: (1) U.S. and Soviet specialists met on June 10 in Philadelphia and exchanged information on results of the Soviet Venera 9 and 10 missions, U.S. radar observations of Venus, and on plans for the U.S. 1978 Pioneer Venus missions; (2) two Soviet scientists participated at NASA's Goddard Space Flight Center May 30-June 13 in joint analysis of Soviet Mars gamma-ray spectrometer data; (3) steps were initiated in September by NASA to obtain soil samples from the Soviet Luna 24 probe pursuant to previous agreement; and (4) NASA prepared to share preliminary results of the Viking missions to Mars.

In other areas, the two sides continued coordinated magnetometer observations by the NASA Applications Technology Satellite and Soviet ground stations. The Space Biology and Medicine Joint Working Group met in Yerevan, U.S.S.R., in September and finalized plans for the flight of five U.S. biological experiments on a Soviet satellite to be launched in the fall of 1977. A coordinated rocket meteorology study of diurnal variations under different geomagnetic conditions was conducted in August. In November, two joint working groups on satellite and rocket meteorology met in Moscow to plan further projects and cooperative efforts, including coordinated experiments in atmospheric

temperature sensing and microwave sensing and implementation of a sounding rocket intercomparison test. The cooperative study of the natural environment moved into a second and important phase in the spring of 1976 when the Soviets began providing ground truth data for the remote sensing of vegetation. These data will be useful in the U.S. Large Area Crop Inventory Experiment aimed at developing a capability for world wheat crop prediction.

In October a delegation from the U.S.S.R. Academy of Sciences' Interkosmos Council met with NASA representatives in Washington to continue discussions aimed at defining major cooperative projects that might follow the successful rendezvous and docking of the Apollo and Soyuz spacecraft in 1975.

### **User Affairs**

The Office of User Affairs under the Office of Space Applications identifies user needs and requirements; disseminates information to potential users of NASA's space technology; and plans and implements technology transfer in space applications.

In November 1976, NASA sponsored a conference at the Jet Propulsion Laboratory in Pasadena concerning recent advances in image processing technology and new computer applications to stimulate the development and transfer of this technology to industry and commerce. Additional symposia co-sponsored by NASA in 1976 were the William T. Pecora Memorial Symposia on Earth resources survey techniques in Sioux Falls, South Dakota, and the Conference on Remote Sensing for Land and Resource Management in the South and Southwest at Texas A & M University in College Station.

To devise better means for transferring NASA technology outside the agency, four Application Survey Groups were formed from experts in the following areas: land inventory, inland water resources, agriculture, and mineral and petroleum exploration. Because of successful experience with these groups, planning got under way to develop a process for a permanent advisory structure consisting of representatives from the Federal, state, and local governments, private industry, and the universities.

Interaction between users also increased. A Federal Interagency Decision Team and Working Group, comprised of representatives from the U.S. Departments of Interior and Agriculture, Army Corps of Engineers, Agency for International Development, and NASA, was created to identify needs and potential applications for future Earth resources satellites. To improve technology transfer to state, regional, and local users, NASA worked with a variety of user organizations, including the National Conference of State Legislatures, Southern Growth

Policies Board, and the Pacific Northwest Regional Commission, to develop alternative strategies concerning user/NASA roles, responsibilities, and financial commitments. Interaction with the private sector included presentations and discussions with user communities such as petroleum and mineral exploration firms and the suppliers of data analysis equipment and services.

### **Technology Utilization**

#### *Low Cost Space Systems*

The Low Cost Systems Office was established to reduce the cost of space systems through development of standard components that will satisfy a majority of anticipated mission requirements. To date, 17 spacecraft components have been declared standard, including: tape recorders, hydrazine thrusters and valve assemblies, power regulator, spacecraft computer, inertial reference unit, pyrotechnic initiator, transponders for both near-Earth and deep space missions, star tracker, reaction wheel, telemetry and command components, and a pyrogen igniter.

Under evaluation were 24 additional candidates for standardization, including not only components for spacecraft maintenance functions, but also the experiment and instrument interface support equipment and ground support equipment. Some items under evaluation were: solar cell panels, central power regulator, Sun sensors, solid state star tracker, magnetometer, universal articulation system, magnetic bubble memory, phased array antenna, Global Positioning Satellite receiver/processor, common sensor subsystems, scanner-chopper drive system, test sets, spacecraft checkout system, and a spacecraft simulator.

As standard hardware becomes available, flight projects can obtain flight-qualified equipment at significantly less expense than in the past. Cost savings have already been realized in the Mariner Jupiter/Saturn, Tiros-N, Nimbus G, Seasat, Sage, and Solar Maximum Mission projects. These savings will continue to accrue as additional standards are used by future projects.

#### *Disseminating Technology and Benefits*

Since its inception in 1962, the NASA Technology Utilization Office has relied heavily on its publications to facilitate secondary use of NASA technology in commerce and industry. More than 10,000 innovations judged to have commercial potential have thus been made available to industry. The format for the familiar NASA tech brief was changed significantly in 1976. Tech briefs and related NASA technical innovations and improvements are now disseminated in a quarterly journal, *NASA Tech*

*Briefs*, which also includes information on new product ideas and technology utilization services.

In 1976 the university-based Industrial Applications Centers expanded the products and services to better serve non-aerospace clients. Likewise, technology coordinators, experienced in NASA research and development programs, were located at four NASA field centers to assist the Industrial Applications Centers by matching their client's problems to appropriate NASA scientific and engineering expertise.

The purchase of improved NASA-developed firefighter's breathing systems by the Boston Fire Department marked the successful culmination of that important technology applications project. Another achievement of note in 1976 was the construction of the NASA Technology Utilization House at Langley Research Center, Hampton, Virginia. Tech House, as it is called, integrates NASA technology, recent commercial building techniques, and other innovations into an energy-efficient home that offers the potential of savings to the individual family and national benefit in energy conservation. Opened to the public in June 1976, Tech House will be evaluated when a family is selected to occupy it early in 1977, at which time all energy conserving systems will be monitored by NASA engineers.

#### *Scientific and Technical Information*

NASA's publication of the results of its own aerospace research and development, together with its acquisition of worldwide aeronautics, space, and related literature, created a broad and growing national information resource. Remote terminals located at NASA centers, the congressional Office of Technology Assessment, Industrial Applications Centers, and a number of state universities permitted on-line literature searching of a centralized computer data bank containing over 1.5 million report, book, and journal citations. International cooperation in the generation of useful aerospace information continued, with the European Space Agency processing European literature for direct entry into the NASA data bank, while providing Western Europe with on-line computer access to a NASA-furnished portion of the data bank.

#### **NASA Energy Programs**

The purpose of NASA's energy program is to assure the effective use of NASA technologies and experience in support of national energy needs. A substantial part of the 1976 activities resulted from projects assigned to NASA and reimbursed by the Energy Research and Development Administration (ERDA) and other agencies having direct responsibilities in the energy field. Included was work in wind energy, conversion systems, low cost solar

cells, solar heating and cooling, coal energy extraction, industrial gas turbines, and advanced ground propulsion.

In addition, NASA also had a number of projects to identify and evaluate the applicability of aeronautics and space capabilities to energy problems. The process of technology identification and verification is designed to lead to soundly conceived technology plans in selected areas forming the basis for possible reimbursable activities in support of ERDA, the Department of Interior, and other agencies. Areas of interest included work in fuel cell systems, magnetohydrodynamics, energy storage systems, combustion technology, and materials and heat exchanger technology.

#### **Aeronautics Research and Technology**

Aeronautics Research and Technology programs are directed at developing technology to (1) improve the energy efficiency of aircraft, (2) reduce the undesirable environmental effects of aircraft such as noise and pollution, (3) improve aviation safety and terminal area operations, (4) advance long-haul and short-haul aircraft systems, and (5) provide technical support to the military in maintaining the superiority of military aircraft.

#### *Improving the Energy Efficiency of Aircraft*

During 1976 NASA initiated the Aircraft Energy Efficiency program with the objective of providing the technology for future commercial transport aircraft with 50 percent lower fuel consumption than current aircraft. This major program expanded NASA's efforts in technology developments, particularly those associated with engine systems, aerodynamics and active controls, and structural composite materials.

*Engine Systems.* Engine component evaluations have indicated the feasibility of improving the performance of components to increase fuel efficiency in future large turbofan engines. In 1976 tests of a new engine mixer component, for example, measured a two to three percent reduction in specific fuel consumption.

*Energy Efficient Transport.* NASA initiated the energy efficient transport program to evaluate aerodynamic features such as the supercritical wing and winglets, singly and in conjunction with active controls. Active control systems would allow reduction in the size of the horizontal tail by electronic control of aircraft stability and reduction of the weight of structural components by control of the structural loads experienced by aircraft.

*Composite Primary Aircraft Structures.* Future applications of composites, with the potential to

reduce fuel consumption by 10 to 12 percent, were being demonstrated. On May 27 the composite DC-10 upper aft rubber segment was certificated by the Federal Aviation Administration (FAA). As of September, four rudder segments had been installed on commercial airline transports and a total of about 2000 flight hours had been achieved. The composite component weighs about 30 percent less than the metallic component it replaces. A second composite component, the L-1011 Vertical Fin, is entering the ground subcomponent test phase.

### ***Reducing Undesirable Environmental Effects***

**Noise Prediction.** Analytical techniques have been developed to predict aircraft noise caused by the multiplicity of noise sources on aircraft. These methods have been computerized into a program capable of predicting ground noise levels from existing and conceptual aircraft. More sophisticated approaches are under development and will be incorporated into the existing program. Comparison of analytical with experimental data continues to validate the predictive capabilities of the program.

**Psychoacoustics Studies.** Comprehensive studies have been made to determine how a person's previous experience with aircraft noise affects annoyance. Two findings are noteworthy. First, a relationship between acceptability and annoyance has been identified. Second, laboratory subjects tend to judge as equivalent those test conditions comparable to their worst day-at-home experiences. Future studies will build upon these findings to provide better methods for assessing and predicting community response.

**Piston Engine Emissions Reduction.** Emissions from current piston engine aircraft have been characterized for ten representative general aviation engines. Tests reveal that some reductions in pollutant emissions are attainable by leaning the fuel/air mixture, but suggest that engine modifications may be required to attain acceptably low emission levels. Results were presented in a symposium hosted by NASA and attended by general aviation industrial firms, governmental regulatory agencies, and interested parties from the scientific and academic communities.

**Gas Turbine Emissions Reduction.** NASA's Experimental Clean Combustor program for modern gas turbine engines has reached the hardware demonstration phase in ground tests of complete engines. Preliminary results suggest that major reductions in emissions during landing and takeoff may be realized, as well as a significant reduction in oxides of nitrogen during high-altitude cruise operation.

### ***Improved Safety and Terminal Area Operations***

**Wake Vortex Reduction.** Trailing vortices from large aircraft pose potential hazards to following smaller aircraft. Controlling the spacing between aircraft provides safe operations but tends to reduce the capacity of busy airports. To restore capacity, NASA is exploring ways to minimize the trailing vortex strength by aerodynamic means. Wind tunnel model and flight tests with a B-747 aircraft demonstrated that selective deflection of wing spoilers can cause a significant reduction in vortex strength. Model tests with other widebody transports have also indicated equivalent vortex reductions with spoiler deflection. NASA is continuing to investigate other vortex minimization concepts and to assess the potential operational impacts associated with their practical application.

**Wind Environment.** Large variations in wind direction and speed (wind shear) along aircraft take-off and approach paths have been factors in aircraft accidents. NASA has identified conditions favorable to low-altitude wind shear around airports and has developed hazard definition models applicable to aircraft design and operations.

**Improving Terminal Area Operations.** NASA's 737, equipped with display, navigation, and flight control systems that represent the first application of all-digital systems to a conventional transport aircraft, was engaged in a cooperative program with the FAA to demonstrate a newly developed Microwave Landing System to the International Civil Aviation Organization. This aircraft made many fully automatic (hands-off) landings using the new equipment for approach and flare guidance.

**Aviation Safety Reporting System.** The Aviation Safety Reporting System began collecting reports in mid-April. In addition to report analysis, the system forwards to FAA reports dealing with critical areas of information. Both the quantity and quality of the reports indicate the system's acceptance by the aviation community.

### ***Advancing Long-Haul and Short-Haul Aircraft Systems***

Research continued to focus on identification and study of advanced aircraft systems and the technologies necessary to make development of advanced commercial aircraft systems possible.

**Supersonic Cruise Aircraft Research.** Progress continued in the technologies pertaining to the environmental compatibility and economic viability of supersonic transports. During 1976, an advanced 2.4-mach transport model test completed in a NASA Ames Research Center wind tunnel showed a significant 30 percent increase in super-

sonic cruise lift-to-drag ratio over the U.S. 1971 supersonic transport design. Various variable-cycle or multi-cycle engines, aimed at optimizing performance over the range of flight regimes encountered by a supersonic aircraft, have been identified and studied extensively. During 1976, the critical components of two most promising engine concepts were identified for component testing.

*Quiet Propulsive-Lift Technology.* In February 1976 NASA awarded a contract to the Boeing Commercial Airplane Company for the design, construction, and test of a Quiet Short-Haul Research Airplane. The experimental aircraft, scheduled for delivery in 1978, would perform flight research to obtain design certification data for future quiet short-haul transport aircraft.

*Low Speed Airfoils.* Complete design information has been developed for a second low-speed airfoil in the General Aviation Wing series. The new airfoil, thinner than its predecessor, demonstrated higher maximum lift and lower drag characteristics.

General aviation aircraft designers were exploring applications of these new data.

#### *Technical Support to the Military*

In addition to the continuing broad-based support of military aircraft technology, a number of notable accomplishments occurred during 1976. The joint NASA/Air Force Highly Maneuverable Aircraft Technology program completed its design phase and began fabrication of two remotely piloted research aircraft. During the design phase, the application of several design methodology innovations resulted in an aerodynamic performance twice as efficient as current vehicles and developed in half the time at a third of the cost. NASA was conducting two joint experimental aircraft programs with the Army—the Rotor Systems Research Aircraft and the Tilt Rotor Research Aircraft. Fabrication for both vehicles was completed during 1976. The Rotor Systems Research Aircraft began flight testing in 1976, with the Tilt Rotor Research Aircraft scheduled to begin in 1977.





## Department of Defense

### Introduction

The Department of Defense maintained emphasis on important advances in space systems and aeronautics in 1976. These Defense efforts include technology investigations and development of operational systems to improve the security of the United States during the 1980s and beyond.

The NAVSTAR Global Positioning System continued as a major development effort within the Department of Defense. It is a system using satellites which will provide continuous, all-weather positioning information on a global basis. Suitably equipped users will be able to obtain their positions to within 10 meters in three dimensions and velocity to within 0.03 meter per second in real time. During 1976, prototype satellites were built in preparation for the launches of the first six satellites in 1977. An inverted test range was installed on the desert near Yuma, Arizona, initially using satellite transmitters on the ground to act like satellites for airborne user tests. As satellites are launched, the ground transmitters will be turned off. Several general demonstration models have been produced for testing purposes. If the concept is validated, plans are to deploy a limited system (for navigation only) during the early 1980s. The system is expected to achieve full operational status in the mid-1980s. The Navy Navigation Satellite System (TRANSIT) will continue as a major system for providing position fixing information to strategic submarine forces until the NAVSTAR Global Positioning System is operational.

DoD has placed increasing emphasis on satellite communications systems to support its diverse requirements of worldwide military communications. The Defense Satellite Communications System (DSCS) supports requirements for worldwide military command and control and was used effectively in the Korean Demilitarized Zone action and the Beirut evacuation. The space segment of the DSCS continues to function with full use of the one Phase II satellite in the Pacific, augmented over the Atlantic Ocean, through mutual agreement be-

tween the U.S. and the North Atlantic Treaty Organization (NATO), by use of the NATO IIIA satellite. The Skynet IIB satellite is used in the Indian Ocean by arrangement between the U.S. and the United Kingdom (U.K.). New, large terminals are available for operational use. The U.S., U.K., and NATO have signed an agreement for a post-1975 SATCOM arrangement to exchange satellite capacity on a contingency and day-to-day basis. Significant progress has also been made toward establishing the U.S.-U.S.S.R. Direct Communication Link via communications satellites.

Contracts for construction of the first two spacecraft of the Navy Fleet Satellite Communications System (FLTSATCOM) have been awarded and a decision has been made to procure three additional spacecraft for a total of five. The first FLTSATCOM launch is scheduled for late 1977. A production contract for AFSATCOM strategic terminals was awarded in November. The Air Force Satellite Communications System provides command and control communications for strategic forces. The Army is developing ground terminals for use by all the services. Terminals for ground mobile forces were tested and are being procured. Engineering developments continue on manpack and vehicular terminals.

DoD maintained close liaison with NASA on the Space Shuttle program during 1976. The Space Shuttle holds great promise for reducing the cost of future space operations, and DoD requirements have been incorporated in the Shuttle design. A solid-fueled Interim Upper Stage was chosen by the Air Force, because of its reliability, safety, and lower cost, for development and use with the Shuttle. The Interim Upper Stage will be used beginning in 1980 for DoD and civil payloads from Kennedy Space Center which require low-inclination or high-altitude orbits. The Space Shuttle launch and landing capability at Vandenberg Air Force Base (AFB) will be ready for operational use in December 1982. A contract was awarded in July to define Shuttle ground support systems at Vandenberg.

Equally important to DoD is the aeronautical research and development that leads toward: lower costs for buying and maintaining aircraft, new operational concepts and capabilities, and modernization of the operational aircraft inventory. The first development F-16 air combat fighter rolled off the assembly line in October. The aircraft is being produced in partnership among five countries: U.S., Belgium, Denmark, Norway, and The Netherlands. Full production of the F-15 air superiority fighter was reached in April 1976. Tactical Air Command received more than 130 F-15s by the end of 1976. Fleet deployment of F-14As aboard carriers and the newly selected F-18 combat fighter now entering full development will provide naval weapon systems to counter a broad range of threats in the future.

The Air Force continued its program to modernize the strategic bomber force through development and procurement of B-1 aircraft. Deployment of this aircraft will strengthen the triad of strategic retaliatory forces by providing a more capable and survivable successor to the B-52 to perform the manned bomber mission.

All three services made significant progress in 1976 in advanced composite structures and materials technology. The Air Force tested a graphite/epoxy structure for the B-1 horizontal stabilizer which is lighter and cheaper than the metal components previously used. The Navy completed development testing of composite materials components for S-3 spoiler, F-14 overwing fairing, and F-14 main landing gear door, as well as a replacement for the H-46 metal rotor blade. The Army expanded research into advanced hybrid composite concepts for primary helicopter components including blades, hubs, airframes, landing gear, and drive shafts.

DoD made advances on other fronts in aeronautical research and technology as well. The Army developed computer programs for prediction of helicopter flow fields to improve the accuracy of air-launched missiles. Also, the Laser Obstacle Terrain Avoidance Warning System was flight-tested in 1976 and successfully detected obstacles as minute as a small wire. In addition, a Synthetic Flight Training System successfully simulated helicopter flight characteristics under instrument flight conditions. In aircraft propulsion, advanced gas generator programs continued to seek increased performance and life expectancy at reduced cost. The services also pursued the development of alternative aviation fuels.

## Space Activities

### *Space Systems and Programs*

*Defense Satellite Communications System.* The primary mission of the Defense Satellite Communications System (DSCS) is to provide rapid, reliable, and secure satellite communications for the National Command Authorities and World-Wide Military Command and Control System. The system provided exceptional communications support to the National Command Authorities in controlling the U.S. response to the North Korean action in the Demilitarized Zone. The DSCS also allowed Washington to closely monitor evacuation of U.S. dependents from Beirut, Lebanon.

The initial Defense Communications Satellite Program (Phase I) provided a limited operational system from 1966 through 1974, primarily out of research and development assets. Phase I is no longer operational.

Two synchronous-orbit satellites, launched in December 1973, make up the present DSCS Phase II space segment. One satellite is positioned over the western Pacific Ocean and one over the Atlantic Ocean. The Pacific satellite is functioning satisfactorily. The Atlantic satellite experienced some anomalies in September 1975, recovered in October 1975, and functioned satisfactorily until it again experienced difficulties in September 1976. The impact has been minimized by rerouting circuits through other defense communications facilities, the use of commercial systems, and the use of the NATO IIIA satellite.

In 1975 the Air Force contracted for six more DSCS II satellites (numbers 7 through 12). Delivery was accelerated so that the first two satellites of this group are scheduled for launch in April 1977. This dual launch will provide one satellite for Atlantic Ocean coverage and one for western Pacific Ocean coverage. The present Pacific satellite will be repositioned to provide either eastern Pacific or Indian Ocean coverage. In addition, during 1976, the Air Force completed negotiations for the procurement of four additional Phase II satellites (numbers 13 through 16) in order to replenish the DSCS space segment in the 1978-1979 time frame. The latter satellites will upgrade the performance of DSCS by incorporating higher power and a defocused antenna for wider coverage.

During 1976, a total of eight new 19-meter terminals became available for operational use. Additional digital modulation equipment procured by the Army represents progress toward an all-digital system.

A conceptual design of the next generation (Phase III) DSCS satellite was developed and made

compatible with the Space Shuttle. Critical portions of the satellite were fabricated, and parts of the ground segment were tested. DoD plans to contract for the development of two R&D spacecraft in 1977.

*Fleet Satellite Communications System.* The purpose of the Fleet Satellite Communications System (FLTSATCOM) is to develop, procure, and implement a satellite communications system to satisfy the most urgent, worldwide, near-term tactical and strategic communications requirements of the Navy and Air Force, respectively. Contracts for the first two FLTSATCOM spacecraft were awarded and a decision on the production of three additional spacecraft has been made. The first FLTSATCOM launch is scheduled for late 1977. Installation of fleet broadcast receivers is virtually complete. Installation of shipboard transceivers and information exchange systems is on schedule. Two leased Marisat spacecraft, also called Gapfiller, became operational in 1976, with a third Marisat scheduled to be operational in early 1977. The shipboard terminal equipment will be operated through the Marisat spacecraft until the FLTSATCOM is operational.

*Air Force Satellite Communications System.* The Air Force Satellite Communications System (AFSATCOM) will provide command and control communications for strategic forces. The AFSATCOM space segment includes transponders on the Navy FLTSATCOM spacecraft, the Air Force Satellite Data System, and other DoD satellites. The AFSATCOM terminal segment will consist of airborne terminals and ground mobile and fixed terminals. Initial operational testing of strategic terminals was completed in 1975; production began in November 1976; and Satellite Data System capability was available in 1976.

*Army Satellite Communications Activities.* The Army is developing strategic and tactical satellite communications ground terminals for use by all services. Two major projects are DCSC Phase II and the Ground Mobile Forces Tactical Satellite Communications. The Army has completed the modification of all existing DCSC ground terminals to upgrade their reliability and communications capability. An AN/FSC-78 heavy transportable terminal is operational at Fort Detrick, Maryland. Additional heavy terminals were contracted for to satisfy the needs of the Defense Satellite Communications System and have been installed at locations worldwide. The antenna for the AN/MS-61 medium terminal is undergoing engineering development. The AN/TSC-86 light transportable terminal completed development and operational testing.

The terminals that provide mobile multi-channel communications for ground mobile forces using DSCS satellite completed all operational testing and are being procured. Engineering development continues on ultra high frequency (UHF) manpack and vehicular terminals.

*International Cooperation in Space.* During 1976, the United States and the United Kingdom continued to operate under an agreement whereby the U.S. and the U.K. would exchange an essentially equivalent amount of satellite power between U.S. DSCS and U.K. Skynet satellites and to interoperate with each other's Earth terminals.

The U.S., U.K., and NATO have signed an agreement for a post-1975 SATCOM arrangement. The parties will exchange satellite capacity during specified conditions and will allocate channels temporarily on a day-to-day basis if SATCOM difficulties are experienced.

Another agreement was signed in September 1976 between the U.S. and NATO which will permit the U.S. to use the NATO IIB satellite. In return the U.S. will provide NATO with equivalent DSCS satellite capacity at a time to be designated by NATO and agreed to by the U.S.

Significant progress has been made toward establishing the U.S.-U.S.S.R. Direct Communication Link, which uses satellite communication circuits via Intelsat and Molniya satellites. The link was created in accordance with the 1971 Strategic Arms Limitations Talks between the U.S. and U.S.S.R. Since August 1976, the Molniya system has been usable 24 hours a day, and end-to-end testing is now being conducted, using both Intelsat and Molniya.

*Navigation Satellite Activity.* The Navy Navigation Satellite System, referred to as TRANSIT, operated for its eleventh year in 1976. TRANSIT provides the Navy with a worldwide, two-dimensional system for position fixing to an accuracy of better than one eighth of a kilometer—primarily in support of strategic submarines. The five satellites in operation provide an opportunity at least every two hours, depending upon the latitude, for a user to fix his position. Usage has expanded both militarily and commercially. It has been adapted for use in such diverse activities as offshore oil exploration and to measure the drift of ice over the poles.

Since the early 1970s, a TRANSIT Improvement Program has been under way. Improved satellites with greater survivability are to be launched to join the operational constellation; however, the first two test satellites in 1975 and 1976 experienced partial failure. Plans for future improvement are currently under review.

*NAVSTAR Global Positioning System.* The NAVSTAR Global Positioning System (GPS) is a joint service development to fulfill the position-

finding needs of all the services and DoD agencies beginning in the 1980s. It will provide continuous, worldwide, all-weather coverage using a common grid to enable suitably equipped users to passively determine their positions to within 10 meters and velocity to within 0.03 meter per second. For routine navigation, a relatively inexpensive receiver will provide less accurate information (100–200 meters). The system may also be used to provide worldwide precise time transfer. The operational NAVSTAR GPS will consist of 24 satellites in three orbital planes at 20,400 kilometers altitude, a ground segment for calibration and control of the satellites, and 25,000 to 35,000 user equipments of various classes.

NAVSTAR GPS is in the concept validation phase with the launch of six satellites and initiation of extensive field testing of all classes of user equipment scheduled in 1977. User equipment to be tested will include high performance, low cost, and manpack models designed to satisfy a variety of DoD requirements. During 1976, the Joint Program Office conducted qualification testing of prototype satellites and environmental testing of working receivers. Increasingly detailed information was exchanged with interested civil agencies and with NATO.

*Defense Meteorological Satellite Program.* The Defense Meteorological Satellite Program (DMSP) continued to provide high quality visual and infrared imagery and other specialized meteorological data to support military operations. The DMSP provides weather data for the entire Earth four times a day using two satellites in polar orbits. One collects early morning and evening data and the other collects noon and midnight data. These weather data are stored aboard the satellites and later transmitted to Air Force Global Weather Central in Nebraska and the Fleet Numerical Weather Central in California. The imagery is also transmitted in real-time to transportable read-out stations at key locations worldwide to support tactical operations. During 1976, a new temperature sensor and other specialized meteorological sensors were developed. Satellite reliability and life have also been improved.

DoD continued to cooperate with NASA and the National Oceanic and Atmospheric Administration in development of the Tiros-N domestic weather satellite. The Tiros-N will be an adaptation of the DMSP Block 5D satellite.

*Space Shuttle.* The Air Force maintained close liaison with NASA during 1976 to ensure that DoD requirements are incorporated in the evolving Shuttle design. An expendable, solid propellant Interim Upper Stage (IUS) concept was chosen by the Air Force in September 1975 for validation and

development. NASA participated in source selection and a contractor was selected in September 1976 to define the design in the validation phase contract. The solid-fueled IUS should provide advantages in cost, reliability, and safety, and will be used with the Shuttle by both DoD and NASA for missions requiring low-inclination, high-altitude orbits. The Interim Upper Stage will be available in 1980 for launch from Kennedy Space Center.

DoD plans to construct new facilities or to modify existing facilities at Vandenberg AFB, California, to provide a West Coast Shuttle launch and landing capability. The planned operational date of the Vandenberg facilities is December 1982, when DoD and civil payloads requiring polar or near-polar orbits will begin using the Shuttle. In July 1976, Air Force contracted for definition of Shuttle ground support systems at Vandenberg AFB.

*Space Boosters.* The DoD family of space boosters is comprised of the Atlas and Titan III standard launch vehicles and the surplus IRBM SM-75 Thor and surplus ICBM Atlas E/F vehicles. These boosters launched 11 space missions during 1976: 8 Titan IIIs, 2 SM-75 Thors, and 1 Atlas F. One of the Thor launches was unsuccessful by DoD criteria. The mission was in orbit long enough, however, to be considered successful by the Cospar definition.

*Space Test Program.* The Space Test Program provides spaceflight test and evaluation of DoD experimental and advanced development payloads. During 1976, three missions were flown. In March, four satellites were placed in orbit by a single Titan IIIC launch vehicle. Two of these satellites, LES 8 and 9, were developed by MIT Lincoln Laboratory to evaluate advanced satellite communications techniques. The other two satellites, called Solrad Hi, were developed by the Naval Research Laboratory to measure solar x-rays, ultraviolet light, and particle emissions. In May 1976, a single satellite, called Wideband, was launched to collect information on effects of ionospheric scintillations on a wide range of communications frequencies. In July 1976, the third in a series of small S-3 satellites was launched under the Space Test Program as a secondary payload on a DoD vehicle. This satellite carried five Air Force Geophysics Laboratory and two Office of Naval Research space experiments to orbit. These experiments are measuring the intensity, distribution, and effects of protons, electrons, and alpha particles in space.

#### *Space Ground Support*

*Range, Tracking, and Data Acquisition Facilities.* DoD space activities are principally supported by the Air Force's Eastern Test Range, Space and Missile Test Center, Satellite Control Facility, and

Arnold Engineering Development Center; the Army's White Sands Missile Range; and the Navy's Pacific Missile Test Center. A wide variety of test and evaluation activities is supported by these facilities which are available to DoD, other Federal components, industry, and international agencies.

*Eastern Test Range (ETR)*. The mission of the Air Force ETR is to provide support to DoD space and ballistic missile operations, NASA space programs, and commercial communications satellite launches. An improvement program at ETR is directed toward correcting operational deficiencies created by extended use of equipment beyond its expected life and providing increased operational capability consistent with support requirements. Current emphasis is on enhancing telemetry, radar tracking, range safety, real-time data, and adaptation of selected instrumentation to a mobile configuration. During 1976, launch and data acquisition support was provided to the NASA Viking Mars Lander program, communications satellites for commercial organizations and foreign governments, as well as several scientific and operational space payloads for DoD and NASA. The ETR was also actively engaged in planning to support the Space Shuttle which will be launched initially from the Kennedy Space Center in 1980.

*Space and Missile Test Center (SAMTEC)*. The mission of SAMTEC is to operate the Western Test Range and to support development and operational testing on aerospace vehicles for the DoD, NASA, and others. During 1976, the SAMTEC workload increased, primarily because of the complexity of user systems and requirements for greater quantities and higher quality of test data. Through programmed system upgrading such as the Telemetry Integrated Processing System and refinements in scheduling, SAMTEC can meet current and projected test requirements. SAMTEC supported many programs during 1976, including Minuteman II and III, Airborne Warning and Control System, B-1, F-15, F-16, Trident I, and various space launches. Planning for the Space Shuttle program at Vandenberg AFB continued.

*Satellite Control Facility (SCF)*. The SCF supported 23 launches (15 DoD and NASA, 8 ballistic), 51,000 satellite contacts, and 55,000 network support hours during 1976. The SCF tracking station at Guam was severely damaged by typhoon Pamela on May 21, 1976, but the station was restored to a minimum capability within two and a half months. Permanent restoration is in progress with completion expected in 1977. Work continues on an improved communications and data system for the worldwide tracking network and is expected to be completed in 1977. Replacement of the on-line computers at the Satellite Test Center was

completed in February 1976. Several mission control centers were relocated, and two new ones were developed during 1976. Studies are continuing on the configuration and use of SCF resources in support of the Space Transportation System.

*Arnold Engineering Development Center (AEDC)*. AEDC has 40 test facilities that simulate flight environments on the ground. Over half of these facilities are unique because of one or more of the major test parameters they simulate. The types of work range from basic research and development associated with environmental testing to full-scale flight hardware testing. In 1976, AEDC provided over 45,000 test hours on major programs such as B-1 and F-16 aircraft, Air Launched Cruise Missile, Sea Launched Cruise Missile, and support to the Energy Research and Development Administration. In 1977, AEDC will begin acquisition of the Aeropropulsion Systems Test Facility which provides the capability to simulate the severe flight environments in which present and future aircraft engines must operate. With the new facility, air-breathing propulsion systems can be fully tested on the ground prior to flight, thus minimizing the need for extensive flight tests and avoiding possible costly modifications to complete propulsion systems.

*White Sands Missile Range (WSMR)*. In 1976, the Army's WSMR supported DoD and NASA aeronautics and space programs by providing ground and flight safety, surveillance, command and control, data acquisition, and analyses. NASA program support included calibration and upper atmospheric sounding rocket programs using the Aerobee, numerous smaller rocket systems, and a variety of astronomical test programs. DoD efforts included sounding rockets and balloon measurements.

*Pacific Missile Test Center (PMTTC)*. The PMTTC supported DoD and NASA missile, aeronautics, and space programs in 1976. PMTTC provided support range services for most launches from Vandenberg, including the NASA satellites Lageos and Itos-G. PMTTC aircraft provided real-time telemetry reception and data transmission from the ATS 1 and ATS 3 satellites to the NASA Rosman, North Carolina, tracking site for real-time relay through the NASA computer network.

### *Space Research and Technology*

*Space Research*. Air Force space-related research and development is directed toward defining the space environment and assessing its effect on the performance of Air Force systems operating within it. Programs to measure atmospheric density and composition include rocket observations and accelerometers on satellites. Atmosphere Explorers

C, D, and E are providing data to define the changes in atmospheric density resulting from large geomagnetic disturbances. Rocket flights gather data on the chemical composition of the atmosphere at altitudes from 90 to 160 kilometers. Detailed measurements on the ion and neutron composition changes during auroral activity have been made and are being used to develop models of those processes.

Another area in which the Air Force is actively involved concerns the measurements and monitoring of charged particles and electric fields in space. Data from satellite S72-1 have been used to improve models of the particle population of the Earth's radiation belt. A series of measurements from the recently launched S3-2 satellite are being used to study the details of the energy input into the upper atmosphere. Instruments designed and built under Air Force sponsorship to measure charged particle fluxes, particle densities, and electric and magnetic field intensities at the S3-2 orbital altitude are currently providing the data to support this investigation. Measurements of the space environment, obtained from these satellites and other satellite programs, are being used to improve the estimates of charged particle dosage rates that orbiting spacecraft will experience under operational conditions. This information is needed to determine shielding requirements, satellite lifetime, and overall life-cycle costs.

The Defense Advanced Research Projects Agency (DARPA) is pursuing advanced sensor technology for strategic surveillance from space. New concepts in optics, detector arrays, and signal processing are being investigated. The technology development activities are supported by signature measurements and sensor design efforts to supply a solid phenomenological base for the application of these techniques to detection of a wide variety of strategic vehicles. Space experiments are being planned to evaluate the optimum concepts as well as provide relevant data from a real environment.

*Solar Monitoring.* As part of the Air Force technology program in propagation environment prediction, solar processes are being investigated and solar emissions are measured. The programs in solar emissions include the theoretical study of the processes leading to solar flares. The Air Force Geophysics Laboratory works closely with the National Science Foundation's Sacramento Peak Observatory. Air Force scientists are developing techniques to forecast the time-history of high energy solar particles that may impact the Earth following a major solar flare. The Air Force is designing and installing a worldwide Radio Solar Telescope Network for use with the Solar Optical Observing Network.

Air Force scientists are also participating in rocket and satellite observations of solar ultraviolet (UV) emissions. Working closely with NASA scientists, Air Force personnel are studying the variation of solar UV observed by spectrophotometers on the Atmosphere Explorer C, D, and E satellites. Rocket flights designed to measure solar UV flares between 230 and 1220 Angstroms have been made in conjunction with satellite measurements to develop models of the solar UV emission spectrum.

The Solrad Hi project is a significant part of the Navy's effort to measure and forecast solar parameters and their effect on electromagnetic systems. Two satellites were launched on March 14, 1976, into 112,000-kilometer circular orbits on a single Titan III booster as part of the Space Test Program. The Solrad Hi data are being received at the Naval Research Laboratory ground station at Blossom Point, Maryland. The data are transmitted to the Naval Electronic Laboratory Center, La Posta Astrogeophysical Laboratory, in California and to the NOAA Space Environmental Laboratory, Boulder, Colorado. Selected information is transmitted by La Posta to the Naval Communications Station, Stockton, California, to include predictions of propagation phenomena affecting very low frequency radio and navigation systems, ultra high frequency satellite systems, and sensors that respond to solar induced variations in the Earth's magnetic field.

*Environmental Remote Sensing.* The Air Force Geophysics Laboratory is monitoring space environment-induced effects as observed at the surface of the Earth. Using transmissions from beacons on both orbiting and geostationary satellites, ionospheric scintillation and signal time delay are being measured at a number of ground stations around the globe. These measurements indicate signal statistics (fade margins, message reliability) for satellite communications systems and positional accuracy for navigation satellite systems and Air Force surveillance radars.

The Navy Environmental Remote Sensing Program explores the potential of satellites to provide a global data base for an integrated air-ocean prediction system for strategic and tactical fleet support. A coordinated research and development effort is assured through a continuous overview by the Navy Environmental Remote Sensing Coordinating and Advisory Group. Activities in 1976 included application of data from space and aircraft platforms as well as collection, analysis, and dissemination for operational fleet usage. The effectiveness of coastal surveys was improved using thermal, infrared, and visual imagery with sea surface temperature maps. Installation has begun of a central Satellite Data Processing Center at Fleet Nu-

merical Weather Central and of readout equipment aboard aircraft carriers for acquiring, analyzing, and disseminating data for strategic and tactical operations. The analysis of altimetry data from Geos 3 and Skylab, along with passive microwave data, contributed to development of sensors for global all-weather measurements at sea. Cooperative planning continued with NASA and NOAA to ensure effective use of the data from future satellites such as Tiros-N, Nimbus-G, Seasat-A, and Goes.

*Meteorological Satellite Applications.* The Army meteorological satellite applications research program is examining ways to provide data in directly usable form to operational commanders in support of nuclear fallout predictions, air operations, artillery, and ground mobility activities. Comparison tests conducted at White Sands Missile Range have demonstrated that vertical temperature profile radiometers on Sun-synchronous, polar-orbiting meteorological satellites produce vertical temperature, density, and wind structure information at 15 to 30 kilometer altitudes as accurate as or better than balloon sounding techniques. A direct readout ground station at White Sands Missile Range has provided the research information from SMS/GOES satellites for use in designing a minute-by-minute observational system to provide mesoscale meteorological data required by the Army. Research efforts are now concentrated on techniques for observing the intensity of severe storms, including areas of high turbulence, precipitation, and icing.

## Aeronautical Activities

### *Aircraft and Aircraft Systems*

*F-16 Combat Fighter Program.* In 1976, F-16 development progressed according to schedule and included YF-16 flight test of many major avionics components. The first full-scale development aircraft rolled off the assembly line in October. Although the prime airframe and engine contractors are located in the United States, the F-16 is being produced as a partnership among five countries: the United States, Belgium, Denmark, Norway, and The Netherlands. On July 14, 1976, the initial co-production subcontracts were signed with the industries of the European Consortium.

*F-15 Air Superiority Fighter.* The F-15 air superiority fighter development is essentially complete, with only limited systems integration and ground support equipment testing remaining. Full production of nine aircraft per month was reached in April and more than 130 F-15s were delivered to the Tactical Air Command by the year's end. The first F-15 Tactical Fighter Wing at Langley AFB, Virginia, became operational in October.

More than 18,000 flying hours have verified the superior performance indicated by the F-15 during developmental testing.

*F-18 Carrier-Based Strike Fighter.* The F-18 is a new Navy fighter and attack aircraft to replace the F-4 and A-7 aircraft and to complement the F-14 aircraft. The development of this new aircraft stresses the use of the latest proven technology and new thresholds of reliability and maintainability. The Secretary of Defense approved full-scale development in December 1975; detailed design of the aircraft, wind tunnel testing, testing of engine components, and fabrication of component test articles. The design reviews will extend through October 1977. In 1978, the preliminary flight rating test of the engine will be completed and the radar test bed will enter evaluation. Flight test of the F-18 will begin with the first flight in September 1978.

*F-14A Carrier-Based Tactical Fighter.* The F-14A Tomcat continues to prove its versatility as an advanced missile platform and as a highly maneuverable fighter. F-14A squadrons are now routinely deployed on carriers of the Atlantic and Pacific Fleets. Ten operational and two training squadrons have completed transition to this aircraft, and two additional squadrons are programmed to receive the Tomcat in 1977.

*F-4G Wild Weasel Avionics.* During 1976, the F-4G Wild Weasel completed development as a replacement for the F-105G and F-4C Weasel aircraft. The object of this Air Force program is to provide an enhanced defense suppression system to search out and destroy hostile air defense weapons. The first F-4G (a modification of the F-4E fighter) was delivered to the Air Force in October, and the second entered the depot facility for modification in November. Subsequently, a significant number of new F-4E aircraft will be modified to the F-4G Weasel configuration by Air Force personnel. With its improved avionics, the F-4G will employ advanced guided munitions and improved antiradiation missiles.

*AV-8B V/STOL Light Attack Aircraft.* The AV-8B aircraft, an advanced version of the Marine Corps AV-8A Harrier, will provide significant range/payload improvements over the AV-8A through design refinements and aerodynamic changes. The AV-8B will replace both the AV-8A and A-4M light attack aircraft and will provide the Marine Corps with a flexibility especially suited for support of amphibious assault. The improved Harrier will permit quick reaction in support of troops ashore while operating from ships off the coast during initial landing phases, or from austere landing pads ashore during later phases of the battle.

*A-10 Close Air Support Aircraft.* The A-10 is being built to support ground forces. The research and development phase of the program is drawing to a conclusion as production rates increase to the planned 15 aircraft per month. Approval has been given for the first 195 of the planned 733 production aircraft. Reports from the initial operational units have been favorable, and maintenance goals are being met so that an anticipated low support cost appears to be achievable. Test of the new GAU-8 gun, carried by the A-10, against armored vehicles clearly demonstrated the lethality of this new weapon against tank-type targets. The A-10 is a major element in the modernization of our tactical air forces.

*B-1 Bomber Program.* The Air Force is continuing its program to modernize the strategic bomber force through development and procurement of the B-1 aircraft. As a key element of the nation's strategic triad of manned bombers, land-based missiles, and sea-launched missiles, the new bomber will support the nuclear deterrent objectives of the United States through its ability to deliver heavy payloads over long ranges and through a hostile environment.

Three research, development, test, and evaluation aircraft are currently flying in the test program at Edwards AFB to measure overall performance, to gather data on air loads, and to evaluate the offensive avionics subsystem. Primary emphasis has been placed upon low altitude penetration to test terrain-following equipment, weapons delivery capabilities, navigation, and communications.

Production of a fourth B-1 development aircraft was begun in August 1975, and this aircraft, to be delivered in August 1979, will be used primarily for defensive avionics testing. Congressional approval has been given for production of aircraft 5, 6, and 7.

*Advanced Medium STOL Transport (AMST).* The AMST prototype program is designed to prove STOL (short takeoff and landing) technology, demonstrate operational utility, and provide an option for modernization of our tactical airlift forces. The AMST will provide an option to modernize tactical airlift forces and meet both current and forecast tactical mobility requirements for support of Army combat forces.

Both the YC-14 and YC-15 (advanced development prototypes of the AMST aircraft) were flight-tested during 1976. The two YC-15s completed their initial tests with over 450 flight hours accumulated. The YC-14 had its first flight in August 1976, and the second aircraft followed in October. Extensive performance tests are now being conducted with the two YC-14 aircraft.

*Advanced Tanker/Cargo Aircraft (ATCA).* Re-

quests for proposals were released to industry on August 27, 1976, for procurement of the ATCA although first procurement has subsequently been delayed until at least 1979. As a result of previous commercial development of wide-bodied freighter aircraft, ATCA will be procured without the research and development normally associated with acquisition of a new weapon system. The Air Force intends to make only those changes necessary to the selected commercial aircraft to provide an air refueling capability and to make full use of existing cargo carrying potential. The Air Force expects to reduce costs further by contracting with private industry for logistical support. By taking full advantage of the existing worldwide support system for wide-bodied aircraft, the Air Force will avoid large costs associated with setting up a separate system of its own.

*Utility Tactical Transport Aircraft System (UTTAS).* The UTTAS helicopter is designed to replace a portion of the Army's UH-1H to provide increased payload capability, increased survivability, and reduced maintenance as compared to the UH-1H. The UTTAS will transport 11 combat-equipped troops, resupply them in combat, and perform aeromedical evacuation. Contracts were awarded for production of three prototypes in August 1972. Each prototype design was flown approximately 1400 hours and a decision on the final prototype design was made in December 1976.

*CH-53E Helicopter.* The two CH-53E production prototypes were completed in early 1976 and entered flight test. Correction of deficiencies on the horizontal stabilizer and improved rotor blades was required during Navy Preliminary Evaluation (NPE) II, and changes made to the analog automatic flight control system verified the need for development of a digital control system for increased reliability and maintainability. The CH-53E completed NPE III during September and began initial Board of Inspection Trials in November. The CH-53E will significantly enhance the heavy lift capability of amphibious forces.

*Advanced Attack Helicopter (AAH).* The competitive airframe development program (phase 1 of 2 phases) made major progress during 1976. Both contractors completed their developmental flight tests, and the four prototype aircraft were delivered to the Army in May for competitive tests. The tests were completed in early October. A Phase 1 airframe contractor was selected in December for engineering development, including development and integration of weapons and target acquisition systems. Early in 1976, the Army decided to replace the Tube Launched Optically Tracked Wire Guided (TOW) missile system on the AAH with the Hellfire laser terminal-homing missile. This



will result in a far more lethal weapon system and will enhance AAH survivability significantly.

*Cobra/TOW.* The Cobra/TOW program, including retrofit of some existing Cobra helicopters and purchase of new aircraft with the highly effective TOW missile, continued in 1976. Deliveries of 290 retrofitted Cobra/TOW helicopters began in June 1975 and will be completed in July 1977. Upgraded engine, transmission, and dynamic components will be incorporated in new aircraft delivered in early 1977 and will be installed in the field on 290 retrofitted Cobra/TOWs. The Army's plans include the retrofit of an additional 200 Cobra helicopters and a modernization program of the Cobra/TOW fleet. The modernization program will increase the Cobra's secondary armament and enhance reliability substantially. The modernization program also includes a new composite structure main rotor blade that will increase hover performance and survivability and will double blade life.

A new family of warheads for the 2.75-inch Folding Fin Aerial Rocket (FFAR) is being developed. This family includes screening smoke, illumination, and multipurpose submunition warheads. The fuzing for these warheads will be set remotely by the pilot from the cockpit of the aircraft. A 100 percent increase in accuracy and a 30 percent increase in range will increase the overall effectiveness of the FFAR five-fold. This new family of 2.75-inch FFARS will be compatible with the delivery systems for both Cobra/TOW and the Advanced Attack Helicopter.

*CH-47 Modernization.* The CH-47 modernization program is designed to increase the life of older CH-47A, B, and C aircraft and to improve performance of A and B models. The current CH-47 fleet will be modernized through development and testing of seven systems: rotor, drive, hydraulic, electrical, advanced flight control, cargo handling, and auxiliary power unit. Integration of these changes will improve reliability and reduce vulnerability. The development contract was awarded June 4, 1976.

*E-3A Airborne Warning and Control Systems (AWACS).* The E-3A provides a unique capability for all-altitude surveillance over land and sea coupled with appropriate command, control, and communications functions. It is rapidly deployable worldwide to provide a survivable surveillance, command, and control capability for either tactical control or air defense roles.

Following the Secretary of Defense's February 1975 certification of E-3A cost effectiveness, Congress authorized production of 6 aircraft in FY 1975, 4 in FY 1976, and 6 in FY 1977, with advanced procurement funds made available for 6 more aircraft in FY 1978. In the FY 1978 DoD

amended budget request, procurement funds for 3 aircraft are requested, as well as advance procurement funds for 3 aircraft in FY 1979. The planned initial operational capability date of September 1977 remains unchanged.

Activity continued in various NATO forums regarding potential NATO procurement of a variant of the USAF E-3A (the NATO Airborne Early Warning and Control (AEWC) aircraft). The previously approved project definition studies, begun in June 1975, were completed in June 1976 and supported by a draft letter of offer and acceptance. The NATO Defense Ministers reviewed the results of the NATO contract definition activities on June 10, 1976, and again on December 8, 1976. They endorsed in principle joint funding by interested nations for preparatory research and development that will preserve the option to buy a NATO AEWC force before the Air Force AWACS production line is terminated.

*E-4A/B Advanced Airborne Command Post.* The E-4 will provide a modernized, highly survivable capability for command and control of our strategic forces on a continuous basis before, during, and after any nuclear attack on the U.S. The three interim E-4As have been operational in support of the National Command Authorities since September 1975. The test-bed aircraft is being equipped with advanced command, control, and communications equipment that has been developed for integration into this aircraft as the first E-4B.

*EF-111A Tactical Jamming System.* The EF-111A is being designed to provide ground and airborne radar jamming in support of all tactical air missions. The peacetime mission will be to provide training in electronic countermeasures for our own air defense and tactical forces. The final aircraft and avionics designs were completed in August 1976. Airframe modification (less avionics) for the first of two prototypes was completed in December. Initial software and qualification testing and antenna pattern testing were also accomplished during 1976. First flight test for flight stability is scheduled for February 1977.

*Tactical Airborne Signals Exploitation System (TASES).* The Navy requires a carrier-based, land-compatible TASES to improve effectiveness of fleet weapon systems. The TASES program objective is to develop a multi-source tactical electronic warfare support system in a carrier aircraft. TASES will collect communications intelligence, electronic intelligence, and radar surveillance data; analyze it; and provide pertinent real-time information to the officer in tactical command. TASES is required to exploit, correlate, and corroborate electronic emissions used by hostile forces in communications, surveillance, acquisition, tracking, targeting, guidance,

and reporting. Electronic communications, infrared, acoustic intercept, and radar sensors will be integrated into the S-3A aircraft. The three crewmen will be assisted in processing and correlating intercepted data by a highly automated sensor management system to overcome the complexities of electronic warfare in the 1980s and 1990s. A feasibility demonstration model using one S-3A aircraft is being developed under the TASES program to demonstrate TASES capabilities in an "at sea" test.

*Joint Tactical Information Distribution System (JTIDS).* The JTIDS program objective is to develop a data link to satisfy multiple tactical operational users. When deployed it will provide a high capacity, jam-resistant, low-probability-of-intercept data link to interconnect participants in an area of tactical military operations. JTIDS employs modern spread spectrum and time division multiple-access technology to provide jam-resistant communications as well as accurate relative navigation with other cochannel transmissions.

All services are participating in this program and a joint program office has been established. Initial operational application of the early phase of JTIDS will be in the Airborne Warning and Control System aircraft. Compatibility with existing and anticipated systems will be stressed.

### *Aeronautical Research and Technology*

*Aircraft Structures and Materials Technology.* All three services made significant progress in advanced composite structures and materials technology during 1976. The largest graphite/epoxy structure fabricated to date is the composite B-1 horizontal stabilizer developed by the Air Force. Appreciable weight and cost savings are predicted. Other developments addressing secondary structures also appear to have impressive weight and cost advantages.

Beyond weight and cost considerations, the Navy is evaluating structural systems consisting primarily of composite materials to improve corrosion resistance and battle damage tolerance. Components which have completed development testing include the S-3 spoiler, F-14 overwing fairing, and F-14 main landing gear door. Development is continuing on a composite wing for the Marine Corps AV-8B. Hardware verification of critical wing assemblies will be completed in 1977 with fabrication and structural test of a full-scale wing in 1978. Future development work will expand to include assemblies for fuselage, landing gear, and engine nacelles for future vertical/short take-off and landing aircraft.

The Navy continued development during 1976 of a fiberglass composite rotor blade as a replace-

ment for the H-46 metal rotor blade. The fiberglass blade is designed to be corrosion resistant and insensitive to small defects. Predictions are that it will require only visual pre-flight inspections and will increase the mean time between removal by 500 percent. The development will significantly increase the effectiveness of the H-46 helicopter fleet.

The Army efforts over the past years have resulted in development of composites with identified basic structural, fatigue, and manufacturing characteristics. Specific programs to fabricate and completely test blades of advanced composites have led to a manufacturing capability within industry. Rotor blades incorporating this technology are used in prototype helicopters for UTTAS and AAH competition. Replacement blades for AH-1Q and CH-47 emphasizing increased life, improved performance, and reduced radar cross section will use composite technology directly evolved from Army programs.

Advanced blade concepts continue to be developed to further reduce fabrication and life cycle costs and improve survivability. Advanced hybrid composite concepts are being considered for other primary components. These include rotor hubs for reduced cost, weight, and vulnerability; airframes for reduced cost, weight, and maintenance; landing gear for increased crashworthiness; and drive shafting for reduced cost and weight. A metal matrix composite structure is being considered for lighter, quieter transmission cases.

*Advanced Helicopter Rotor System.* The basic objective of the Navy's Advanced Helicopter Rotor System is to prove flight feasibility of the Circulation Control Rotor (CCR) concept—a non-articulated rotor in which aerodynamic angle of attack is achieved by boundary layer control. The 42-month, incrementally funded program for the feasibility demonstration continued on schedule during 1976. The X-wing concept, incorporating CCR technology and high-speed rotor technology (Reverse Velocity Rotor), was started in development by the Navy and DARPA in 1976. The X-wing program will demonstrate high-speed rotor feasibility in parallel with the CCR program. Both programs are scheduled for completion in 1979.

*Helicopter Acoustics Research.* The YO-3A quiet aircraft has been instrumented with microphones on wing tips and tail to provide an in-flight, far-field acoustic measurement system which will allow for triangulation on acoustic phenomena. This system will provide data which can be compared with scale-model acoustic data from the Army 2.1 x 3-meter wind tunnel. Results of this program have been applied to both civil and military helicopters.

*Advancing Blade Concept (ABC) Demonstration Aircraft.* The ABC development program, initiated

by the Army in 1971, included fabrication and flight test of two aircraft to verify and demonstrate the concept of elimination of a tail rotor and a hingeless main rotor. The ABC demonstrator is equipped with two coaxial, counter-rotating, hingeless rotors. Flight tests of the second aircraft totaling 52 hours have been completed at level flight speeds up to 160 knots. Maneuvering capabilities up to 2.5 g have been established. The concept has demonstrated alleviation of retreating blade stall at speeds and altitudes where this is normally encountered, good hovering performance, rapid control response, low noise, and generally acceptable vibration characteristics. Current plans are to complete flight testing of the vehicle in its pure helicopter configuration in early 1977.

*Helicopter Rotor Aerodynamics.* A number of aerodynamic investigations are under way to improve efficiency, drag, and vibration characteristics that affect helicopter performance and structural life. The dynamic stall phenomenon is being investigated to develop techniques to reduce high dynamic blade loads and to develop theoretical means for determining aerodynamic behavior of airfoils which penetrate the stall regime. A prototype in-flight rotor blade angle-of-attack sensor has been fabricated to determine blade/vortex interaction and to define quantitative time-dependent angle-of-attack variations. Development of a three-axis laser velocimeter has been initiated and a velocity survey has been conducted on a static stalled airfoil section using the current laser velocimeter. A method to predict hub drag is being developed to identify important parameters, model the three dimensional flow field, and determine interference effects. A hub fairing, designed to reduce drag, will be tested in a wind tunnel to verify the design.

*Helicopter Aerodynamic Launch Environment.* An attack helicopter experiences numerous transients, such as vibration, rotor downwash, and rotation and translation of the aircraft. These factors particularly affect the launch of weapons. During the first few meters of missile flight, the helicopter rotor induces a downwash about the missile which influences its accuracy. Computer programs for analytical prediction of this effect are now developed. The experimental program is being carried out by Army Aviation Engineering Flight Activity and data are being processed by Army Missile Command.

*U.S. Army Avionics.* The Laser Obstacle Terrain Avoidance Warning System (LOWTAWs) was flight tested in 1976 and successfully detected obstacles as delicate as a small wire. The addition of other functions to LOWTAWs, such as terrain following and range finding, is being examined. The

Army is assessing the potential of charged coupled devices to provide a lower cost solution to the wire detection problem. The AN/ASN-128 Doppler navigation subsystem neared the end of competitive, design-to-cost engineering development in September 1976. Starting in October 1976, the AN/ASN-128 was procured for installation in Utility Tactical Transport Aircraft Systems and AH-1S helicopters and provides an accurate, self-contained navigation capability.

*Synthetic Flight Training System (SFTS).* The UH-1H SFTS, which simulates helicopter flight characteristics under instrument flight conditions, has been sent to the field. A prototype program is underway for development of a CH-47 and AH-1 simulator. Both systems will have a television model-board visual system that will permit simulation of the full range of flight characteristics for both helicopters. The AH-1 simulator will also have a weapon system simulation capability using model-board and computer-generated imagery. A prototype program for a UTTAS simulator was begun in September 1976, with delivery expected in September 1978. Research now in progress will lead to development of an Advanced Attack Helicopter simulator with full weapon systems simulation. The prototype program will begin in 1979, with delivery expected in 1981.

*Research in Aircraft Propulsion Systems.* A major milestone in the T700 engine development program was reached in March 1976, when the 150-hour endurance demonstration of the military qualification test was completed. A program was initiated in 1976 to design, fabricate, and test advanced transmission components such as gears, bearings, shafts, and seals to achieve a 20 percent reduction in weight, a 100 percent increase in mean time between removals, and a 20 percent reduction in costs.

The Small Turbine Advanced Gas Generator program demonstrated improvements in specific fuel consumption of 30 percent at typical helicopter cruise conditions and increases in specific horsepower of 45 percent relative to current production engines. Gas generators have been used as test vehicles for other programs and have provided technology for the proposed 800-shaft-horsepower advanced technology demonstrator engine program which is to start in 1977.

In the Aircraft Propulsion Subsystems Integration program, advanced low spool (fan and fan turbine) turbine engine components are integrated with the Advanced Turbine Engine Gas Generator (ATEGG) to form complete propulsion systems. Technology demonstrator engines are assembled and tested to obtain the additional critical component assessments required to demonstrate that advanced turbine engine component technologies

can be confidently transitioned to engineering development. The Joint Technology Demonstrator Engine (JTDE) is an Air Force/Navy program to assess the advanced turbine engine technologies for a broad range of military missions. The initial JTDE demonstration will occur in 1979.

The ATEGG program will integrate the most advanced turbine engine component technologies into a gas generator in which the performance, cost, and lifetime characteristics of advanced technologies can be assessed under realistic conditions. Design for reduced life cycle cost has become an integral objective of this program. Future emphasis will be directed toward incorporating dedicated gas generators into a structural/life testing program.

The alternate fuels program is part of a long term coordinated effort among the services, NASA, and ERDA to ensure that liquid fuels obtained from domestic resources such as oil, shale, tar sands, and coal will be acceptable in high performance engines. The initial DoD effort is an experimental program to produce aviation turbine fuels from three shale oils and two coal liquids. Results obtained to date provide encouraging evidence that the aviation industry can use fuel produced from the vast U.S. oil shale resources.

### **Relationship with NASA**

#### *Aeronautics and Astronautics Coordinating Board*

The Aeronautics and Astronautics Coordinating Board (AACB) met four times during the past year. The AACB primarily addresses major policy issues of interest to the DoD and NASA in space and aeronautics. It serves as the highest level formal coordination mechanism between the two agencies.

On January 23, 1976, the AACB Co-Chairmen agreed to work together to resolve the Space Shuttle orbiter procurement issue. Joint studies were undertaken by Air Force and NASA to examine the requirements for Space Shuttle orbiters based on national traffic projections for space launches, alternatives and implications of procuring fewer than five orbiters, and funding alternatives. On June 8, 1976, the Office of Management and Budget formally advised DoD and NASA that more information would be required on procurement of additional orbiters and requested an expanded joint DoD/NASA study. The requested joint study concluded that five orbiters constitute the minimum fleet size needed to support the National Space Transportation System. The integrated Shuttle traffic model is established at 560 Shuttle flights, of which 112 are allocated to DoD. NASA and DoD agree that the two additional orbiters needed to make up the five-orbiter fleet should be procured by NASA.

The NASA/DoD Memorandum of Understanding on Management and Operation of the Space Transportation System, which was signed last year, has been updated. It will be the basis for more detailed documentation further defining management and operations concepts and the specific roles and responsibilities of each agency.

The Board is now examining the question of reimbursement for Shuttle services provided to DoD. In June 1976, NASA provided DoD with a proposed preliminary policy for detailed examination. NASA also briefed the Office of Management and Budget, congressional committees, and personnel from the General Accounting Office. DoD comments have been provided to NASA and negotiations are under way.

This past year the Aeronautics Panel was requested to develop a recommended power-augmented ram wing technology program. Considerable interest has developed in this technology. Analyses, supported by very recent model test data, indicate a good vertical take off and landing capability for surface effects vehicles. Funding is now included in the budgets of both agencies to examine this technology in more detail and to evaluate its applicability to a variety of potential Navy and Air Forces uses.

The Board maintained overview of the National Aeronautical Facilities Program (NAFP) which was defined and submitted to Congress last year. Congress appropriated in FY 1977 \$437 million for the Air Force Aeropropulsion System Test Facility (ASTF) under the Defense Military Construction Bill. The Corps of Engineers has issued requests for proposals for construction starting in 1977. ASTF will be in operation in 1982. The two other facilities which comprise the NAFP are the NASA 12 x 24-meter Subsonic Wind Tunnel modification and the NASA National Transonic Facility, both of which should be in operation in 1981. The Aeronautics Facilities Subpanel reviewed the initial Transonic Facility test section design and recommended redesign to achieve a greater angle-of-attack test capability to meet future test needs. The Board will continue to assess design and construction cost implications of recommended changes. A management and test funding plan for National Aeronautical Facilities is also in preparation.

#### *Joint Programs*

*Rotor System Research Aircraft.* This joint Army/NASA program will provide an in-house research capability to evaluate the potential of promising new advanced rotor concepts, to investigate and document the characteristics of current or develop-

mental rotors, and to verify numerous areas of supporting research and technology. The first of two aircraft was received on June 7 and first flight of this aircraft took place late in 1976.

*Tilt Rotor Research Aircraft.* The Tilt Rotor Research Aircraft project, a joint Army/NASA program, will lead to a complete flight demonstration of the tilt rotor concept and an evaluation of tilt rotor capabilities with respect to mission performance, survivability, and safety. On August 1, 1973, a contract was awarded for design, fabrication, and testing of two XV-15 Tilt Rotor Aircraft. Fabrication of the first aircraft is complete. The second aircraft is in final assembly. First hover flight is scheduled for January 1977, followed by full-scale wind tunnel and extensive flight tests.

*Spacecraft Charging Technology.* The Air Force Geophysics Laboratory (AFGL) is actively involved in the joint USAF/NASA Spacecraft Charging Technology program. In addition to developing theoretical and empirical models of the natural environment leading to spacecraft electrical charging at synchronous altitude, AFGL is providing instrumentation to be flown on the Scatha satellite (P78-2). This instrumentation includes electrostatic analyzers and electron ion-beam emitters. The objective is to measure the natural environment of near-synchronous altitudes with emphasis on how this environment leads to the process of spacecraft charging.

*Astronaut Selection.* DoD and NASA plan to enter a new agreement which provides for DoD-wide participation in the astronaut selection cycle for the forthcoming Space Shuttle program. NASA wants at least 15 pilots and 15 mission specialists. Applications will be accepted beginning in January 1977 with selection planned in December 1977. DoD expects to nominate 90 pilots and 90 mission

specialists and submit the names to NASA in July 1977 for consideration. At present, DoD has 14 officers assigned to NASA as astronauts and about half have prior space flight experience.

*Technical Development Support.* DoD has detailed a number of technically trained persons to NASA to assist in programs of mutual interest. The technological transfer back to DoD in unique functional areas is important. The total number of detailees under the program is 45 (33 from Air Force, 3 from Navy, and 9 from Army). They are working in a variety of operational and research and development programs but most are associated with the Space Transportation System development. Their activities include space mission planning, maintenance analysis, avionics and communications security, crew procedures, and payloads software.

*Seasat Data Processing.* A DoD/NASA memorandum of agreement has been signed to provide for a real-time user data processing experiment with Seasat-A. Under this agreement NASA will deliver all Seasat-A data collected at Fairbanks, Alaska, to the Navy's Fleet Numerical Weather Central (FNWC) at Monterey, California, within six hours of sensing. FNWC will process these data into Earth-located geophysical units (wave heights, sea surface temperatures, surface winds, etc.) and use these in their global maritime weather analysis and forecasting processes. The processed data will also be made available for NASA delivery to Seasat-A users. The experiment is an important step in several areas: (a) demonstrating the usefulness of oceanographic satellite data in naval operations, (b) providing useful information on the performance and capabilities of Seasat-A sensors, (c) determining methods needed to fully exploit this new source of oceanographic data in weather and ocean forecasting.

# IV



# Department of Commerce

## Introduction

Within the Department of Commerce, aeronautics and space programs are carried out by the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Office of Telecommunications, the Maritime Administration, and the Bureau of the Census.

The broad goals of these agencies include programs to ensure that the environment and its resources are wisely used; to strengthen and advance science and technology and to facilitate their effective application for the public benefit; to improve ship communications, navigation, safety, and management techniques; to provide specialized engineering, management, and advisory assistance to other Federal agencies in telecommunications applications; and to provide information on population trends, urban growth, and internal structure of national land areas.

These goals are pursued by establishing and maintaining operational environmental satellite systems; by continuing marine resource assessment and prediction programs; by monitoring the marine environment continuously with improved sensors on ships, aircraft, and satellites; by improving weather observations and forecasts through the use of automated observation stations and improved radar systems, and continued atmospheric research programs; by conducting research in weather modification; by improving data collection, processing, and dissemination techniques; by providing basic measurement and calibration methods for operating technical systems and engineering data for the design and construction of sophisticated space and aeronautics equipment; by installing, testing, and evaluating shipboard satellite equipment; by conducting electromagnetic wave propagation studies to improve aerospace communications; and by applying satellite images to demographic studies.

## Satellites in Environmental Monitoring and Prediction

### *Environmental Satellite Operations*

At the beginning of 1976, the National Environmental Satellite Service (NESS) of the National Oceanic and Atmospheric Administration (NOAA) was operating three polar-orbiting satellites: Essa 8 of the Tiros Operational Satellite (TOS) series and NOAA 3 and NOAA 4 of the Improved TOS (ITOS) series. On March 12, 1976, Essa 8 was deactivated after its second camera failed. Launched December 15, 1968, the satellite had completed more than 33,000 orbits and provided Automatic Picture Transmission service to more than 120 nations. NOAA 5 was launched on July 29, 1976, and became the primary operational polar-orbiting satellite on September 15, 1976. At the same time NOAA 4 was placed on standby as the in-orbit backup. NOAA 3 was deactivated August 31, 1976.

Development of the Tiros-N series, the third generation of operational polar-orbiting satellites, is continuing. These satellites will replace the present Itos series and provide more accurate data for environmental monitoring and prediction. This new system will consist of two satellites in orbit at 833 kilometers. Sun-synchronous, one satellite will orbit south across the equator in the local morning and the other north across the equator in local afternoon to provide maximum daylight coverage. Tiros-N, the NASA prototype, is scheduled for launch early in 1978; about six months later NOAA A, NOAA's first operational version of this series, will be launched.

In 1976, NESS contracted for development, installation, and test of the Tiros-N series ground system. A new ground system is required because of the change to a completely digital data system and increased demand by operational users for timely delivery of processed data. The major components of the ground system are the Data Acquisition and Control Subsystem and the Data Processing and Services Subsystem.

No Geostationary Operational Environmental Satellites (GOES) were launched in 1976. On Jan-

uary 8, 1976, Goes 1 was positioned at 75° West longitude to replace the Synchronous Meteorological Satellite, SMS 1, which was moved to 105° West longitude on February 16, 1976, and placed on operational standby. SMS 2 was moved to 135° West longitude on December 19, 1975. These satellites continue to provide nearly constant viewing of severe storms, helping weather forecasters to provide timely warnings to the public.

In October 1976, NESS increased to 68 the number of experimental Weather Facsimile broadcasts from Goes 1 and SMS 2. The duration of each broadcast is 8 minutes. The products transmitted are processed visible and infrared spin-scan radiometer images from the geostationary satellites and processed scanning radiometer images from the polar-orbiting satellites. Plain language operational messages also are broadcast once a day from each satellite.

### *Uses of Environmental Satellite Data*

*Determining Winds and Temperatures.* Geostationary satellite wind data continued to be provided to the National Meteorological Center (NMC) for use in their numerical weather forecast models. However, research continued on automated computation of winds from cloud motions observed by these satellites. Motions were computed from temperature data at three levels. Objective analysis was made of the computed winds at the lowest level to eliminate invalid estimates and improve the quality and quantity of wind data. Similar objective analyses applied to upper levels provided wind field information in data-sparse areas. This technique is being implemented operationally.

Wind data derived from geostationary satellite pictures were used to study the relationship between diverging jet streams and severe weather. Studies of five cases suggested that severe weather occurs between the polar and subtropical jet streams but is sharply inhibited at and to the south of the subtropical jet stream.

Radiance measurements from the NOAA 4 and 5 Vertical Temperature Profile Radiometer were being used to derive polar jet stream and upper tropospheric winds. Radiation from the 150 to 100-millibar level provides a direct indication of the thermal wind pattern above the polar jet level. Using these data, a wind scale giving 300-millibar speeds as a function of radiance gradient and latitude has been derived. These data also are used routinely by the NMC in numerical weather forecasting programs.

Nimbus 6 High Resolution Infrared Sounder (HIRS) data were used in two Global Atmospheric Research Program (GARP) Data System

Tests (DST). This concept was used to test proposed observation, data management, and data utilization systems for the First GARP Global Experiment in 1978. Global sets of conventional and satellite meteorological observations were collected, processed, and analyzed. These data sets were used in global analysis and forecast models to determine the accuracy and utility of the various observing systems. In particular, experiments were made to determine the impact on numerical forecast systems by satellite-derived atmospheric temperatures and cloud-tracked winds. During DST 5, Nimbus 6 temperature profiles were compared with mean temperatures from the NMC analyses. The results approached the theoretical limit of remote sounding by the Nimbus 6 HIRS. Introducing these data into the NMC model demonstrated that they provide accurate information unavailable from conventional sources.

*Monitoring Global Radiation.* Processing of Nimbus 6 Earth Radiation Budget (ERB) Experiment data continued in 1976. Global maps and latitudinal profiles of albedo, longwave radiation, and net radiation to space were produced. Limited comparisons of the results from ERB scanning data agreed more closely with NOAA 4 Scanning Radiometer (SR) data than with calculated Nimbus 6 HIRS data. Also, monthly global net radiation values derived from the ERB wide-angle data show a cyclical variation about zero, similar to those observed from earlier satellites. The solar constant, which is important in determining net radiation, varied less than 0.2 percent during the first year in orbit.

In 1976 NOAA SR-derived heat budget information continued to be processed. Results from a study comparing albedo and longwave radiation data for the summers of 1974 and 1975 showed that in 1975 more solar energy was available for heating over continental Asia, more absorbed solar energy reached North Pole regions, and more net radiation over the eastern North Atlantic reached the sea surface. Consequently, there was increased intensity of the Asian monsoon, decreased ice and snow cover in the Canadian Arctic, and warmer water temperatures near the Azores.

*Environmental Warning Services.* Over 100 satellite-interrogated platforms of the GOES Data Collection System (DCS) provided data and services to users in the United States and Canada during 1976. Requests for DCS services also were received from Chile and Bolivia. This system is being upgraded with second-generation ground processing equipment, and through automation of the operational and test function. For this purpose four computers, two at NOAA's Wallops, Virginia,

Command and Data Acquisition Station and two at NOAA's World Weather Building, Camp Springs, Maryland, have been installed and are now undergoing operational tests. This fully redundant system will permit continuous 24-hour reception except during the spring and autumn equinox periods when the satellites are eclipsed by the Earth. Data will be received from 2000 platforms and can be expanded to handle more. The DCS provides a near-instantaneous source of information for many applications such as river and flood monitoring and forest-fire index measurements. A recent test involving relay of data from a prototype Shipboard Environmental Acquisition System demonstrated the technical feasibility of collecting marine environmental data from ocean vessels.

To improve reception from Data Collection Platforms located on the periphery of the communication range (Earth edge), a new DCS Ultra High Frequency antenna is being developed; this antenna will provide maximum omnidirectional gain at low elevation angles to the spacecraft. Two prototype antennas have been built; one will be placed on a buoy and the other on a ship for extended operational tests.

The GOES-TAP system, instituted in 1975 for distributing images received from the GOES satellites, has now been expanded to more than 20 subscribers. This system permits Federal, state, and local agencies, television stations, universities, private enterprise environmental consulting firms, and others to receive any of the variety of standard sectors available to the NESS Satellite Field Services Stations. The National Weather Service now provides this service directly from its Weather Service Forecast Offices (WSFO). Users near the local WSFOs may obtain the limited inventory of satellite products more economically because of shorter communication lines.

In 1976, the National Environmental Satellite Service (NESS) initiated a new cloud analysis chart based on geostationary infrared data. The chart was transmitted experimentally on facsimile circuits once each day. Prepared primarily for aviation use, it depicted the areas and types of clouds and cloud tops over the continental United States and adjacent oceans.

On July 6, 1976, the Satellite Field Services Station (SFSS) at Kansas City started to monitor and analyze satellite photographs showing weather conditions in the Gulf of Mexico. This is an area where severe weather systems go undetected because of the sparsity of conventional surface and upper air observations. The Kansas City SFSS combines low-level satellite wind data with other satellite meteorological interpretations into a Gulf of Mexico Satellite Interpretation Message. These messages are

transmitted each six hours to the WSFOs at New Orleans and San Antonio. Whenever observed weather conditions warrant, messages are updated and transmitted off schedule. Strong emphasis is placed on the early detection of small scale, short-lived severe weather phenomena which can adversely affect oil drilling operations, boating, and aviation in the Gulf. Three times each week this message includes an analysis of the Gulf Loop Current, providing information to commercial and sports fishermen on the probable locations of the most productive fishing areas with significant savings to fishermen of both time and fuel.

NESS used enhanced infrared images from the geostationary satellites to develop a method for estimating hourly rainfall. Empirical relationships were established between rainfall amounts and the growth, merging, and decay of convective cloud systems. The method, now being tested, will be applicable to flash flood forecasting, especially in areas where there are no reporting stations. These infrared images also were used to estimate hurricane intensity, especially during nighttime.

NESS is developing a method to estimate winds by tracking low-level cumulus clouds visible in one-half-mile-resolution Goes 1 images taken at three-minute intervals. This method will provide up to twice as many wind samples as obtained from longer interval images. This includes areas where no winds can be obtained from 30-minute images. These short-interval pictures give new insight into the development, growth, and movement of severe storms.

Severe drought in much of the Midwest and Canada in 1976 contributed to many forest fires. By early June more than 243 square kilometers were on fire in a number of remote locations in Ontario. NOAA 4 and Goes 1 images were used to establish the location and relative size of the fires, thus providing considerable assistance to the firefighters.

In a cooperative effort between the National Weather Service (NWS) and NESS, on nights when frost is expected, the Miami SFSS provides specially enhanced infrared Goes 1 images and interpretations to the Weather Service Office at Ruskin, Florida. This program was developed by NASA and NWS to support the Florida citrus industry. The method was first successfully tested in January 1976, and became operational during the 1976-1977 winter. The satellite images display ground temperatures critical to freeze predictions. Ground temperatures, monitored every 30 minutes over the entire citrus belt, are accurate to within 1°C. Heating the citrus groves cost the growers an average of \$830,000 an hour as opposed to \$37,000 an hour during



normal operating periods. Thus more reliable forecasts produce significant economic benefits.

*Search and Rescue Support.* NESS provided satellite data to assist in Search and Rescue (SAR) planning throughout the U.S. Air Force Inland SAR area and for U.S. Coast Guard SAR missions in United States coastal waters.

The Air Force Rescue and Coordination Center used geostationary satellite cloud pictures to detect areas of severe weather not observed by conventional means. This information enabled the center to provide almost immediate aid to pilots in distress. Satellite photographs, available every 30 minutes, were used to determine if certain preferred mountain routes were open or blocked by weather, and to determine if a missing pilot could have flown over a storm or had to fly through the weather. The California wing of the Civil Air Patrol has been able to reduce most of its searches from an average of two weeks to two days by using satellite data. Also, satellite data enable SAR forces to avoid many of the hazards they normally would face during a rescue attempt.

The Coast Guard has been using both polar-orbiting and geostationary satellite data to find lost or disabled ships and aircraft. Wind velocities and directions, major ocean currents such as the Gulf Stream, low-level cloud cover and fog, and sea surface temperatures are carefully evaluated from satellite data. Using this material, NESS personnel can suggest to the Coast Guard the areas with the greatest potential for successful search and rescue operations.

*Determining Ocean Conditions.* NOAA has prepared a Program Development Plan and established within NESS a special project to coordinate research and applications of Seasat-A data. Seasat-A is a NASA oceanographic satellite scheduled for launch in 1978. Planned research includes experiments on surface winds, waves, sea surface temperatures, ice, tides, and geoid determinations, and a demonstration element directed toward applying Seasat-A data in near-real time to meteorology and oceanography.

NESS continues to sponsor development of techniques to use satellite data to measure ocean color and chlorophyll-a, an important chemical indicator of ocean productivity. These data will be obtained from a Coastal Zone Color Scanner to be carried on the Nimbus-G satellite.

NESS has developed a technique to improve the accuracy of sea surface temperatures (SST) derived from polar-orbiting satellite scanning-radiometer measurements. The calibrated Vertical Temperature Profile Radiometer (VTPR) water vapor channel (18.69 micrometer) data and SST data were used in new equations to produce tempera-

tures corrected for atmospheric absorption. To account for the amount of cloud cover, data from the VTPR 11.97- and 13.38-micrometer channels were applied to the uncorrected SST measurements to determine if the data were from clear, moderately cloudy, or heavily cloudy areas. The result of these modifications is a 40 percent increase in the number of reliable SSTs. Today, the SST field is derived solely from satellite data and is no longer dependent on climatology for estimates in data-sparse areas.

Infrared images from Goes 1 were used by NESS to produce time-lapse films of the Gulf Stream along the Florida coast. Northward propagating eddies were detected at the inshore edge of the current. A project was initiated to study the Gulf Stream deflection at 32° north. Satellite data were used to map the topography of the current in this area.

Investigations conducted during the Arctic Ice Dynamics Joint Experiment support the hypothesis that different sea ice types (multi-year, first year, etc.) can be determined from temperature distributions. Very High Resolution Radiometer data from the NOAA satellites were compared with aircraft infrared scanner data. Aircraft and satellite data sets show a striking similarity.

NOAA, NASA, and the Coast Guard conducted a joint remote-sensing ice reconnaissance experiment along the north coast of Alaska. A Coast Guard C-130 aircraft demonstrated the feasibility of observing ice conditions with a Side-Looking Airborne Radar. The ice data proved valuable to the barge operators resupplying Prudhoe Bay. In addition, the Anchorage Satellite Field Services Station supplied ice charts from satellite data for use by the barge and oil companies in their daily planning.

*Determining Lake Condition.* The NOAA Great Lakes Environmental Research Laboratory (GLERL) and NESS continued their studies of whittings (chemical precipitation of calcium carbonate). Comparisons of aircraft, ship, and satellite data show that whittings occur just below the lake surface in relatively warm water and are most evident in late summer following periods of upwelling. The whittings, which can continue for several months, serve as a tracer mechanism for assessing horizontal circulation in the Great Lakes, and also are useful in studies of carbon dynamics and the distribution of nutrients in the Lakes.

GLERL used Landsat and *in situ* data to detect sediment transport patterns to verify circulation models for western Lake Erie, Lake St. Clair, and the St. Clair River. Landsat data, used to study the influence of the spring runoff into Lake Michigan, show the shape of the river plumes in the Lake

and the distribution of sediment, carbon compounds, and nutrients.

GLERL used NOAA satellite data to monitor ice formation, growth, decay, and distribution on the Great Lakes. In addition, these data are being used to support ship operations, and for research on the geographical extent and physical properties of ice.

NESS has demonstrated that the Multi-Spectral Scanner data from the Landsat satellite can be used to assess the coverage of chlorophyll-a in the Great Lakes when concentrations exceed 10 micrograms per liter. Use of these satellite data enables scientists to obtain information on nutrient productivity and to describe surface current circulation.

*Determining Hydrological Conditions.* The NOAA geostationary satellites continued to play an important role in monitoring snow cover in United States and Canadian river basins. The number of snow basins mapped during the 1975-1976 winter season was increased to 22. Images from Goes 1 and SMS 2, every 30 minutes, increase the chances of obtaining a cloud-free view of the Earth. These geostationary satellite images are superior to polar-orbiting satellite data for delineating small bodies of water such as lakes and reservoirs. NESS hydrologists forward daily interpretations of snow cover conditions to the National Weather Service River Forecast Center in Kansas City. These data are used to forecast river levels and issue flood warnings and also are critical to irrigation planning, hydro-electric power generation, and reservoir regulation.

Snow and ice charts of the Northern Hemisphere, derived from satellite data from 1966 through 1975, were used by NESS to determine the extent of snow cover in Eurasia and North America. These analyses showed no significant overall increase in snow cover but larger fluctuations occurred in Eurasia than in North America. Using satellites to monitor worldwide snow cover provides important information on global temperature and albedo, each of which has an impact on hydrology, agriculture, and weather forecasting.

*Monitoring Agricultural Conditions.* In cooperation with the Great Plains Council, NESS is investigating the ability of geostationary satellites to gather insolation data. These data will be compared with data collected at ground test sites. Insolation is an important parameter in yield models for many Great Plains crops such as sorghum and wheat.

Noaa 4 satellite data were used in the development of a method to control locusts in southern Algeria. The U.N. Food and Agricultural Organization used Very High Resolution Radiometer images to locate rainfall areas and hence areas of

emergent vegetation. Algerian control teams examined these areas to determine if insecticide spraying was needed to inhibit the development of migratory swarms. This application of satellite data to locust control shows promise and may eventually be applied to the entire desert locust zone, covering about 31 million square kilometers from Dakar, Senegal, to Daccah, Bangladesh.

The Large Area Crop Inventory Experiment, a cooperative effort of NOAA, NASA, and the Department of Agriculture, is designed to develop technology to provide accurate and timely crop production estimates. Computer-assisted analyses of archived meteorological satellite data are used to develop mathematical models to relate weather to crop yields. In 1976, the Environmental Data Service Center for Climatic and Environmental Assessment developed mathematical models for Russia, Argentina, Brazil, Australia, and India and refined existing yield models for the United States and Canada.

*Fisheries Monitoring.* To help tuna and salmon fishermen find productive fishing grounds along the California coast, chart coverage was expanded during 1976 to include the area between the Strait of Juan de Fuca and Point Concepcion, California. These charts, based on Noaa 4 and 5 and SMS 2 images, depict the ocean surface thermal structure. They are produced by the San Francisco Satellite Field Services Station and transmitted experimentally to fishermen by NOAA's Sea Grant Advisory Agent. The National Marine Fisheries Service (NMFS) and Western Fishboat Owners Association transmit this information operationally by single-sideband radio.

In another effort to assist fishermen, the Inter-American Tropical Tuna Commission (IATTC), in cooperation with the NMFS Southwest Fisheries Center, correlated NOAA and Landsat satellite images with surface-truth data to determine the feasibility of using satellite data to identify upwelling areas and ocean frontal boundaries. Albacore migration in the eastern North Pacific has been found to be associated with ocean fronts.

NMFS, state agencies, and private industry demonstrated that the distribution of menhaden and thread herring can be inferred from Landsat Multi-Spectral Scanner data. A test conducted in July 1976 used color differentiation in Landsat images to determine high-probability fishing areas. Reports from the fishing industry indicated that most of the predicted high-probability fishing areas produced good fish yields.

*Environmental Monitoring Using Data Buoys.* The NOAA Data Buoy Office (NDBO) expanded its capability to acquire environmental data from oceanic areas by advancing data buoy technology.

In June 1976 the NDBO conducted a pilot data communication demonstration between a Pacific Ocean buoy and the World Meteorological Center, Suitland, Maryland, using the GOES satellite as a communications link instead of standard radio links. All NDBO meteorological buoys used this satellite communication link by the end of 1976. Marine meteorological information from data-sparse areas is obtained from deep ocean, continental shelf, and drifting buoys. The deep ocean buoys provide three-hourly data for national and international weather services. Continental shelf and drifting buoys provide environmental data to the scientific research community, offshore industries, fisheries, environmental protection groups, and recreational interests. During 1976, the NDBO had nine deep ocean and eight continental shelf buoys operating in the Atlantic and Pacific Oceans and the Gulf of Mexico. Over 80 drifting buoys were deployed in the oceans of the world.

## **Other Satellite and Space Applications**

### *International Cooperation*

*Sharing Data.* NESS expanded assistance in the form of satellite views of major disaster areas to the Office of Foreign Disaster Relief Coordinator of the Agency for International Development (AID), Department of State. This information was used to plan relief operations for and aerial photographic surveys of disaster areas, including earthquakes in Italy and Guatemala, floods in Nicaragua, Typhoon Pamela in Guam, and Typhoon Ruby in the Philippines.

The United States and the Soviet Union continued to exchange environmental satellite data in 1976. Russia received data from NOAA 4 and 5, and the U.S. received data from Russia's Meteor series. Russia launched Meteor 23, 24, 25, and 26 in 1976.

The National Weather Service, under the Voluntary Assistance Program of the World Meteorological Organization, has established Automatic Picture Transmission (APT) stations with improved satellite video capability in Ethiopia and Trinidad. These stations can receive data from both polar-orbiting and geostationary satellites, and are the prototype for eventual replacement of most of the older APT equipment.

*Demographic Studies.* The Bureau of the Census, under AID auspices, continued to support Bolivia and Kenya in the application of Landsat satellite data to demographic studies. The Census Bureau is aiding these countries in preparing maps for estimating population and land use.

The Census Bureau also continued to study the potential use of Landsat data in domestic census

activities. Negotiations have begun with NASA for an Advanced Systems Verification Test (ASVT) based on the results of studies in the Washington, D.C., and Austin, Texas, metropolitan areas. The goals of the ASVT are to develop an operational program for delineating urban fringe zones and to transfer this technology to the Census Bureau, and to implement a land-use information system to integrate 1980 census data with Landsat images for monitoring changes in the geographic structure of urban areas following the 1980 census.

### *Weather Modification*

The NOAA National Hurricane and Experimental Meteorology Laboratory (NHEML) expanded its use of satellite data in research on the modification of hurricanes and tropical convective clouds. Using geostationary satellite data, real-time estimates of rainfall from Atlantic Ocean tropical storms were made for the National Hurricane Center and the River Flood Forecast Offices of the National Weather Service.

NHEML also used satellite and aircraft data to construct sea surface temperature patterns in advance of and in the wake of eastern Pacific hurricanes. These measurements were used to calibrate satellite-determined temperatures used in the study of air-sea interactions in and near hurricanes.

### *Commercial Satellite Service*

The Maritime Satellite (MARISAT) consortium launched three satellites in 1976 to provide commercial satellite communication for ships. The satellites cover an area between 75° North and 75° South latitudes. Full service from Atlantic and Pacific Ocean satellites was initiated in August 1976, with Indian Ocean service begun by the end of the year. By reducing the time required to conduct ship operations, satellite communications have significant potential for improving ship safety and increasing cargo throughput, thus enhancing profits from merchant vessels. The Maritime Administration and six participating shipping companies are evaluating this new service, and the MARISAT consortium is providing no-cost support to this evaluation.

### *Determination of the Earth's Shape and Gravity Field*

The National Ocean Survey (NOS) Geodetic Research and Development Laboratory (GRDL) used NASA's Geos 3 satellite altimeter data to measure large-scale features of the Earth's gravitational field. A system was developed to handle data

from Geos 3 and the planned Seasat-A satellite. GRDL prepared plans to use Seasat-A data experimentally for computing precise satellite positions and for obtaining more accurate determinations of the geoid commensurate with the expected 10-centimeter precision of the Seasat-A altimeter.

NOS continued to evaluate the use of Lageos satellite laser observations and very long base-line radio interferometry to monitor temporal variations in horizontal and vertical positions, polar motion, and Earth rotation. One application of these methods is to provide more accurate information on the slope of mean sea level along the U.S. Pacific coast; the Sea Level Observation and Prediction Experiment has been initiated for this purpose. Another study showed that adding Doppler observations to a ground network improved the accuracy of horizontal positioning. Doppler satellite stations were established at 67 United States locations including 6 on offshore oil platforms.

### **Satellite Communications**

*Mathematical Modelling.* The Office of Telecommunications (OT) undertook the qualitative and quantitative description of electromagnetic transmission characteristics for satellite communications in frequency bands above 10 GHz. OT began the development of a mathematical model of atmospheric turbulence, terrain reflection, and ionospheric depolarization effects for satellite-terrain interaction.

*Propagation Modelling.* OT developed theoretical considerations for inclusion in a propagation model of space communication links, taking into account atmospheric time variants. These considerations include study of bandwidth limitations to electromagnetic transmissions imposed by clear air turbulence; the impact on the far-field of rainfall that occurs within the near-field of the antennas; prediction of radio frequency spectra for propagation through a random, complex, turbulent medium; atmospheric influence on the digital bit-error-rate above 10 GHz; and the transfer function of a gaseous, cloudy, and rainy atmosphere in the 10- to 40-GHz band.

*Small Earth-Stations.* Present-day communication satellites transmit a wide beam that covers the entire United States. The next generation of satellites will have higher power and narrower beams, which will focus on smaller regions of the country. This will permit the use of smaller, less expensive antennas on the ground. OT has begun a study of how to lower regulatory, technical, and economic barriers so that satellite communication systems

using low cost antennas may be made more readily available to public service institutions.

*Time Services.* The National Bureau of Standards (NBS) completed the development of a time code for the GOES Data Collection System; accuracy is within 100 microseconds and is available continuously from Goes 1 and SMS 2. NBS also developed an inexpensive decoding clock for use with the time code. This clock is capable of compensating automatically for the approximately 260-millisecond propagation delay between the Wallops Command and Data Acquisition Station and any point on the Earth's surface via the satellite.

*Lunar Ranging.* NBS continued to obtain new information by analysis of laser distance measurements to the Apollo retroreflectors on the Moon. Analysis of six years of lunar ranging data shows a negligible difference between the gravitational and inertial mass of the Earth. This demonstrates that the Earth's gravitational self-energy contributes equally to its inertial and passive gravitational mass. Analysis of data on the Earth's rotation, for which the estimated median accuracy of 194 single-day determinations of the Earth's angular position in space was 0.7 milliseconds, agreed closely with the expected 2-millisecond uncertainty of the 5-day averages obtained by classical techniques. Little evidence was found for very rapid variations in the Earth's rotation.

## **Space Support Activities**

### **Weather Support**

The National Weather Service (NWS) assisted Johnson and Kennedy Space Centers in preparing background and planning studies for the Space Shuttle flights. NWS also worked with the Jet Propulsion Laboratory in predicting potential weather effects on signals from the Mariner Jupiter-Saturn mission scheduled for launch in 1978. Weather support was provided to the Wallops Flight Center for its rocketsonde and atmospheric ozone measurement programs.

### **Solar Activity**

The Space Environment Services Center (SESC), operated jointly by NOAA and the U.S. Air Force, is the National and World Warning Agency for disturbances in space and the upper atmosphere. SESC provided forecasts and warnings of adverse effects of solar and geomagnetic activity to military command and control systems; scientists performing diverse experiments with balloons, rockets, and satellites; operators of communication satellites; the Federal Aviation Administration; electric

power utilities; and geophysical exploration groups. Interference with geosynchronous satellite operations by the type of geomagnetic storms that occur most often near solar sunspot minimum continued to be a frequent problem. The SESC uses data from a variety of space and terrestrial sensors, relying primarily on information from the SMS/GOES Space Environment Monitors, the NOAA 4 and 5 Solar Proton Monitors, and the NOAA-Air Force Global Flare Patrol network.

### *Space Processing Research*

NBS continued to support NASA's effort to develop the Space Shuttle as an orbital workshop for materials science. Data and instrumentation have been provided for designing and evaluating processing procedures to obtain materials of higher purity and more uniform properties. Studies are under way on the rate of preferential evaporation of impurities, growth from the melt of nearly perfect metal crystals, stable limits in floating zone systems, surface tension gradient forces, and vapor transport synthesis for improved processing of ionic materials.

### *Measurements and Calibrations*

NBS provides NASA with radiometric standards and calibrations from the infrared to the extreme ultraviolet region of the electromagnetic spectrum. Spectral irradiance standards, an electrically calibrated ultraviolet photodiodes were supplied to NASA investigators and contractors. The NBS synchrotron ultraviolet radiation facility is being used by NASA investigators to calibrate spectrometers and detectors.

NBS has extended the near-field measurement techniques for directive microwave antennas. This approach will be applied to large antennas used for satellite ground communication systems and for pre-launch assessment of the total performance of satellites using complicated multi-antenna configurations. The technique is very accurate for obtaining data on gain, pattern, polarization, and side-lobe levels for antennas associated with systems such as the Intelsat V and the Defense Satellite Communications Systems.

Studies also have been carried out to develop measurement techniques using radio stars to characterize the performance of large ground-based antenna systems. These techniques are used to measure the degradation of antenna gain for large operational antennas and to measure the Effective Isotropic Radiated Power (EIRP) of a satellite. The EIRP is an important measure of satellite performance and is used in determining incentive clause payments under contracts.

### *Cryogenic Measurements and Data*

NBS has pioneered in providing NASA with accurate data on the cryogenic fluids used as propellants and for life support and power generation systems. The initial data, needed in the design and operation of the Gemini and Apollo programs, are now being extended for use in the Space Shuttle program. NBS provides benchmark data on the properties of oxygen and hydrogen used by all NASA centers and their industrial contractors. Examples include data on the life support consumables aboard the Space Shuttle, design data for the Space Shuttle main engine, and data for the design of the New National Transonic Facility (cryogenic wind tunnel).

### **Space and Atmospheric Physics Research**

#### *Space Physics*

*Interplanetary Physics.* The NOAA Space Environment Laboratory (SEL) performed numerical simulations of the magnetohydrodynamic (MHD) solar wind stream interaction and shock propagation for comparison with data from several spacecraft. Skylab observations of the solar corona also were simulated with steady-state, nonradial flow models of MHD solar wind dynamics in the corona. The simulations produced information on the temperature and magnetic field in coronal holes.

As a result of a cooperative theoretical study with the University of Mexico, the viscous-like solar wind interaction observed by the Soviet spacecraft Venera is now well understood. The theory is especially applicable to Venus because of its weak magnetic field.

#### *Atmospheric Physics*

*Ionospheric Physics.* The ATS 6 geosynchronous satellite, moved to a location near India from July 1975 to August 1976, observed the seasonal and diurnal variations of equatorial ionospheric and plasmaspheric electron content. Indian scientists, in cooperation with Stanford Research Institute scientists, also studied the severe scintillation of ATS 6 satellite radio signals in equatorial regions. These scintillations affect satellite-to-ground telecommunications.

*Magnetospheric Physics.* On the basis of SEL analysis of Explorer 45 and ATS 6 data, it is now believed that portions of the Earth's radiation belt is composed of ions heavier than protons. A proposed theory is that many of the energetic radiation-belt ions, once believed to have originated from the Sun, actually originate from the Earth's ionosphere.

The analysis of rocket data taken over an auroral arc was used to describe the electrical currents that flow in the Arctic ionosphere. Results indicate that these currents are not necessarily strongest in the highest conducting portion of the ionosphere. Also, ionospheric winds may exert strong control of the currents flowing near auroral arcs and consequently may influence currents flowing in the outer magnetosphere.

*Atmospheric Photochemistry.* Carbon tetrachloride ( $\text{CCl}_4$ ) is one of the important chlorine-containing substances that diffuse from the Earth's surface.  $\text{CCl}_4$  absorbs solar radiation and decomposes in the stratosphere. NBS showed that under simulated stratospheric conditions, decomposition at lower wavelengths produces two chlorine atoms, as opposed to one chlorine atom at a high wavelength. The chlorine atoms released would be available to react with ozone, producing modifications of the stratosphere similar to those postulated for industrial chlorofluorocarbons. It has been demonstrated that the lifetime of  $\text{CCl}_4$  in the troposphere exceeds ten years. Assuming that no tropospheric sinks exist, then over 99 percent of  $\text{CCl}_4$  released at ground level will diffuse up to the stratosphere.

NBS determined the rate constants for the reaction of chlorine atoms with methane, ethane, methyl chloride, and methyl fluoride. This information is of current interest for the possible role that naturally occurring or man-made chlorine compounds might play in controlling ozone levels in the stratosphere.

NBS conducted studies of the reaction products of the interaction of ozone and olefins (unsaturated organic compounds) to determine the reaction mechanism in the troposphere. These data are useful in making worst-case predictions of the fate of ozone as a pollutant in the lower atmosphere.

#### *Atomic and Molecular Data*

NBS measures, compiles, and publishes data on atomic spectral lines and energy levels, atomic transition probabilities, and infrared and microwave transitions and molecular constants. These data are frequently used to interpret planetary, solar, stellar, and interstellar spectra. Data on atmospheric constituents such as nitrogen dioxide and ozone have been used to interpret upper atmosphere measurements obtained from telescopes and instrumented balloon flights. The microwave spectrum of chlorine nitrate was studied recently to aid in a spectroscopic search for this molecule in the upper atmosphere to determine if it can affect the chemistry of atmospheric ozone.

## **Data Programs**

### *Environmental Data*

*International Magnetospheric Study.* The World Data Center-A for Solar and Terrestrial Physics of NOAA's Environmental Data Service (EDS) established an International Magnetospheric Study (IMS) Central Information Office to gather and distribute information about IMS investigations. The IMS, scheduled from January 1976 through 1979, is a study of the structure, time change, and physical processes of the outermost parts of the Earth's atmosphere; emphasis is on simultaneous measurements by groups of satellites and includes complementary experiments and monitoring by rockets, balloons, aircraft, and ground-based sensors.

*Satellite Rainfall Estimates.* Scientists at the EDS Center for Experiment Design and Data Analysis (CEDDA) are cooperating with NASA's Goddard Space Flight Center, the University of Wisconsin's Space Science and Engineering Center, and NOAA's National Hurricane and Experimental Meteorology Laboratory to evaluate and calibrate techniques for using visible, infrared, and microwave satellite data to estimate rainfall over tropical ocean areas. The program is based on very accurate precipitation estimates derived by CEDDA scientists from shipboard digital radar data for a 125,000-square-kilometer area over the eastern tropical Atlantic, collected as part of the Global Atmospheric Research Program's Atlantic Tropical Experiment.

## **Aeronautical Programs**

### *Aeronautical Charts*

Concern for the environment together with the sustained growth of air traffic have added to the complexity of managing the national airspace. Consequently, the National Ocean Survey has introduced new aeronautical charts and products to keep pace with increased requirements. In addition to the continuous maintenance of existing charts, chart services for video maps, instrument approach procedures, and terminal areas were expanded and disseminated to airspace users and controllers. Also a prototype Alaska Planning Chart was developed and submitted to the Federal Aviation Administration for evaluation by the Alaska region.

### *Use of Sensor Data from Aircraft*

*Outer Continental Shelf Studies.* The NOAA Outer Continental Shelf Environmental Assessment Program scientists used remote-sensing data from the Landsat and NOAA satellites and aircraft data

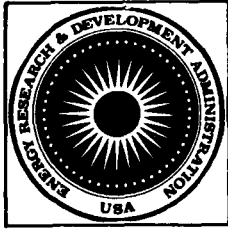
obtained by the Cold Regions Research and Engineering Laboratory, the National Ocean Survey, and the Environmental Research Institute of Michigan to conduct scientific investigations in the Arctic. Side-looking airborne radar and thermal infrared images were used to study large scale geological features and ice activity along the Arctic coast. Low-level optical color and color-infrared images of the western Alaskan coast from the Yukon Delta to Cape Lisburne were used to assist in mammal and bird inventories, habitat studies, and geological investigations. Low-level, high resolution data from a multi-spectral scanner and color mapping camera were compiled to support inshore ecological studies in the northwest Gulf of Alaska.

*Safety Services for Aeronautics.* The NOAA National Severe Storm Laboratory (NSSL) used data from a 460-meter instrumented tower, closely spaced surface weather stations, aircraft, and Dual-Doppler radar to measure the outflow regions of thunderstorms for development of an improved three-dimensional gust-front model. The multi-observational system measures both horizontal and

vertical wind shear, the distribution and strength of up and down drafts, and turbulence, all of which can be hazardous to aircraft. NSSL also made Single-Doppler radar measurements of low-level wind shear in clear air as part of a continued effort to develop the use of pulsed-Doppler radar for flight safety.

The Atmospheric Physics and Chemistry Laboratory continued development of an infrared, water-vapor band, clear air turbulence radiometer. Tests conducted aboard NASA's C-141A aircraft directed the radiometer forward at an elevation between 7° and 22° above the horizon. These tests gave from 4 to 14 minutes of advance warnings of clear air turbulence.

NBS assisted the Federal Aviation Administration in a study of factors that control the vertical separation of aircraft. A mathematical model of the height-keeping process was developed; the model includes principal measurements, equipment, information flow, and control logic. The results of the study will be used to set vertical separation standards for safer and more efficient air traffic control.

**V**

# Energy Research and Development Administration

## Introduction

The Energy Research and Development Administration (ERDA) has a significant role in numerous missions in the nation's space program. Through its Office of Space Applications in the Division of Nuclear Research and Applications, ERDA provides essential mission support, including the development and production of nuclear electric power generators and specialized component heaters. By efficient transfer of isotope decay heat to sophisticated thermoelectric converters, a long-life, reliable energy supply is made available for spacecraft navigation, operations, telemetry, scientific studies, and analysis, as well as for transmission of televised pictures of planetary surface detail. Also, in 1976 ERDA's Division of Solar Energy acquired a new space-related mission when the responsibility for studying Satellite Power Systems was transferred from NASA to ERDA.

## Support to Space Programs

### *Apollo Lunar Surface Experiments*

The Apollo Lunar Surface Experiments obtained and transmitted data on Moon temperature and gravity, seismic activity, and meteorite impact. Radioisotope heaters were required to maintain operating capability of the solar-powered instruments during the extremely cold lunar nights. These units are still operating effectively.

### *Pioneer Missions*

The Pioneer 10 spacecraft, launched in March 1972, which performed close-up studies of Jupiter and its moons, now is more than one and one-half billion kilometers from Earth, on its way out of the solar system. Its mate, Pioneer 11, was launched in April 1973, and after a Jupiter fly-by was targeted for Saturn encounter in 1979. Both units are supplied over 120 watts of radioisotope power for their overall electrical requirements, and continue regular data transmission to Earth.

### *Viking*

The Viking Mars Landers, which were deployed on the surface of the red planet on July 20 and September 4, 1976, have pursued their assignment of characterizing the Martian surface, atmosphere, and weather conditions, and of performing numerous experiments in the search for vestiges of life or life-related materials. Today, the precise detail of Viking landing sites on the plains of Chryse and Utopia are as familiar to the television viewing public as were the presumed canals of Mars to astronomers. Space nuclear power sources provided power for this striking achievement.

### *Lincoln Experimental Satellites*

The Lincoln Experimental Satellites, launched for the U.S. Air Force in March 1976, carry new and more powerful generators to supply a minimum of 250 watts on each of two units for a duration of five years or more. Communications between satellites and from satellites to Earth over this interval will be used to demonstrate and evaluate performance, reliability, and survivability of such systems in a hostile environment.

### *Mariner Jupiter/Saturn*

The Mariner Jupiter/Saturn (MJS) spacecraft, to be launched by NASA in August and September 1977, will continue and extend outer-planetary exploration into the farther reaches of the solar system. Building upon the experience gained in prior missions, NASA and ERDA anticipate improved performance and reliability as well as an expanded scope of scientific data retrieval for this mission. Each of the two spacecraft will be powered by three radioisotope generators to supply a total of at least 450 watts initially, to satisfy all electrical energy requirements.

Following interplanetary flights, the MJS spacecraft will make near-equatorial passes of Jupiter on trajectories to Saturn, approximately 1.3 billion kilometers from Earth. The scientific objectives of the MJS 1977 mission are to conduct exploratory



investigations of the Jupiter and Saturn planetary systems and the interplanetary medium out to Saturn and to return these data to Earth for analysis. Both spacecraft will escape the solar system following the Saturn encounter.

To ensure operational capability of a variety of data sensors and devices in the deep cold of outer space, 21 one-watt thermal heater units will provide local warmth in a number of sensitive areas of each MJS spacecraft. These, too, are fueled with Pu-238 radioisotope for compactness, reliability, and long operating life.

The radioisotope thermoelectric generators (RTGs) discussed above were developed and produced by the ERDA laboratory and industrial contractors' organizations. During the year, five of the seven multi-hundred watt generators and all of the radioisotope heater units were produced, with the balance of two flight units to be delivered early in 1977. In addition, numerous test units were prepared and evaluated in detail, in support of safety assessments.

### *Development*

The trend toward higher power, improved performance, and greater reliability at reduced cost is accompanied and supported by technology development in both static thermoelectric and dynamic generator systems. By application of novel selenide thermoelements in static converters, efficiency of power output is expected to rise to 10 to 14 percent,

essentially double that of the Pioneer, Viking, or MJS generators. The competition begun in 1975 for the Brayton and Organic Rankine Cycle dynamic power systems and culminating in ground demonstrations in 1978 is expected to produce further improvement, to an efficiency of 20 to 25 percent.

The static isotope systems are expected to deliver up to 500 electrical watts over their mission lifetime, whereas the dynamic isotope systems should supply one to two kilowatts.

### **Satellite Power Systems**

Satellite Power Systems (SPS) in geostationary orbit, which convert solar energy to microwave energy for transmission to Earth and ultimate use as a terrestrial energy source, were first suggested in 1968 and have been under study by NASA. In the FY 1977 budget, the responsibility for this endeavor was transferred from NASA to ERDA. To meet this new responsibility, the ERDA Administrator established a task group on SPS to review the NASA work and recommended an ERDA policy position and program. This group was formally appointed on March 15, 1976, provided an interim report to the Administrator on June 24, a final briefing report on August 12, and a final draft report in September.

The Division of Solar Energy within ERDA presently has the task group recommendations under review.



## Introduction

The Department of the Interior is responsible for the Nation's public lands and for maintaining a balance between the use and conservation of natural resources on these lands. Effective resource management and research require accurate and timely data, whether collected on the ground, from high- or low-altitude aircraft, or from satellites. In some investigations data from more than one level of observation and from various sensors such as multispectral scanners, cameras, and radars can be useful. To collect data, the Department relies on aircraft for acquiring aerial photography, carrying experimental airborne instruments, and executing programs such as selection of utility corridors, cadastral surveys, and resource inventories.

The need for surveying and repetitive monitoring of vast and often inaccessible areas has also created a growing interest in the Department in satellite data, primarily from the experimental Landsat system because of its synoptic, repetitive, and uniform coverage. Digital Landsat data have made possible the extraction of information by computerized techniques. Because of the flexibility that digital data offer in collecting and managing large volumes of information, resource managers in some bureaus of the Department are incorporating this new technology into their activities.

### Earth Resources Observation Systems Program

The purpose of the Interior Department's Earth Resources Observation Systems (EROS) program is to develop, demonstrate, and encourage applications of remote-sensing data acquired from aircraft and spacecraft which are relevant to functional responsibilities of the Department. The primary areas of activity are:

- 1) applications demonstration and research
- 2) user assistance and training
- 3) data reproduction and dissemination.

The key facility of the EROS program is the EROS Data Center (EDC) in Sioux Falls, South Dakota, the principal archive for remotely sensed

data collected by U.S. Geological Survey (USGS) aircraft, by National Aeronautics and Space Administration (NASA) research aircraft, and by Landsat, Skylab, Apollo, and Gemini spacecraft. Training and user assistance in applying remote-sensor data are also major functions of EDC.

To facilitate regional applications, the EROS program operates seven Applications Assistance Facilities where the public may view microfilm of imagery available at EDC and receive assistance in searching and ordering data via computer terminal link to the central computer complex at EDC.

### *Applications Demonstration and Research*

The objective of this activity is to demonstrate and document applications of remote sensing to significant resource and environmental problems, with emphasis on the use of NASA and National Oceanic and Atmospheric Administration (NOAA) satellite data. Results indicate that remote sensing is a potentially useful tool for resource and environmental problem solving. Eighty-five experiments on the application of Landsat data to Earth resource mapping, monitoring, and inventory were published in 1976 in USGS Professional Paper 929 entitled *ERTS-1, A New Window on Our Planet*. Ninety-two authors from the USGS, other Interior Bureaus, NOAA, U.S. Army Corps of Engineers, and several universities contributed to the 362-page illustrated report.

### *User Assistance and Training*

Technical training programs at EDC range in length from a few days to one month and stress the use of remotely sensed data for particular applications such as forest inventories or mineral exploration. As an adjunct to formal courses, EDC operates a Data Analysis Laboratory which contains state-of-the-art analysis equipment such as interactive computer systems for the analysis of digital Landsat and aircraft data, as well as densitometers, additive color viewers, zoom transfer scopes, and stereo viewers. Experienced machine operators and resource scientists provide technical assistance to new users.

The Sixth and Seventh International Remote Sensing Workshops, each of 4 weeks in length and stressing the fundamentals of remote sensing, were held at EDC in 1976. Since 1973, 160 scientists from 53 countries have attended this series. In response to continued high interest, two more workshops are scheduled for 1977. In addition, the EROS program presented short courses during 1976 in Saudi Arabia, Somalia, Ethiopia, Argentina, and Turkey.

During 1976, more than 30 workshops were conducted for resource managers from various Federal and state agencies. Personnel trained included representatives from the Bureaus of Land Management, Reclamation, Mines, and Indian Affairs, and the Fish and Wildlife Service of the Department of Interior; Forest Service of the Department of Agriculture; the Army Corps of Engineers and the Defense Mapping Agency of the Department of Defense; the Atlanta Regional Commission, North Dakota State Water Commission, and the Pacific Northwest Regional Commission. In total, approximately 500 domestic resource scientists and land managers participated in these workshops.

Cooperation among the Pacific Northwest Regional Commission, NASA, USGS, and the states of Idaho, Oregon, and Washington, demonstrates multidisciplinary assistance. After training periods at EDC and Ames Research Center, resource managers from the three states completed maps and overlays displaying soils, land use and ownership, drainage, and energy features.

#### *Data Reproduction and Distribution*

Photographic reproductions and magnetic computer tapes are processed and distributed and other services are provided by EDC to domestic and foreign users at prices which will be raised to amounts equal to the full cost of labor and materials. To improve the quality of Landsat data products and shorten delivery time to users, a digital image processing system is being installed at EDC. As of June 30, 1976, there were over 6.5 million images in the data base, including over 800,000 frames of Landsat images and Landsat data in the form of computer-compatible tapes. Aerial and space imagery holdings increased at an average rate of 38,000 frames per month, of which 20,000 were Landsat imagery.

The demand for reproductions increased rapidly in 1976. In Fiscal 1976, EDC distributed 26 percent more frames of Landsat imagery than in 1975, but in addition, sales of computer-compatible tapes increased from 729 to 2289, an increase of 213 percent. This indicates an increased trend toward use of digital processing of Landsat data by users. Landsat and other satellite products constituted 70 percent of the \$2,464,554 value of data produced by

EDC during Fiscal 1976. Among the customers, private industry was the largest single purchaser with 22 percent of the total dollar value; followed by agencies of the Federal government with 21 percent; non-U.S. customers, 17 percent; NASA principal investigators, 16 percent; academia, individuals, and state and local government agencies accounted for the remainder.

#### **Remote Sensing Activities Using Space Data**

##### *Viking Mission to Mars*

The USGS provided scientific leadership and extensive technical support for the Viking mission in the following areas: mission planning, orbiter and lander imaging, geologic interpretation, landing-site selection, and analyses of geochemistry and physical properties of the surface materials. Geologic interpretations and topographic maps made from pictures taken by the Viking orbiters were used to select and certify safe and scientifically significant sites for the two Viking landers.

##### *Other Planetary Studies*

USGS support of other planetary exploration includes analysis and synthesis of data from the Moon, Mars, and Mercury and participation in planning and design of future missions to Mars, Venus, the Moon, and the moons of Jupiter and Saturn. The USGS seeks to ensure that exploration of the solar system will contribute a maximum to the understanding of geologic phenomena. Comparison of geologic materials, processes, and history of the other planets with those of the Earth provides new insight on the development of the Earth's crust and on processes that affect land, mineral, and energy resources.

##### *Geology*

Magnetic data from the Polar Orbiting Geophysical Observatory (POGO) series were compiled by USGS scientists to show the gross worldwide magnetic character of the Earth's crust. The detection of the Bangui magnetic anomaly in POGO data of central Africa led to field investigations of the region to determine the extent of ferromagnetic and associated minerals. The need for a magnetic model of the Earth prompted NASA to begin planning a new satellite, Magsat, to map the Earth's magnetic field from low orbit.

USGS studies of thermal infrared emission and of microwave scattering and emission are expected to provide a basis upon which to interpret the data from the Heat Capacity Mapping Mission satellite

and from the radar on board the Seasat satellite, both scheduled for launch in 1978.

USGS geologists are interpreting linear and curvilinear features as seen on Landsat mosaics of the U.S. produced by the Department of Agriculture in cooperation with NASA. The initial interpretation is being repeated independently by several scientists to assess the level of confidence in the results. The close relationship of some of these features to occurrences of minerals, petroleum, geothermal sources, and seismic events is being investigated.

In an investigation in the Nabesna quadrangle, Alaska, large linear features too long to be recognized on conventional aerial photographs have been correlated with known mineral deposits. Computer interpretations of enhanced images suggest that 56 percent of all known metallic mineral occurrences in this quadrangle lie within approximately 1 mile of Landsat-identified linear features. About 70 percent of the known mineral occurrences in the study area appear as color anomalies on computer-enhanced Landsat imagery.

### *Cartography*

In using the advantages of space systems in the national mapping program, the USGS has continued to produce experimental cartographic products from Landsat and Skylab images. A second experimental edition of the satellite image map of Upper Chesapeake Bay was compiled from a Landsat image enhanced by IBM Corporation using computer processing techniques. In cooperation with the state of Georgia, a 1:500,000-scale satellite image mosaic of the state was published, incorporating 14 Landsat images. Landsat image maps of selected areas of Antarctica have been printed at scales of 1:250,000; 1:500,000; and 1:1,000,000. Skylab pictures were mosaicked to compile a 1:250,000-scale gridded photomap of the Hartford quadrangle (1° by 2°), which covers most of Connecticut.

Analyses of the ability of Landsat wavebands to penetrate shallow water, conducted in cooperation with NASA and the Defense Mapping Agency, demonstrated that large underwater reefs and bottom details could be located to depths of 22 meters under very favorable conditions. Analysis of satellite images taken at night revealed that concentrations of light flux indicate population centers and the locations of gas and oil fields where gas flaring is practiced. Experiments with mirrors for identifying the location of control points on Landsat images have been continued.

### *Land Use Analysis and Mapping*

Research has been completed on applying Skylab imagery and data to land-use mapping and

related resource problems in the Central Atlantic Regional Ecological Test Site and in the Census Cities Projects. These efforts indicate that several Level II subdivisions of categories of land use and land cover, such as *residential*, of the Level I category, *urban and built-up areas*, and some Level III subdivisions such as *single-family residential* of the Level II category, *residential*, can be obtained from the Skylab photography in sufficient detail to be useful for state or regional planning purposes.

### *Hydrology*

The USGS has continued to research applications of Landsat imagery to the study of ground-water hydrology. The USGS, in cooperation with the Soil Conservation Service, has used Landsat digital tapes to prepare 15 quadrangle maps that depict hydrologically related land-cover categories covering 1000 square kilometers of the New River Basin, Tennessee. The maps were used to select sub-basins for intensive study as part of a 5-year energy development program to evaluate the impact of strip mining on hydrologic processes involving geomorphology and water quality (especially sediment). Results of the New River study will be used as the basis for analysis of other drainage basins of the region.

The USGS has broadened the scope of evaluating satellite Data Collection Systems (DCS) as a potential operational hydrologic monitoring tool. For several years data-transmitting radios have been tested through the Landsat DCS, and in 1976 they were tested through the NOAA Geostationary Operational Environmental Satellite (GOES) DCS. USGS and COMSAT General Corporation will conduct a 6-month demonstration of a DCS in 1977 using an existing geostationary commercial communication satellite integrated with USGS sensor networks and computer facilities to simulate operational data collection.

### *Water Management*

To develop techniques and procedures for operational use in water-resources projects, the Bureau of Reclamation is using digital analysis of computer-compatible tapes to inventory the total surface water area on the Columbia Basin Project.

The Bureau of Reclamation is also cooperating with the Soil Conservation Service in a project sponsored by NASA to monitor the extent of mountain snow cover to aid in runoff forecasting.

Under the High Plains Cooperative Program, a Landsat data collection platform is being used to relay data from several remote rain gages. NOAA's GOES satellite is being used to collect cloud photo-

graphs in near-real-time, which are then used to direct aircraft to cloud formations most promising for seeding. GOES is also being used as a data relay platform.

### *Sea Ice*

USGS scientists are cooperating with other agencies in ice dynamics and energy-release studies using data from near-polar orbiting satellites. Data from ground sensors and aircraft are also utilized.

### *Land Management*

The need to collect and handle large quantities of information concerning the National Resource Lands has committed the Bureau of Land Management (BLM) to a program of information systems management. A strategic long-range plan which will adopt the latest in automatic data processing and remote-sensing technologies has been put into effect.

### *Surface Mining*

A pilot study using Landsat computer-compatible tapes to identify active and inactive kaolin surface mines in Aiken County, South Carolina, was undertaken by Bureau of Mines, EROS, and various state agencies in assessing Landsat technology. Digital area calculations from the Landsat data were compared with planimetric calculations of the same areas. Accuracies over 99 percent were achieved when comparing areas of over 360,000 square meters, whereas approximately 88 percent accuracy was achieved in comparisons of 72,000-square-meter sites using low-altitude photographs. Mining areas disturbed over a one-year period were also calculated using Landsat imagery taken one year apart.

### *Wildlife Management*

Contract research was begun through the Western Energy and Land-Use Team of the U.S. Fish and Wildlife Service to define, in quantitative terms, the utility of digitally processed Landsat imagery.

The Migratory Bird Management Office of the U.S. Fish and Wildlife Service used data from Landsat and the very high resolution radiometer on NOAA's Tiros to monitor the melting of the lake ice in the Canadian arctic and thereby predict nesting success and game production of Arctic geese.

### *Natural Resource Information System (NRIS)*

Bureau of Indian Affairs (BIA) has delivered a final report to the northwest Indian tribes showing

forest cover classification from automated interpretations of original Landsat digital data.

### *PEACESAT Project*

The Pan Pacific Education and Communication Experiments by Satellite located at the University of Hawaii operated 18 hours a week to provide education and social communication experiments to 14 Pacific territories and countries utilizing NASA's ATS 1 satellite.

### *Remote Sensing Activities Using Aerial Data*

#### *Wetlands Mapping*

Remotely sensed data, primarily color infrared aerial photographs, are being used by the USGS in several departmental and interagency research projects on wetlands hydrology, classification, delineation, and mapping.

#### *Wildlife Management*

The Northern Prairie Wildlife Research Center, U.S. Fish and Wildlife Service, is assessing the utility of aircraft and spacecraft data for defining continental migratory bird habitats.

#### *Aeromagnetic Surveys*

Aeromagnetic surveys show distribution of rocks potentially related to mineral deposits. During 1976, the USGS used aircraft for 114,000 traverse kilometers of aeromagnetic surveys in the Eastern Coastal Plain, 18,000 traverse kilometers in Alaska under the minerals program, 18,000 traverse kilometers in Arizona and New Mexico for BIA, 6400 traverse kilometers off the California coast under the reactor hazard program, and 5300 traverse kilometers for a geological investigation of the state of Washington, as well as 1600 traverse kilometers of gamma ray and aeromagnetic surveys under the uranium program.

#### *Airborne Experimental Instruments*

USGS aircraft were used during field studies associated with various experimental instruments, including a multichannel infrared scanner, microwave and infrared radiometers, an airborne resistivity system, and a Fraunhofer line discriminator.

#### *Aerial Photography and Radar*

In 1976, the USGS contracted for more coverage by aerial photography for the national mapping program than ever before—1,350,000 square kilometers, 10 percent more than in 1975. More than

75 percent consisted of high-altitude, quad-centered photographs for support of orthophotoquad production as well as for aerotriangulation and other photogrammetric applications.

### *Hydrologic Studies*

The USGS, in cooperation with various state and Federal agencies in Arizona, used low- and high-altitude aerial photographs and orthophotoquads in flood-hazard mapping, geologic and ground-water reconnaissance studies, and snowcover distribution analyses. Orthophotoquads, prepared from aerial photographs of south Florida, are similarly being used in hydrologic studies.

### *Ice Studies*

In cooperation with other agencies, the USGS conducted Arctic sea-ice dynamics and energy-release studies. The energy exchange is primarily through open-water leads in the ice, and passive and active microwave (all-weather) data from NASA's Convair 990 aircraft are used to identify open areas.

### *Vegetation Studies*

Aircraft were used extensively for data collection, cloud seeding, and observation in the Bureau of Reclamation's High Plains Cooperative Program, which is developing precipitation management techniques to increase rainfall from summer showers, of great importance to agriculture in the Great Plains.

Aircraft were used to obtain multispectral scanner imagery of a portion of the Colorado River between Arizona and California for an inventory of riparian vegetation and for archeological surveys. The data are being retained on tapes for computer analysis or generation of film products.

BIA agreements with NASA and USGS to obtain high-altitude photography over all Indian reservations continued in effect, with 95 percent of the

photography acquired. The orthophoto base mapping, for which the photography is used, is now 70 percent complete.

### **National Cartographic Information Center**

The National Cartographic Information Center (NCIC), a facility of USGS located at Reston, Virginia, is a focal point for information on aerial photography and cartographic data from Federal, state, and private organizations, as well as data collection plans of those organizations. The Aerial Photography Summary Record System, an automated system to catalog most U.S. aerial photography planned, in progress, and completed, is now operational. The archive at EDC is a major component of NCIC.

### **International Activities**

The USGS participates in an expanded program of scientific cooperation with other countries, including long-range technical assistance programs. In 1976, the Office of International Geology of USGS met with representatives of more than 20 countries to discuss applications of satellite and aerial remote sensing data in support of natural resource studies, development projects, and environmental protection programs. These discussions were both technical and administrative, and included the exchange of scientific knowledge as well as technology transfer and technical assistance.

The USGS will lead a new project, "Remote sensing and mineral exploration", which has been approved as part of the International Geological Correlations Program (IGCP). The IGCP is jointly sponsored by the International Union of Geological Sciences and UNESCO. A U.S. National Committee of 20 representatives of Federal and state governments and university and industry groups has been formed to work with international participants to identify features related to mineralization.

# VII



# Department of Agriculture

## Introduction

The U.S. Department of Agriculture (USDA) has a continuing interest in improving its agriculture activities dealing with crops, forests, range and wildlife management, soil surveys, watershed management, land use classification and management, environmental protection, outdoor recreation, and man-environment interactions. As one of the steps in meeting its responsibilities, the USDA in 1976 continued to develop and evaluate the use of aerospace remote sensing technology as a means of more accurately and in a more timely fashion

- (1) improving the inventorying and quantitative predictions of the food, feed, and fiber resources of the U.S.
- (2) evaluating land productivity
- (3) monitoring changes affecting the total production and quality of our resources and environment.

## Remote Sensing Activity

Recognizing that aerospace remote sensing offers a means toward the improvement of many USDA functions, the Department continues to seek technically feasible and economical remote-sensing systems that are effective for inventorying, protecting, and managing our agricultural, forestry, and wildlands resources. The following represent a number of significant developments and applications during 1976 using remote-sensing techniques:

### *Research and Development*

The Agriculture Research Service (ARS) is developing a practical method for more accurate assessment of the water status of crop plants by remote measurement of plant canopy temperatures concomitant with air temperatures, using infrared scanners. More precise plant-water stress data would improve crop yield predictions and also improve the scheduling and amount of irrigation.

The ARS is also completing a system of computer-aided operations that will provide agricultural crop and soil surveys and delineate growing

conditions, using Landsat and other sources of digital spectral data. Spectral categories can be related to crop yields, plant maladies, environmental stresses, and growing conditions. The system has been modified and tested by periodically classifying the crop and land uses in a 3900-square-kilometer county that has diverse agricultural enterprises.

Functionally independent physiological and spectral models developed at Temple and Weslaco, Texas, are being tested by ARS to determine how well the output from each augments and cross checks the predictions of the other. Data sources and procedures are amenable to eventual deployment of such models for improving crop condition information and yield estimates for extensive areas, such as the Great Plains.

The proximity of Mediterranean fruit fly infestations in Guatemala provides a sense of urgency in establishing a barrier zone that will prevent this serious pest from moving up into the major fruit producing regions of Mexico and ultimately the U.S. ARS is determining the density and distribution of host plants of the Medfly in the Isthmus of Tehuantepec by means of aerial color infrared photography.

Recognizing its need for a dedicated remote sensing research airplane, the ARS recently acquired a Cessna 182J high-wing aircraft outfitted with a turbo-charged system, short take off and landing conversion capability, an autopilot with altitude hold, radio and navigational equipment (including a transponder with an encoding altimeter), a closed-circuit television system for accurate mapping, and aerial cameras. While in the photographic mode the airplane will carry two persons, one an ARS pilot-photographer.

### *Applications*

The Forest Service-NASA cooperative Forestry Applications Program (FAP) completed its pilot project on 6500 square kilometers of East Texas "flatwoods" land. The two specific objectives were accomplished and are documented in a Johnson

Space Center publication (JSC-1143). Computer-aided Landsat data classification procedures for inventorying forest and rangeland by administrative boundaries were developed and tested. Procedures were developed and tested also for using a sampling approach to inventorying and evaluating results of computer-aided automatic analysis of Landsat data. As part of the Forestry Applications Program's interest in large-area multi-resource inventory, FAP is now testing and modifying its procedures for use in 10 major ecosystems throughout the continental U.S.

Public Law 93-378, the Resources Planning Act of 1974, requires that the Forest Service prepare a natural resources assessment. This assessment is to be updated in 1979 and after that on a 10-year cycle. The Forest Service Resource Evaluation Techniques Program has been established in the Rocky Mountain Forestland Range Experiment Station to develop the procedures for updating the assessment. Since there are approximately 6,500,000 square kilometers involved, aerospace remote sensing is expected to play a significant role in gathering information. The Resources Evaluation Techniques Program is coordinating with FAP to develop remote sensing procedures applicable to the Resources Planning Act requirement.

Large amounts of timber have been killed by insects and disease in the National Forests of the Rocky Mountains. The Forest Service is using aerospace remote sensing techniques to assist in the dead timber assessment. The study area covers 26,000 square kilometers and will be put onto a cartographic base of 7.5' quadrangle sheets.

The Economic Research Service (ERS), in cooperation with the Department of Natural Resources, Cornell University, has completed a study of land-use change (1961-1970) in 53 rapidly urbanizing counties distributed over the continental U.S., using airphoto interpretations. Inventories comprising 7 rural and 5 urban categories of land use were developed for 1961 and 1970; and changes among the 12 categories were identified and quantified. An April 1976 bulletin, "Dynamics of Land Use in Fast Growth Areas" reports the results of the study. ERS and Cornell will use Landsat imagery to identify cropland development in 130 sample countries in the Southeast and Great Plains.

A unique application of remote sensing as applied to an operational problem is the Soil Conservation Service's (SCS) snow telemetry (SNOW-TEL) system that is being installed in the 11 Western states. Remote sensors to measure snow and related information (temperature, precipitation, wind, etc.) have been installed at 260 high mountain sites. A communication system, utilizing the meteor-burst phenomenon for transmitting the

radio signal from the site to its point of use, is expected to be operational in early 1977. This new system, which partially replaces a manual network that has been in operation nearly 40 years, will provide near-real-time data to SCS field offices for use in developing improved water supply forecasts and reservoir operation, primarily for agricultural purposes.

The SCS is also testing the use of Landsat imagery to interpret the extent of snow cover and its changes throughout the snow accumulation and melt season for selected river basins in Colorado. This information, combined with the near-real-time snow data, will be used to determine whether the accuracy of water supply forecasts can be significantly improved.

Use of aerial black and white and false color infrared photography provided by the states and ranging in scale from 1:15,840 to 1:48,000 is being evaluated by SCS for selected areas in Illinois and Minnesota as a tool to accelerate the soil survey and to improve the quality of mapping.

The Rural Electrification Administration has funded two projects utilizing Landsat imagery for locating transmission-line corridors and alternative routes, as well as for developing environmental data for locating plant sites.

The Agriculture Research Service (ARS) has determined that high resolution thermal data from satellites, such as NOAA 4, SMS 2, and Defense Meteorological Satellites, can identify local variations in surface temperature across the Lower Rio Grande Valley of Texas. Practical application of the information was tested by relating the severity of sugarcane freeze damage to satellite-indicated temperatures for 45 commercial fields. Average sugar content in these fields was found to be related more closely to the satellite-indicated temperatures of the fields than to air temperatures extrapolated for those fields from ground observations.

ARS used Landsat multispectral digital data from a December 11, 1973, overflight to estimate the sugarcane acreage in Hidalgo County, Texas. The computer-aided estimate was 89 square kilometers compared with the Texas and Livestock Reporting Service estimate of 82 square kilometers for the 1973-1974 crop year. Although there were errors of omission—harvested fields that were identified as base soil and some citrus and native vegetation that were mistakenly identified as sugarcane—the mapped location of the sugarcane fields in the county compared favorably with their location on the thematic map generated by the computer.

ARS has also found that areas of cotton root-rot can be readily delineated on aerial photographs,

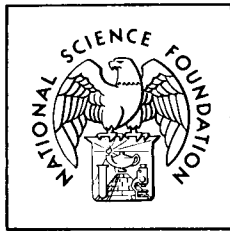


and the acreage so affected can be accurately determined by optically planimentering the photographic transparencies. Because chemical control with a commercial fumigant is costly, the photographs can reduce costs considerably by guiding the applicators to only those portions of fields that are affected.

The spread of the imported fire ant throughout the southeastern U.S. and along the Gulf Coast from Florida to Texas has become a major concern to agricultural interests and the general public. Currently, fire ant infestations are spread over 510,000 square kilometers. Present ground surveys cover only 2 percent of the infested area and are very costly. The ARS has found that aerial color infrared photography is a useful tool for establishing the location, number, and size of fire ant

mounds within an area at a much lower cost and with 80 percent accuracy.

The walnut caterpillar has been defoliating pecans over large areas in south-central and east Texas. The most widespread activity and subsequent defoliation occurred in August 1973, over some 78,000 square kilometers. Subsequent defoliation has been associated primarily with recurrent infestations in the area originally affected. Investigation of walnut caterpillar defoliation has resulted in the development of techniques by the ARS to identify pecans in mixed-tree native stands in south-central Texas through the use of aerial color infrared photography. This capability should be of value to the pecan industry in identifying total acreage for potential pecan production, and in locating pecans that may be endangered by exogenous insects.



### Introduction

The National Science Foundation, the only Federal agency with the express mission to advance basic scientific knowledge, supports research in several areas related to aeronautics and space science. The majority of this research is in astronomy and atmospheric sciences, which benefit substantially from the work done by staff and visitors at the NSF-supported National Research Centers.

### Astronomy

#### *General*

The need for both ground-base and space observing in astronomy is dictated by the varying ability of photons at different wavelengths to penetrate the Earth's atmosphere. The atmosphere is more or less transparent to visible light and longer wavelengths—millimeter, radio, and some infrared. It is, therefore, economically and technically possible for astronomers to use large, sophisticated instruments for ground-based observing at these wavelengths. But because x-rays and ultraviolet photons are absorbed by the atmosphere, astronomers must depend on rockets, balloons, and satellites to carry detectors above the atmosphere.

Complete understanding of stars, radio galaxies, quasars, and other objects requires that they be observed at all wavelengths. Space observing programs, therefore, complement ground-based programs, which still account for most of the work done by astronomers. NSF, which is responsible for approximately two-thirds of the Federal support for ground-based astronomy in the United States, coordinates its support with other agencies that are primarily supporters of rocket and satellite programs. NSF also supports some aspects of data analysis related to these programs.

#### *National Astronomy and Ionosphere Center*

The National Astronomy and Ionosphere Center (NAIC) is a visitor-oriented facility for research in aeronomy and radio and radar astronomy. The world's largest single radio/radar telescope, located

in a radio-quiet valley near Arecibo, Puerto Rico, is the primary NAIC instrument. A 305-meter-diameter, spherical, aluminum-panelled reflector, a suspended feed platform, and associated receivers and transmitters comprise the telescope. Interferometric observations are made with the addition of a 30-meter-diameter antenna located 10 kilometers from the 305-meter antenna.

This past year was the second full year of operation of the S-band (2380 MHz) planetary radar transmitter and maser receivers. During the week of July 4, 1976, NAIC produced last-minute maps of Martian landing sites for NASA's Viking 1. The new maps allowed NASA to change the projected course and avoid a possibly disastrous landing in rough terrain. In another project, the first detailed contour maps of a large area of the cloud-covered surface of Venus revealed some surprising features. There is a large 1,554,000-square-kilometer basin which appears similar to lunar "seas." The 19-kilometer horizontal resolution of the radar also depicted parallel canyons and ridges extending for hundreds of kilometers—geologic features unlike any on Earth.

#### *Sacramento Peak Observatory*

On July 1, 1976, the Sacramento Peak Observatory (SPO) was transferred from the U.S. Air Force to the National Science Foundation. SPO is an excellent solar observatory, with a 100-meter-high solar vacuum tower telescope, located in the Sacramento Mountains of New Mexico. It is also equipped with an echelle spectrograph, a digital diode array, and a universal birefringent filter capable of simultaneous real-time images of the Sun in separated wavelength bands. There are also two 40-centimeter aperture coronagraphs, a 40-centimeter telescope with a solar magnetograph, and several smaller instruments. NASA operates a 30-centimeter evacuated fixed telescope feeding a multiple line photoelectric spectrograph at SPO.

SPO scientists are participating in several space missions, including the design of ultraviolet and extreme ultraviolet spectrometers for the Solar

Maximum Mission, design of a Space Optical Telescope for the Space Shuttle, membership on the Space Shuttle Facility Definition Team, and the Skylab Solar Workshop.

Last year, SPO staff made a number of valuable contributions to solar astronomy, including: optical evidence that magnetohydrodynamic waves cool sunspots; detection of coronal holes at the east edge of the Sun, which can now give us 9- or 10-day advance notice of an impending geomagnetic disturbance on Earth; and a several-month study that shows coronal holes to move rigidly across the face of the Sun.

### *Kitt Peak National Observatory*

The Kitt Peak National Observatory (KPNO) provides facilities for research on the solar system, on stars and nebulae in our own Milky Way Galaxy, and on galaxies outside our own. KPNO, near Tucson, Arizona, has the largest collection of modern optical telescopes and auxiliary instrumentation in the world, including a 4-meter telescope. Kitt Peak is also the home of the McMath Solar Telescope, the largest telescope designed especially for observing the Sun. Other instruments include a solar vacuum telescope; a 2.1-meter telescope with a 1-meter feed telescope for the main spectrograph; a 1.3-meter cassegrain reflector; two 92-centimeter coude feeds; two 41-centimeter telescopes used primarily for photoelectric photometry; and a 30-centimeter Schmidt telescope.

KPNO staff and guest investigators conduct major programs related to space sciences. One of KPNO's objectives is to increase our knowledge of the structure, constituents, and radiation characteristics of the planets, including the Earth, using ground-based observational instruments. In addition, KPNO scientists have joined in several NASA-sponsored space programs, including the contribution of experiments aboard NASA satellites that are designed to determine the concentration of the main constituents in the atmosphere of Jupiter, Saturn, and Titan; and to investigate the atmospheres of Venus and Mercury. In addition, KPNO scientists serve on NASA Mission Definition Study Teams to define the scientific objectives best related to specific satellite planetary programs.

In support of the NASA infrared telescope to be constructed on Muana Kea, Hawaii, KPNO scientists and engineers provided a conceptual design and KPNO is grinding, polishing, and providing the final figure of the telescope's 3.2-meter primary mirror and two secondary mirrors. The telescope will, at appropriate times, furnish observations of the planets in support of NASA space probes.

Daily magnetograms of solar observations conducted with the solar vacuum telescope continue to be provided to NASA. The magnetograms indicate magnetic fields on the Sun and are used by NASA in support of its orbiting solar observatory (OSO-H) program.

### *National Radio Astronomy Observatory*

The National Radio Astronomy Observatory (NRAO), headquartered in Charlottesville, Virginia, provides the large radio telescopes, auxiliary equipment, and support services required to conduct advanced research in radio astronomy. The three telescopes at the principal observing site in Green Bank, West Virginia, operate in the wavelength range between a few meters and one centimeter. Of these, the 91-meter transit telescope is especially suited for sensitive surveys of radio sources; the 43-meter telescope is used primarily for studies of spectral lines at centimeter wavelengths and as an element in very long baseline interferometer networks; and the four-element interferometer is used to measure positions and map the radio structure of sources. Observations over the wavelength range between 1 centimeter and 2 millimeters are conducted with an 11-meter telescope on Kitt Peak, near Tucson, Arizona. Early in Fiscal Year 1977 research will begin with NRAO's partially completed Very Large Array interferometer, located on the Plains of San Augustin, 80 kilometers west of Socorro, New Mexico.

During the year, NRAO contributed 21-centimeter wavelength observations to a program employing both optical and radio telescopes to obtain radio velocities and magnitudes for an all-sky sample of 200 distant high-luminosity spiral galaxies. The aim of the programs was to determine if the Hubble expansion of the universe is uniform in all directions as observed at the Sun. As a result, not only has a nonuniform Hubble expansion for these galaxies been ruled out, but a new and unexpected component has been discovered in the motion of our own Milky Way Galaxy. The composite of this and other velocities (for example, the component due to galactic rotation) is so large as to be of considerable interest to cosmologists. This is because measurements of the  $-270^{\circ}\text{C}$  cosmic background radiation (which, according to the most generally accepted theory of the origin of the universe, is the 15-billion-year-old remains of the Big Bang) infer a lower velocity than these newer measurements for the galaxy and its local group of galaxies.

## Atmospheric Sciences

### *Meteorology*

This program investigates the dynamical and physical behavior of the atmosphere by means of field observations, laboratory experiments, and theoretical and numerical analysis. There is also considerable support for the development of remote sensing techniques and support for research on the interpretation of satellite data for severe-weather analysis.

### *Solar Terrestrial Research*

In 1976 further progress was made in implementing the International Magnetospheric Study, an intensive cooperative effort for the period 1976–1979. It will further our knowledge of the near-Earth environment and the way it is influenced by the Sun. Studies will include auroral particle precipitation, geomagnetic perturbations, hydromagnetic wave propagation, plasma physics, and electric fields. In anticipation of increased solar activity during 1979–1980, planning of special solar experiments was undertaken in 1976.

### *Aeronomy*

Aeronomy is concerned with the Earth's high-altitude atmosphere and its interactions with the lower atmosphere and with the space environment. The Foundation supports theoretical, laboratory, and field studies of phenomena that occur in this region, including airglow, aurora, ionospheric dynamics and instabilities, and chemical processes. In addition to the general ongoing work, particular emphasis is currently placed on high latitude investigations related to the International Magnetospheric Study.

### *Atmospheric Chemistry Program*

This new program is concerned with the chemistry of both the lower and upper atmosphere. Considerable effort is directed at stratospheric chemistry, and both modeling and observational efforts are supported.

### *National Center for Atmospheric Research (NCAR)*

NCAR plans and carries out atmospheric research programs in cooperation with universities and other institutions. It develops and operates special research facilities in support of the national atmospheric research effort. NCAR's long-range goals include producing knowledge that will help to extend the range and quality of weather predic-

tion, improve predictions of severe weather, determine trends and influences on air quality, understand climatic trends and their causes, and understand solar processes and their ultimate terrestrial influences.

The Tropical Wind, Energy Conservation, and Reference Level Experiment (TWERLE), a joint project of NCAR, the University of Wisconsin, and NASA, was carried out between June 1975 and February 1976. In that period, 411 TWERLE balloons carrying weather sensors and signaling equipment were launched from tropical and subtropical sites; information on tropical atmospheric circulation gathered by the balloons was relayed to the ground by the Nimbus 6 satellite. The TWERLE scientific team's preliminary data analysis is turning up significant differences between tropical and temperate-zone air circulation patterns. The balloon sensor system has proved to be a sensitive probe of a region of the atmosphere (at about 14 km) not easily studied by other means.

Another kind of balloon was used to carry NCAR's cryogenic sampler high into the stratosphere in a continuing program of measurements that is shedding light on the physics, chemistry, and dynamics of the upper atmosphere. During the past year, a coordinate program of *in situ* sampling and remote sensing of the upper atmosphere (with lasers and from satellites) has given NCAR scientists considerable information on the behavior of chlorofluorocarbons (used as aerosol spray propellants and refrigerants) and their influence on the ozone layer in the stratosphere.

A group of solar researchers at NCAR spent the past year working together with 60 colleagues in the Skylab Solar Workshops, a program devoted to obtaining scientific results from the battery of solar telescopes operated by the astronauts aboard Skylab. The workshops were devoted to the topic of coronal holes, areas of dramatically reduced density compared to the ambient plasma in the solar outer atmosphere or corona. These are believed to be the source of the high-speed streams of solar wind observed at the distance of the Earth—a steady stream of electrons, protons, and ionized atoms given off by the Sun. The workshops have yielded a theoretical picture of the conditions under which coronal holes form, grow, and decay and a picture of the dependence of these phenomena on the solar activity cycle.

In the field of atmospheric technology, a new mesoscale weather-reporting system was put into the field for the first time, where it turned in a superior performance. The Portable Automated Mesonet (PAM) was developed at NCAR in an effort to improve on the current generation of surface weather-station networks used in severe storm

research and other mesoscale investigations. In PAM, remote stations measure rainfall, temperature, pressure, humidity, and other parameters and transmit their information to a base station, where a computer processes and displays the information from the whole network simultaneously. The synchronous sampling and the instant display permit scientists to study surface weather patterns over a wide area in real-time. The system was successfully used this past summer in the National Hail Research Experiment, an NCAR-led effort to investigate the causes of hailstorms and the feasibility of modifying them.

### *The Solar Output and Its Variation*

Climatologists, meteorologists, and solar physicists share an abiding interest in the amount and form of the solar output of radiation and particles. The need for a quantitative description of solar radiation at all wavelengths and for the ability to predict variations in solar output is strongly felt in many physical sciences.

A summary of the most authoritative information and a projection of the measurements still needed will be published in the spring of 1977. *The Solar Output and Its Variation*, the result of a conference held at NCAR in April 1976 under the joint sponsorship of the Sacramento Peak Observatory, NOAA, NASA, and NCAR, will serve as a reference volume for scientists in climatological, aeronomical, and solar research.

### *Polar Research Programs*

The Foundation supported investigations of the upper atmosphere, the ionosphere, the magnetosphere, and the interplanetary medium from four Antarctic stations (McMurdo, South Pole, Siple, and Vostok) and from Siple's geomagnetic conjugate point near Roberval, Quebec.

Analysis of these studies, centered on very low frequency waves, auroral particle precipitation, electric fields, and geomagnetic perturbations, is in progress. Intensity variations of relativistic primary cosmic rays were monitored at McMurdo and South Pole.

Siple has a 21-kilometer-long antenna that receives and transmits very low frequency signals propagating through the plasmopause region of the magnetosphere. It is the world's only station with

these capabilities. Siple was evacuated and closed in December 1975 because of a hepatitis case just before the winter isolation was to begin, but it was reopened in late 1976 for year-round projects that will contribute to the International Magnetospheric Study, 1976–1979.

### *Materials Research*

Progress in aeronautics and space technology depends critically on the availability of materials with optimum combinations of properties, particularly for advanced structural applications. Materials research provides information that will advance the state of the art for materials used in the construction of aircraft, space vehicles, and attendant devices and instrumentation. Current research includes high-temperature mechanical and thermochemical behavior of both metals and ceramics, studies of erosion by particulate matter, the hydrogen embrittlement of metals and alloys, amorphous metallic alloys, photovoltaic materials, high-strength low-density polymers, and ion implantation.

Several areas of research in condensed matter are also of interest because they underpin research and development work for aeronautical and space activities. One of these is the effect of radiation on materials, and in this context the formation of various kinds of defects and their properties are being studied. Another area of importance is that of solid-state effects that can be used as sensors for various aeronautical and space applications. Examples under study are photovoltaics, photoconductors, and millimeter-wave detectors. Finally, research on superconductivity and liquid helium is important to the development of possible aeronautical and space devices that may use cryogenic components.

### *Education Activities*

In Fiscal Year 1976, the Foundation made 37 awards totaling \$399,000 for activities relating to the aeronautic and space sciences. Most of these funds were devoted to the training of graduate students and postdoctoral scientists. Assistance was also provided to two- and four-year college and university faculty members to help upgrade their subject-matter background relating to the aeronautic and space sciences.



# Environmental Protection Agency

## Introduction

The major activities of the Environmental Protection Agency (EPA) which are associated with the utilization of aerospace technology in 1976 were centered in the Office of Research and Development (ORD). These activities lie within two distinct program areas of ORD, namely, the Energy-Related Environmental Research and Development Program of the Office of Energy, Minerals and Industry (OEMI) and the Remote Monitoring Program of the Office of Monitoring and Technical Support (OMTS).

As a segment of the second year effort of the multi-agency R&D program which it administers, OEMI is funding the development of advanced synoptic monitoring techniques which are applicable to a variety of energy-related environmental problems. In addition, OEMI is supporting research by elements of EPA, NASA, and NOAA in pollutant measurement by long-path instruments. OMTS is continuing its remote monitoring program in support of a variety of national environmental needs.

### Interagency Energy-Related Environmental Research & Development Program

The Office of Energy, Minerals, and Industry (OEMI) is responsible for administering a \$100 million per year, 17-agency, energy-related environmental R&D program whose objective is to provide a scientific basis for protecting the environment while expanding and developing U.S. energy resources and advanced energy technologies. Aerospace technology is being applied to energy-related environmental problems in two distinct areas—advanced synoptic monitoring techniques and advanced pollutant identification, measurements, and tracking methods.

#### *Western Energy/Environment Monitoring Study*

One major activity now underway is the Western Energy/Environment Monitoring Study involving various elements of EPA, U.S. Geological Survey,

NOAA, and NASA. The purpose is to establish a multi-year, multi-media pollutant baseline in areas of the western U.S. where major new energy development is planned over the next ten years.

Besides monitoring and analyzing air and water pollutants, synoptic monitoring is being carried out by EPA's Environmental Monitoring and Support Laboratory/Las Vegas (EMSL/LV) with aircraft using standard color and infrared photographic techniques. The purpose is to characterize the general local ecosystem and drainage patterns at sites where development is planned and to evaluate pollutant control practices already under development. These sites include coal strip mines and power plants; in the future, oil shale, coal gasification, and geothermal development sites will also be monitored.

Aircraft are suited to this problem because of the need for frequent coverage over a relatively broad area surrounding sites which are generally very far apart. However, as more sites are developed and as further leasing occurs in the next few years, regulatory decisions must be made rapidly. The time-consuming process of photo interpretation could cause a bottleneck in the information flow to decision and regulatory processes. To remedy this anticipated problem, EPA and NASA have developed an agreement whereby advanced, automated multispectral analysis technology will be transferred from NASA's Earth Resources Laboratory (ERL) to EPA/EMSL/Las Vegas for application to western and other environmental problems. This automated interpretation technique has been demonstrated by ERL at two designated strip mine sites in Wyoming and New Mexico.

Developmental efforts related to these two western "type sites" have centered on identifying spectrally differentiable classifications and correlating the accuracy of these classifications with ground truth data. An aircraft-mounted laser geolite has also successfully demonstrated its ability to give an accurate record of mine contour. This capability is directly applicable to enforcement of reclamation regulations.

Technology transfer will be effected during 1977. Broad field testing will begin in 1978, after which operational use is planned. This will be a qualitative step upward in EPA's land use monitoring capability.

In concert with this effort, ERL is examining the utility of Landsat imagery as a low-resolution technique for detecting large scale, long term alterations of land use, vegetation, and drainage patterns due to energy-related developments.

#### *Energy-Related Pollutant Monitoring and Tracking Methods R&D*

OEMI is sponsoring a number of projects in the development of pollutant monitoring and tracking techniques which are aimed at increasing mission flexibility of multi-source sampling programs for purposes such as enforcement. Compared with existing procedures, these devices can increase system cost effectiveness by performing many more sampling missions in a given time period and by providing near-real-time analysis.

In addition, the adaptation of such devices to aircraft can yield real-time information and tracking capability for studies of aerosol long-range transport and transformation (e.g., the sulfur particulate complex). The tracking of pollutant plumes is crucial to research in pollutant dispersion and transformation and will be important in future regional enforcement and significant deterioration situations involving large areas.

The following projects are being supported by OEMI:

*Particulate Aerosol.* EMSL/Las Vegas is testing its aircraft-mounted downlooking differential-absorption LIDAR (light-detecting and ranging) system which will give a vertical profile of relative particulate density in the path beneath the aircraft. This tracking capability, with real-time readout, will be of great significance to EPA's studies of power plant plume transport and aerosol transformation.

NOAA/Boulder has demonstrated, with a ground-base research LIDAR scattering system, the ability to differentiate between fugitive dust and particulates from power plants at distances of several kilometers. This is important for anticipated significant-deterioration measurements. While this research instrument is not a real-time system, it is being used in field work at two coal-fired power plant sites. A simplified adaptation, calibrated to the basic scattering data ascertained with the NOAA system, could eventually be developed as an enforcement tool for monitoring dispersed plume particulates.

*Gaseous Pollutants.* NASA Langley Research Center is developing a multipollutant, differential absorption research LIDAR for dispersed plume measurements of sulfur dioxide, sulfur trioxide, carbon monoxide, nitric oxide, nitrogen dioxide, and methane. Construction is near completion and field tests will then begin. The purpose is to demonstrate a mobile, highly accurate system for several important pollutants. In addition to avoiding lengthy setup procedures, the tunability feature will enable monitoring of several stack gases which at present require distinct sampling and analysis systems. In an operational system, this should prove highly cost effective compared to present systems used for systematic monitoring. Furthermore, the LIDAR device provides information on plume dispersion which is beyond the capability of existing systems.

NASA Langley is determining the feasibility of using heterodyne detector techniques as a high-sensitivity receiver of laser radiation from natural topographical targets. This would make possible the use of integrated path laser systems in aircraft for measurement of the total burden of a pollutant, such as ozone, in a vertical plane from a given height. Present integrated path measurement systems depend on a mirror-retroreflector and their flexibility is therefore limited.

*Water Pollutants.* EMSL/Las Vegas is testing the application of a laser fluorosensor system for identifying organics, including specific oils, on surface water. This is important in view of the need to rapidly detect the location and assess the extent of industrial pollution. This has application in enforcement and cleanup actions and in given situations can provide an indicator for the optimum setup of ground-base water monitoring networks.

### **Remote Monitoring**

#### *Oil Spills*

The Environmental Monitoring and Support Laboratory, Las Vegas, continues to respond to requests for information on oil spills. Data have been supplied to the Coast Guard, essentially in real-time, not only on the extent of river, coastal, and estuarine spills but also on the best routes for ground crews to get to the polluted areas. The spill response effort included information on: (1) a sunken tanker in the Delaware River with many additional oil pollution sources visible, (2) the Saint Lawrence Seaway oil spill survey, (3) oil pollution on the Hackensack River (New Jersey), (4) a sunken barge on the Chesapeake Bay, (5) a sunken barge in Puerto Rico.

### ***Ocean Dumping***

Aerial photographic imagery of a chemical spill in the New York Bight was obtained at the request of EPA's Region II.

Ground truth data for remote sensing of the Camden-Philadelphia chemical dump site off the New Jersey coast was obtained by the Environmental Research Laboratory, Narragansett. This consisted of detailed water and biota analyses in the wake of the barges during and after the dumping.

### ***Air Pollution Effects***

Significant outputs in this area include:

- Airborne LIDAR was used to study particulate source and receptor areas within New York City. The study was intended to collect additional data to relate plumes from point sources industrial areas and automobile traffic to the observed high concentrations of suspended particulates.

- A report showing ozone and ozone precursor distribution over the Gulf Coast states was prepared from airborne measurements made by the Environmental Monitoring and Support Laboratory, Las Vegas, aircraft. The object of the program was to establish a cause for the widespread high values of ozone in that area.

- Documentation for air emission sources in the Worcester, Massachusetts, area.

- Wide aerial monitoring was conducted in support of the intensive Washington, D.C., oxidant study.

### ***Waste Pollution and Effects***

Information to assist the Regions in monitoring and enforcement include:

- Reports of possible leaching from landfill and bulk storage sites.

- Data processing and information from Alvin, the deep sea submersible research vessel.

- Interpretation of aerial photography in connection with the effect of silviculture and agriculture practices on the river water quality in Wenatchee National Forest.

### ***Basin Study***

An extensive study has been planned for the Apalachicola River Basin in Florida. This is a multifaceted program to monitor the effects of river dredging, silviculture, agriculture, chemicals, and flow control on a relatively pristine estuarine area which is the principal source (90 percent) of Florida oysters and involves NASA, EPA (Region IV), the University of Florida, and the Environmental Monitoring and Support Laboratory, Las Vegas.

### ***International Cooperation***

At the request of the Remote Sensing Committee of the Swedish Board for Space Activities, a package of technical data and application reports was delivered describing the existing developments in instrumentation and methods for remote sensing of air and water pollution.

### ***Other Environmental Protection Agency Studies***

There is an ongoing program to relate land use inventories to water quality in five rivers emptying into the Great Lakes. EPA's Region V and NASA's Lewis Research Center are cooperating on this program as an assignment from the International Joint Commission as defined by the United States/Canada Water Quality Agreement. EPA has provided the ground truth data for the five-river survey.





# National Academy of Sciences National Academy of Engineering National Research Council

## Introduction

The National Academy of Sciences is a private society of scholars in scientific and engineering research, dedicated to the furtherance of science and its use for the general welfare. Its charter, an Act of Incorporation passed by Congress, calls upon it to serve as an official advisor to the Federal government on any question of science or technology.

The National Academy of Engineering is a parallel organization of engineers that shares with the Academy of Sciences the responsibility for advising the Federal government.

Most of the activities undertaken by the two academies are carried out through the Commissions and the Assemblies of the National Research Council, which draws upon a wide cross-section of the nation's leading scientists and engineers.

## Aerospace Science

### *Space Science Board*

The Space Science Board (SSB) is concerned with helping to formulate the most effective national program in space research. The Board also represents the National Academy of Sciences to the Committee on Space Research (COSPAR) of the International Council of Scientific Unions.

In January 1976 a study cosponsored by the National Academy of Sciences and the European Science Foundation (ESF) was conducted by the Space Science Board and the ESF's Space Science Advisory Board. Its purpose was to consider how the Space Telescope could be used by the international scientific community.

Two special studies were undertaken in 1976. One dealt with institutional arrangements for the Space Telescope. The study reported on the general principles applicable to those ground-based facilities needed to provide the productive interaction between the Space Telescope and the scientific user community. The second study examined space plasma physics to identify future directions of research in this field and to recommend an appropriate role for NASA.

The SSB is assisted in its work by specialized committees and panels. The Committee on Space Astronomy and Astrophysics is preparing a long-range strategy for space astronomy. The Committee on Space Physics is working on a strategy for space physics. The Committee on Planetary and Lunar Explorations is planning for the exploration of the inner planets (to complement the outer planets strategy published in *Report on Space Science, 1975*, National Academy of Sciences, Washington, D.C., 1976). The Committee on Space Biology and Medicine is planning a study (to be completed in 1977) of biological and medical experiments that could be conducted in the Space Shuttle. The Exobiology Panel completed a report on quarantine considerations for Titan, Uranus, and Neptune and monitored the progress of the life-detection experiments on the Mars-Viking landers.

During 1976 the SSB created a Committee on Earth Sciences (CES) to consider the space science aspects of climate dynamics, geodynamics, geodesy, and other areas in Earth sciences. The CES organized a Coordinating Committee to assist NASA in planning its climate research program, drawing on personnel from other National Research Council groups.

The 19th Plenary Meeting of COSPAR took place in Philadelphia, June 9–19, 1976, at the University of Pennsylvania, with the SSB serving as host on behalf of the National Academy of Sciences. A special feature of the meeting was a symposium on the future of space science that included papers by internationally known scientists.

### *Geophysics Research Board*

The Geophysics Research Board (GRB) was established to effect participation by U.S. scientists in the activities of international geophysical organizations and to stimulate and encourage research in geophysics and related fields. The Board's work is conducted largely through a number of committees and panels; the principal ones involved in space-related activities are the Geophysics Study Committee, the Balloon Study Committee, the

Committee on Solar-Terrestrial Research and its Panel on the International Magnetospheric Study, and the Committee on Data Interchange and Data Centers.

The Geophysics Study Committee oversees the work of a number of panels, each of which is preparing a ministudy intended to aid Federal decision making on societal problems that involve geophysics. Studies on energy and climate, upper atmospheric geophysics, geophysics of estuaries, and water and climate have advanced to the point that the papers have been presented at suitable public forums (American Geophysical Union or American Association for the Advancement of Science).

The Balloon Study Committee was appointed early in 1975 as a joint activity of the GRB and the Space Science Board. Its objective was to review past scientific achievements and the future promise of this technique and to obtain high-quality scientific data at low cost (as compared with satellites and other platforms).

The Committee on Solar-Terrestrial Research (CSTR) reviews and makes recommendations on the national program in solar-terrestrial physics and through international bodies, participates in the organization and planning of international research in solar physics, interplanetary medium, planetary atmospheres, and the magnetosphere. The *Government-Wide Plan for the International Magnetospheric Study*, which was prepared by the Science Advisor of the National Science Foundation and is now being implemented by government agencies, is largely based on recommendations of a joint study by CSTR and the Space Science Board in 1973 and a report by the CSTR Panel in 1974. The chief objective of the International Magnetospheric Study is to obtain a comprehensive, quantitative understanding of the dynamical processes operating on plasmas in the geomagnetic field. The operational basis is an international plan of coordinated observations from spacecraft, ground-based facilities, aircraft, balloons, and rockets.

The Committee on Data Interchange and Data Centers was established to meet problems of international exchange of geophysical data through the World Data Centers and to advise the GRB and the Director of the U.S. Center on policies and effectiveness of the service to the U.S. scientific community of both the U.S. complex (eight discipline-based subcenters and the Data Center Coordination Office) and other U.S. data centers and services. The committee is concerned with coordination of these services and their improvement, especially in regard to effective use of the centers, quality control of the data, and services to the scientific community. The most recent publication,

*Geophysical Data Centers: Impact on Data-Intensive Programs* (National Academy of Sciences, Washington, D.C.), was issued in 1976.

#### *Committee on Atmospheric Sciences*

The Committee on Atmospheric Sciences were requested by NASA in 1976 to review the program areas that were being considered for development of the measurement of the Earth radiation budget by means of satellite instrumentation.

In response to this request, the committee established an *ad hoc* panel that met with scientists of NASA, NOAA, and universities who had direct involvement in several parallel studies for measuring the Earth radiation budget from space.

The panel concluded that in order to develop valid radiative parameterization schemes, investigations were needed of large-scale, long-term radiative heating and energy transports and of the smaller space and time scales as well. It was believed this information would be necessary if atmospheric scientists are to achieve significant advances in weather prediction and in better understanding of climate and climatic changes. The panel findings resulted in specific recommendations on the approach, and they were incorporated in the proposed Earth Radiation Budget Satellite System.

#### *Committee on Impacts of Stratospheric Change*

The Committee on Impacts of Stratospheric Change (formerly the Climatic Impact Committee) completed work on its assessment of the extent to which fluorocarbons used largely as spray-can propellants and refrigerants could affect the Earth's ozone layer. Two reports, *Halocarbons: Effects on Stratospheric Ozone* (National Academy of Sciences, Washington, D.C., 1976) and *Halocarbons: Environmental Effects of Chlorofluoromethane Release* (National Academy of Sciences, Washington, D.C., 1976) were released. The reports concluded that "Selective regulation of chlorofluoromethane uses and releases is almost certain to be necessary at some time and to some degree of completeness. Neither the needed timing nor the needed severity can be reasonably specified today." The committee recommended a research program to elucidate the needed timing and severity.

#### *Committee on Toxicology*

The Committee on Toxicology has established a subcommittee on Fire Toxicology to evaluate the state of knowledge in methodology for toxicity screening of the combustion pyrolysis products of polymeric materials used in aircraft and spacecraft, to characterize the parameters of an "optimum"

test system for screening the toxicities of decomposition products, and to evaluate toxicological data on selected polymers. The committee has delivered to NASA a Six-Month Progress Report listing requirements for an optimum screening test for toxicity of combustion products.

The Committee on Toxicology has revised the emergency exposure limits for hydrogen chloride and ammonia and is planning revisions for the hydrazines and rocket fuel oxidants.

## **Space Applications**

### *Space Applications Board*

The Space Applications Board (SAB) was established to advise the Federal government on matters related to the practical applications of space systems. During 1976 the Board continued to bring to the attention of appropriate persons in the private and the public sector the 15 reports resulting from its 1974 summer study of the Practical Applications of Space Systems. Distribution, now essentially completed, has reached about 30,000 potential users interested in space applications. The SAB has begun follow-up meetings between Federal agencies and certain of the summer study user panels to review what has happened as a result of the study and what activities now deserve emphasis.

In the conduct of the summer study, one panel examined the national program of research and development on processing materials in the space environment. The panel concluded that the scientific basis for the program needed strengthening. The SAB decided, in concert with the National Research Council's Solid State Sciences Committee, National Materials Advisory Board, and Division of Biological Sciences, to study in more detail the future course of the program for materials processing in space. A study, to be completed in late 1977, has been undertaken.

At the request of NASA, the SAB established a Committee on Satellite Communications to examine the question, "Should the Federal government resume research and development in satellite communications and, if so, what should the Federal role be?" The committee was constituted of technologists, communications system operators, satellite communication users, communications policy specialists, and regulatory economists. A final report summarizing the findings of the committee is expected to be released in early 1977.

### *Committee on Remote Sensing Programs for Earth Resource Surveys*

The Committee on Remote Sensing Programs for Earth Resource Surveys provides advice to the

Federal government on the use of remote sensing from spacecraft and aircraft for natural resource surveys and environmental monitoring.

During 1976, the committee completed an evaluation of a proposed follow-on sensor, the Thematic Mapper, planned for launch in 1981. As proposed, the Thematic Mapper is to provide a repetitive matrix of high-quality land cover or vegetation data as a basic information product for use by resource managers. The committee reviewed the characteristics of the sensor and concluded that by making some changes in the cut-on's and cut-off's of the spectral bands in the scanner, the effectiveness of these bands for vegetation classification can be enhanced. Furthermore, these adjustments will also increase the utility of the sensor system for geological exploration, water management, land use management, and the study of coastal processes and oceanography. The committee also concluded that the Thematic Mapper, with the suggested modifications, could serve as the basic operational Earth-resource sensing system. The committee recognized, however, the some users will require supplementary data that may be best acquired from another spacecraft with a different sensor and orbit characteristics.

### *Committee on Radio Frequencies*

The Committee on Radio Frequencies (CORF) and its Subcommittees on Space Science and Radio Astronomy coordinate the views of the U.S. scientific and engineering communities on radio frequencies needed for research. CORF worked closely with Study Group 2 of the U.S. National Committee for the International Radio Consultative Committee (CCIR) in preparing documents on space research and radio astronomy for the CCIR Study Group 2 held in Geneva. CORF also worked closely with the Federal Communications Commission (FCC) in developing and documenting the requirements for radio astronomy in preparing for the 1979 World Administrative Radio Conference. Scientists recommended by CORF served on the FCC Radio Astronomy working group, formed to assist the FCC in preparing the U.S. position for the 1979 conference.

### *Committee on Seismology*

The Committee on Seismology reviewed its program in relation to new advances in the field and changing emphasis in government agency missions. The fundamental objectives for 1976 through 1978 have been defined as follows:

- (a) to maintain active surveillance of major trends in seismology and related developments in allied scientific and technical fields;

- (b) to provide special studies for government agencies on appropriate problems;
- (c) to maintain liaison with international seismological activities;
- (d) to provide advice to government agencies on the operation of Federally-supported seismograph networks and data dissemination facilities.

In addition, the following four issues were selected for immediate action:

- Changing trends in seismology, in particular, the shifting Federal missions in the field, with implications for academic research;
- Operation and support of U.S. government-sponsored seismograph networks;
- Collection, storage, and dissemination of seismographic data, particularly data for the new digital stations, and data from arrays;
- Assurance of appropriate response of seismology to the public welfare in regard to earthquake prediction and control, geothermal energy, earthquake engineering, geodesy, geological hazards, land-use planning, and offshore geological exploration.

The first of a series of reports confronting these issues was published in July 1976, and two more are expected to be released in early 1977. The reports are:

- *Predicting Earthquakes: A Scientific and Technical Evaluation—with Implications for Society*, National Academy of Sciences, July 1976.
- *Trends and Opportunities in Seismology: Part I. Opportunities and Benefits, Part II. Background and Progress*.
- *Global Earthquake Monitoring: Its Importance and Support Requirements*.

The work of all U.S. government agencies has been reviewed and referenced in the above reports.

Sources of support for the committee's work include the National Oceanic and Atmospheric Administration, U.S. Geological Survey, Defense Advanced Research Projects Agency, U.S. Nuclear Regulatory Commission, U.S. Energy Research and Development Administration, National Science Foundation, National Aeronautics and Space Administration, and U.S. Air Force Office of Scientific Research.

## **Aerospace Engineering**

### *Aeronautics and Space Engineering Board*

In order to focus the energies and talents of the engineering community on important aerospace policies and programs essential to a strong aeronautical base in this country, the Aeronautics and

Space Engineering Board (ASEB) continued to emphasize the need for a research and development program that would lead to improved commercial aircraft of all kinds.

During 1976 the Board placed special emphasis on reviewing NASA's Aircraft Energy Efficiency Program. The Board's *ad hoc* Committee on Aircraft Fuel Conservation considered the means by which future aircraft could be made not only more fuel conservative but also more cost competitive and environmentally compatible. Special emphasis was placed on alternative fuels technology that would be necessary should the need arise to replace petroleum as a basis for aircraft fuels.

The *ad hoc* Committee on Supersonic Research and Technology reviewed progress being made in this area and noted the advancements that had been made during the year in several related technologies.

The *ad hoc* Committee on Turbine Engine Test Facilities completed its deliberations, taking into consideration not only the essential requirements for national turbine engine test facilities but also the ways by which the competence existing at NASA's Lewis Research Center could support facets of the national energy program that are now the responsibility of the Energy Research and Development Administration.

The Board has commended NASA on the steps taken to implement previous suggestions on recommendations made by the *ad hoc* Committee on the Management of Space Program Costs. The Board is considering the creation of another committee to examine the balance between research conducted in NASA centers and that supported in the academic and industrial sectors by NASA grants and contracts. This committee will also consider how the NASA-academic community relationship could be improved to ensure that sound basic research in support of broad national aeronautical objectives could be attained in a timely manner.

### *National Materials Advisory Board*

The activity of the National Materials Advisory Board covers the entire life cycle of materials from their origin as natural resources, through their application for social purposes, to their disposal or reclamation back into the materials cycle. The studies undertaken by the Board contribute to the materials science and engineering data base. Several studies completed in 1976 should contribute directly to aerospace technology:

- The report of the *ad hoc* Committee on Mechanical Properties of Infrared Transmitting Materials assessed the probability of improving the erosion resistance of radome materials

without sacrifice of their optical properties.

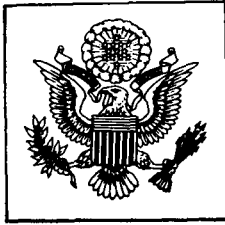
- *Rapid Inexpensive Tests for Determining Fracture Toughness*, (National Academy of Sciences, Washington, D.C., 1976) examined the potential of various rapid, inexpensive methods for determining fracture toughness of production materials for quality control purposes.
- The first volume of the report by the *ad hoc* Committee on Fire Safety Aspects of Polymeric Materials examined natural and synthetic polymeric materials in the presence of fire. Subsequent volumes will address the fire safety aspects of polymers in specific applications. One of the volumes, soon to be published, is devoted to aircraft systems.

## Education

### *Commission on Human Resources*

The Commission on Human Resources of the National Research Council awards research appointments to doctoral engineers and scientists who pursue research at participating centers of the National Aeronautics and Space Administration.

In NRC-NASA Postdoctoral Associateship programs, able investigators conduct research projects that contribute to the goals and programs of NASA and that also provide research experience—often of a unique kind—to the investigators. On August 31, 1976, there were 212 Associates in tenure.



# Office of Telecommunications Policy

## Introduction

The Office of Telecommunications Policy (OTP) was created in 1970 as an independent agency within the Executive Office of the President. OTP has two major functions: (1) to serve as principal advisor to the President on communications policy; and (2) to formulate policies and provide coordination for the Federal government's communications system.

As specified in its charter, OTP develops plans, policies, and programs with respect to communications designed to promote the public interest, support national security, contribute to the economy and world trade, promote the interests of the United States in its relations with foreign nations, and foster effective and innovative telecommunications technology.

During the past year, OTP was active in a broad range of telecommunications issues involving the domestic and international application of aeronautics and space technology.

## International Satellite Systems

OTP has been involved in the development of specialized and regional telecommunications systems throughout the world. In particular, since the beginning of international activity in 1972, OTP has been directly involved in the formulation of U.S. policies and positions on the establishment of an International Maritime Satellite System (INMARSAT).

In addition, during the past years, OTP, as part of a U.S. Government triumvirate including the FCC and the State Department, has been providing guidance and instructions to Comsat (as U.S. Signatory in INTELSAT) as required by applicable legislative and Executive Order requirements.

The possibility of the use of telecommunications satellites for broadcast of television programs directly into home receivers continues to generate international debate in the United Nations and has demanded OTP involvement as well.

The Office also continually reviews the demands for use of the radio spectrum, which is a limited

natural resource. During the year, OTP, in cooperation with the FCC and the Department of State, has been preparing for three important upcoming international conferences on frequency allocation for aeronautical, space, and terrestrial telecommunications systems. The conferences are sponsored by the International Telecommunications Union, a specialized agency of the United Nations.

## INMARSAT

An International Convention establishing an INMARSAT organization was concluded in late 1976 incorporating U.S. requirements that a two-part agreement be signed specifically delineating the rights and responsibilities of designated operating entities.

Recently, OTP proposed designation of the U.S. entity in INMARSAT through legislation. It was proposed that this same entity be designated for future aeronautical as well as maritime satellite systems. This draft legislation is entitled the "International Mobile Satellite Telecommunications Act of 1976."

## Direct Broadcast Satellites

The fundamental difference between the proposed direct broadcast satellites and conventional communications satellites is the former's capacity to broadcast directly into home receivers, avoiding expensive ground stations. The use of receivers designed for direct broadcast satellite reception offers the potential for radical changes in the way telecommunications satellites may be employed.

Active debate on direct broadcasting satellites began in the U.N. in 1966 at the time of discussions of the Outer Space Treaty. The basic political issue is the conflict between the view of the majority of states that DBS cannot be allowed to operate without permission of the receiving state and the view of a small minority of states which advocate free and unlimited operation subject, of course, to applicable technical limitations. Four

differing draft agreements are before the Outer Space Legal Subcommittee.

OTP, along with other interested U.S. agencies, participated in the deliberations of both the Legal Subcommittee and the Outer Space Committee during the year, and it will continue to contribute to the formulation and presentation of U.S. policy views on the issue.

### **Frequency Management**

The radio frequency spectrum is a finite resource. Its application is subject to the laws of physics; and it is shared by all nations and by all classes of radio equipment. Discrete segments of this radio spectrum are used by navigational aids, radars, and all non-wire forms of communications, e.g., AM, FM, and TV broadcasting; satellite transmission; and mobile communications generally. Increasing spectrum use increases the potential for interference. Avoiding such interference is a function of frequency management and spectrum planning.

International spectrum planning is done within the framework of the International Telecommunications Union (ITU), a specialized agency of the United Nations, located in Geneva, Switzerland. The international radio regulations negotiated at conferences of the ITU, when ratified by the U.S. Congress, have the force of treaty. In addition to the relevance of the ITU regulations to national use of the radio frequency spectrum, they have an explicit impact on international communications and commerce. OTP, the FCC, and the Department of State are preparing work for three major ITU conferences:

- A World Administrative Radio Conference to be convened January 10, 1977, to establish technical sharing criteria for the Broadcasting Satellite Service in the 11.7–12.2 GHz frequency band, taking into account the fixed, mobile, and other broadcasting operations to which that band is also allocated;
- A World Administrative Radio Conference planned for later in 1977 to revise the planning for the Aeronautical Mobile Service use of high frequencies on the world's air-route communication systems;
- A World General Administrative Radio Conference to be held in the second half of 1979. This conference will have the authority to re-

view and revise all of the international radio regulations, particularly those dealing with allocation of the radio frequency spectrum. The last ITU conference to have such broad authority was held in 1959. The development of satellites and other sophisticated telecommunication technology, combined with the rapid growth of the organization since 1959 and the ensuing political atmosphere will present the U.S. with greater challenges than any ITU-sponsored conference in the history of the organization.

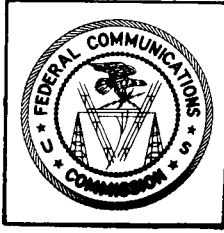
At the initiative of OTP, detailed examinations of planned and proposed aeronautical radionavigation and satellite systems have been undertaken jointly with the sponsoring government agencies to evaluate their electromagnetic interactions with each other and with existing systems. As a result, a number of design adjustments in planned systems have been made by the FAA, NASA, and DoD to avoid the inestimable expenses in hardware replacement or retrofit which might have otherwise been necessary.

### **Domestic Satellite Applications**

As a result of the recent ATS 6 program of NASA, considerable interest has developed in using advanced communications satellites with low-cost Earth stations in the delivery of health and educational services.

OTP, in conjunction with HEW and NASA, has encouraged the transfer of this technology to the private sector. While NASA has eliminated many of the technical barriers associated with this type of satellite, questions of demand and how to bring all the many potential users together into a useful economic market prevented any major private sector initiative in this area.

To correct this situation, OTP and HEW supported the concept of a user consortium that could collect all the various user needs for such service into a single package. As a result, the Public Service Satellite Consortium was formed early in 1975 to make high-powered communication satellite services available to public and private institutions concerned with the delivery of health, educational, and other public services. OTP continues to be supportive of the PSSC in its developmental efforts.



## Introduction

Commercial satellite telecommunications services expanded substantially during 1976 to meet the increasing demand of the public for national and international communications. Two additional countries joined the International Satellite Corporation (Intelsat) in 1976, bringing the total membership to 93. Three domestic satellite systems were in operation, broadening the services offered to the public to include communications services to cable television operators, offshore drilling, and other areas not normally accessible through standard communications services. Maritime-mobile satellite communications was initiated in the Atlantic and Pacific Ocean areas during 1976, and an application was filed by the U.S. co-owner of the AEROSAT aeronautical-mobile satellite system.

## Communications Satellites

### INTELSAT

On September 21, 1976, INTELSAT contracted for the procurement of seven advanced technology satellites known as the Intelsat V series. Each of the new satellites would nearly double the capacity of one of the present generation of Intelsat IV-A satellites by utilizing higher frequency bands, frequency reuse, and dual polarization. The Intelsat V contract sets the delivery of the first satellite in mid-1979. This satellite is capable of being launched by the Atlas-Centaur vehicle, as well as by NASA's Space Transportation System.

INTELSAT's global system consists of two operational Atlantic Ocean satellites (one Intelsat IV-A and one Intelsat IV) and one operational Intelsat IV each in the Pacific and Indian Ocean regions. This space segment is complemented by a ground network of 140 antennas at 112 sites in 78 countries. Besides providing international communications, INTELSAT provides satellite capacity to meet the domestic communications requirements of several countries. The continued construction of Earth station facilities is just one indication of the growing reliance on satellites for international as well as domestic communications.

## Domestic Satellite Service

The number of operational domestic satellites doubled during 1976, with the launch of three satellites, one (Satcom 2) by RCA American Communications, Inc., and two (Comstar 1 and 2) by Comsat General Corporation for the American Telephone and Telegraph Company and GTE Satellite Corporation. In little over a year the Commission has authorized over 100 receive-only Earth stations for reception of television via domestic satellites. Also 69 bush stations in Alaska have been authorized by the Commission to provide message service to remote areas. A selected number of these areas will be provided television service in the near future.

The Commission is evaluating proposals submitted by AT&T and RCA to determine who shall provide Alaska's space communications segment. Until a decision is reached, RCA has been granted authority to carry the Alaska traffic on SATCOM on an interim basis.

Construction of the AT&T/GSAT domestic satellite system has been completed and commercial use was authorized in July 1976. The authorization called for accelerated integration of Hawaii and Alaska telephone rates and for rate integration for Puerto Rico and the Virgin Islands. The International Record Carriers have also been authorized to use the Comstar satellites for provision of their authorized services between the mainland and Hawaii.

Applications for a new domestic satellite system were filed by Satellite Business Systems (SBS), a proposed partnership between Comsat General Business Communications, Inc. (a wholly owned subsidiary of Comsat General Corporation), Information Satellite Corporation (a wholly owned subsidiary of International Business Machines Corporation), and Aetna Satellite Communications, Inc. (a wholly owned subsidiary of The Aetna Casualty and Surety Company). The proposed system would begin operations in the 12 and 14 GHz bands during 1979 to provide wideband switched private communications networks to large industrial



and governmental users on a common carrier basis for voice, data, and image traffic using integrated digital transmission techniques between Earth stations located on customer premises through the 48 contiguous states.

The Corporation for Public Broadcasting (CPB) and the Public Broadcasting Service (PBS) have submitted thirteen applications from public television licensees for construction permits for receive-only Earth stations and one application from PBS for a main origination terminal. These applications are the first of what may be as many as 165 applications for Earth stations. They represent the ground segment of a domestic satellite system of interconnection for all public television stations in the United States, including Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands. The space segment of the interconnection is the subject of a separate application filed by the Western Union Telegraph Company for authorization to provide satellite service to public broadcasting at reduced rates, pursuant to Section 396 (h) of the Communications Act of 1934.

### **Specialized Satellite Services**

#### *Maritime Mobile-Satellite Service*

The Commission is continuing to work both nationally and internationally to develop maritime mobile communications in terms of accuracy, reliability, speed, and a variety of transmission modes which will, eventually, enhance maritime safety and management.

Internationally, the Intergovernmental Maritime Consultative Organization, through the Panel of Experts on Maritime Satellites, completed its final meeting in September 1974, looking toward the establishment of an international maritime mobile satellite service. Operational requirements have been stated and initial economical, technical, and financial studies have been completed.

Three intergovernmental conferences considered the report of the Panel of Experts, discussed arrangements for the establishment of the International Organization for a Maritime Satellite System (INMARSAT), established a Preparatory Committee to make preparations for the Organization, and in September 1976 opened the proposed establishment of INMARSAT the signature agreements. In preparation for those conferences, the Commission instituted an inquiry to help formulate the U.S. position on the establishment of an international maritime satellite system.

Currently maritime service is being provided through the MARISAT system, which presently serves the U.S. Navy and commercial shipping in the Atlantic and Pacific Ocean regions. Authority

was also granted to launch the third Marisat satellite to serve the Navy in the Indian Ocean region. The Commission has adopted rules for licensing commercial ships to operate in this system.

The Navy communications services are provided in the UHF band on a lease basis for a period beginning in 1976. The Navy has agreed to subscribe to full UHF service for two and a half years from the Indian Ocean Marisat satellite beginning January 1, 1977, as well as committing itself to exercise options for full UHF service in the Atlantic and Pacific Marisat satellites through March 1979. However, when the Navy service is completed the entire satellite capacity can be devoted to commercial maritime service.

#### *Aeronautical Mobile-Satellite Service*

In the fall of 1974, a memorandum of understanding was signed by the Department of Transportation/Federal Aviation Administration, the European Space Research Organization, now the European Space Agency, and the Canadian Government on the basic arrangements for an experimental aeronautical satellite system in the North Atlantic area. Comsat General Corporation has been chosen as the U.S. co-owner in the space segment of the system, which is to be placed into operation during 1979.

The objectives of the program are to gain experience and to evaluate and experiment with the use of satellite capacity in providing voice and data communications between aircraft and land stations.

The system will use frequencies at C-band for communications between ground stations and satellites. It is anticipated that this initial system will provide limited VHF capability (the frequencies now used by aircraft over land) in addition to an L-band capability between satellite and aircraft.

#### *Broadcasting-Satellite Service*

The United States, in conjunction with the Indian government, conducted a series of experiments in public service broadcasting with the Applications Technology Satellite (ATS) during 1975-1976, after which it was moved to a position to serve the United States with continued experimental education programming. Action on requests to authorize 4 U.S. government stations and 16 non-government stations to use ATS 6 is expected by early 1977. Approximately 40 additional requests for operating authorization are expected in 1977.

Additional experimentation is taking place with the joint United States-Canada Communications Technology Satellite (CTS), launched in January 1976. There are 14 U.S. government stations authorized to use the CTS and 16 non-government sta-

tions. At least 20 additional authorizations are expected in 1977.

The Commission is investigating the requirements for a Broadcasting-Satellite Service for community and individual reception. As part of its preparation for the 1977 World Administrative Radio Conference on planning for the Broadcasting-Satellite Service in the 11.7-12.2 GHz band, the Commission has issued its Report and Order in a proceeding to develop the proposals of the United States to this conference. These proposals have been finalized and forwarded to the International Telecommunications Union in Geneva. Also, a report entitled, "Satellite System Interference Modeling (11.7-12.2 GHz)", which considers factors pertinent to the planning of this band, was issued by the Office of Chief Engineer in September 1976.

#### *International Telecommunications Union (ITU)*

During 1976, the Commission's activities increased considerably internationally in advance publication, coordination, and notification of space systems, in accordance with provisions of the ITU Radio Regulations. This increase stemmed from the several domestic satellite systems and the U.S. government (including military) systems in use or under development, the significantly increased number of systems in planning or under development by foreign countries, and actions taken by the ITU radio conferences. It also resulted from U.S. responsibilities to carry out these functions on behalf of INTELSAT countries.

The Administrative Council of the ITU, which met during the summer of 1976, reconfirmed the convening of a General World Administrative Radio Conference and set September 1979 for the start of the ten-week conference. This major conference will deal with overall revisions to the current international Radio Regulations governing all radio services, including many aspects of a Special

Joint Meeting of the International Radio Consultative Committee (C.C.I.R.) in the second half of 1978, to consider technical factors in preparation for the 1979 General Radio Conference.

Because of the wide scope of the conference, the extensive preparatory work required is well under way. This work will take into account the frequency requirements of all radio services and the many other technical and operating aspects that will be involved. The Commission has initiated a proceeding and has already issued two notices of inquiry to obtain public comments to assist in the development of U.S. proposals.

Preparatory work has continued for the Aeronautical World Administrative Radio Conference, which will deal with matters relating to the Aeronautical Mobile Route Service, including the revision of their frequency allotment plan on the basis of single-sideband operation. This conference, originally to convene in March 1977, was postponed until February 1978 by the ITU Administrative Council.

#### *Frequency Allocation and Coordination*

A draft report and order to add a new footnote, US222, to the Table of Frequency Allocations has been prepared and action is expected in the near future. The proposed new footnote would permit the use of the frequency band 2025-2035 MHz by government Earth stations for Earth-to-space transmissions for tracking, telemetry, and telecommand at Wallops Island, Virginia; Seattle, Washington; and Honolulu, Hawaii. The action was requested by the Office of Telecommunications Policy to allow the Geostationary Operational Environmental Satellite System (GOES) to operate in the 2025-2035 MHz band. GOES will be used in short range forecasting and warning of weather, ocean, and solar hazards, providing nearly continuous, detailed observations.



### Introduction

International space cooperation in support of foreign policy objectives and the goals of the National Aeronautics and Space Act continued to be a matter of high priority to the Department of State during 1976. Attention was focused both on cooperation with individual countries and on endeavors with multilateral and international organizations.

Particular progress was seen in the continued cooperation of NASA with ten European countries in their development of a large space laboratory for use with the U.S. Space Shuttle system. Canada agreed to provide a remote manipulator for use on the Shuttle. Bilateral relations with U.S.S.R. continued through discussion of post Apollo-Soyuz activities and scientific exchanges. International cooperation for peaceful uses of space by all mankind was advanced in the communications satellite programs, the emerging maritime and aeronautical satellite programs, and the continued interest in space matters in the United Nations. The United Nations, through its Outer Space Committee and various working groups, has continued to be a prime forum for the formalization of multinational viewpoints and programs to advance cooperation in the uses of outer space.

### Activities within the United Nations

#### *Outer Space Committee*

The Committee on the Peaceful Uses of Outer Space met in New York from June 21 to July 2. It reviewed the work of its two Subcommittees—Legal, and Scientific and Technical—on four principal topics: (a) the draft treaty relating to the Moon; (b) the use of artificial Earth satellites for direct television broadcasting; (c) the survey of Earth resources by remote sensing satellites; and (d) the definition and/or delimitation of outer space and outer space activities.

The committee noted the work of its Legal Subcommittee on drafting a Moon treaty. The subcommittee has still not resolved the complex

issue of the exploration and exploitation of Moon's natural resources, although consensus has been reached on other outstanding issues.

The Legal Subcommittee has made significant progress in its effort to establish principles for the use of artificial Earth satellites for direct television broadcasting. It reached agreement on nine principles dealing respectively with (1) purposes and objectives; (2) applicability of international law; (3) rights and benefits; (4) international cooperation; (5) state responsibility; (6) duty and right to consult; (7) peaceful settlement of disputes; (8) copyright and related rights; and (9) notification to the United Nations. It also decided not to formulate principles relating to spill-over and disruption. There was a continuing exchange of views on consent and participation, program content, and unlawful/inadmissible broadcasts. The committee agreed that the Legal Subcommittee should continue giving priority to the formulation of these principles, with a view toward concluding an international agreement or agreements.

The most challenging issue before the committee was remote sensing of the Earth's resources and natural environment by satellite. The committee agreed with the report of the Scientific and Technical Subcommittee that the widespread operation of remote sensing was imminent, and that the data thus gathered would become integral to the economies and planning activities of states. The committee also noted the need to define the term "data," as it is used in discussions of remote sensing. The Legal Subcommittee continued to wrestle with the questions of data dissemination and the legal implications of remote sensing.

The committee also noted that work had begun on the question of the definition and/or delimitation of outer space and outer space activities. The Legal Subcommittee requested the Secretariat to prepare synoptic tables including the various proposals that relate to the framework of the committee's work. The Scientific and Technical Subcommittee continued its deliberations on the options relating to a possible United Nations Conference on Outer Space.

The committee also took note of other related activities including exchange of information between states on space activities and the need for more comprehensive programs in public information. The committee expressed satisfaction on the work carried out at the Thumba Equatorial Rocket Launching Station in India with the CELPA Mar del Plata Station in Argentina, relative to the use of sounding rocket facilities for international cooperation and training in the peaceful scientific exploitation of solar energy through space technology.

The committee decided, against the recommendation of the U.N. Committee on Conferences, to continue to meet annually and scheduled its next session for June 13–24, 1977. It agreed to General Assembly discussion of the committee's system of alternating annual sessions of the subcommittees between New York and Geneva.

### *General Assembly*

The First Committee of the General Assembly considered the two traditional outer space items, "International cooperation in the peaceful uses of outer space" and "Preparation of an international convention on principles governing the use by States of artificial earth satellites for direct television broadcasting" during 18 to 22 October. Priority items included remote sensing of the Earth from outer space, and the principle of prior consent for television broadcasts from space.

On October 21, the First Committee unanimously adopted a draft resolution (sponsored by 40 countries including the United States) which recommended that the Legal Subcommittee should, as matter of high priority, (a) continue to consider a draft Moon treaty, (b) consider completing the elaboration of draft principles governing the use by states of artificial Earth satellites for direct television broadcasting, and (c) give detailed consideration to the legal implications of remote sensing of the Earth from space with the aim of formulating draft principles on the basis of common elements identified by it. The resolution also recommended that the Scientific and Technical Subcommittee pursue its work on matters before it, giving priority to (a) questions relating to remote sensing of the Earth by satellite, (b) the United Nations program on space applications, and (c) consideration of the options relating to a possible United Nations Conference on Outer Space matters. The resolution also endorsed the other recommendations of the Committee on the Peaceful Uses of Outer Space, including those calling for further studies and reports by the Secretary General. The draft resolu-

tion was adopted unanimously by the General Assembly on November 8.

## **International Cooperation**

### *Cooperation with Europe*

During 1976, relations with Europe were characterized by continuing development of existing projects and by discussions of new projects made possible by advances in technology and space transport.

Discussions with the European Space Agency (ESA) led to a tentative selection of experiments for the first joint ESA-NASA Spacelab Mission scheduled for 1980. Progress was made toward early agreement on the Space Telescope, the major payload in astronomy for the Space Shuttle. Additional details regarding the planned launch of joint ESA-NASA Sun-Earth Explorer satellites were worked out.

Bilateral programs experienced renewed activity in 1976. In September, NASA signed a memorandum of understanding with Italy on a San Marco D cooperative satellite planned for launching in 1979–1980. In addition to continuation of existing projects, new bilateral activities included discussions with the West Germans on a probe to Jupiter in 1983, with the British on several Explorer satellites, and with the Dutch on an infrared astronomy satellite.

### *Cooperation with Canada*

An agreement was signed on June 23, 1976, in Washington whereby Canada will build and provide a Remote Manipulator System to be attached to the Space Shuttle, in return for which the U.S. will provide for the use of the Shuttle by Canada and will also cooperate with Canada in certain related activities.

### *Cooperation with Japan*

Space cooperation between the U.S. and Japan, as authorized by the U.S.-Japan Space Cooperation Agreement of 1969, continued at a brisk pace during 1976 and peaked with the second successful launching of Japan's N launch vehicle. The generally cooperative atmosphere was enhanced this summer by the U.S. worldwide sharing of information on the Viking mission.

Future plans call for further collaboration in such projects as the launching of three Japanese satellites in FY 1977, the continuing analysis of data from the Landsat Earth resources surveying system, and analysis of lunar samples. Also, Japan has proposed a joint experiment in plasma accelera-

tion undertaken for the first Spacelab mission. Chief among Japan's priorities is a program to develop, with U.S. assistance, an improved N-series launch vehicle.

### *Cooperation with the Soviet Union*

Following the publicly acclaimed Apollo-Soyuz Test Project (ASTP) of 1975, cooperation in the space field with the Soviet Union continued in 1976 through a variety of highly technical projects. Some of these projects are using data collected during the test project—for example, the study of the effect of zero gravity on the resolidification properties of selected materials, which in turn affect the electrical and mechanical properties of these materials, and the feasibility of using the resonance absorption technique for determining the chemical composition of the Earth's atmosphere.

Projects not directly related to ASTP included the exchange of information on exploration of Venus, with Soviet scientists reporting the results of the Soviet Venera 9 and 10 missions, and U.S. scientists describing radar observations on Venus and the planned 1978 Pioneer (U.S.) Venus missions. Soviet spectrometer readings of gamma radiation from Mars were analyzed by NASA and resulted in the identification of trace amounts of three additional elements (iron, oxygen, and carbon) beyond those already found by Soviet analysis (thorium and potassium). Coordinated magnetometer observations of Earth by the NASA Applications Technology Satellite (ATS 6) and Soviet ground stations continued. Both U.S. and Soviet experiments will analyze ground and spacecraft magnetometer information using full production runs of processed data tapes. The U.S. is profiting from the lunar sample exchange, since the Soviet lunar exploration program, the latest being Luna 24, extends to areas not reached by the U.S. and there are no NASA programs for obtaining additional lunar material.

Several programs, in preparation for some time, only began to bear fruit during the year. Remote sensing of agricultural crops and natural vegetation at analogous U.S. and U.S.S.R. test sites is proceeding according to schedule. Soviet ground truth information, plus their aircraft data from the Kursk test site, will be most useful in the U.S. Large Area Crop Inventory Experiment aimed at world wheat crop prediction, as announced by the Secretary of State at the World Food Conference in Rome.

### *Technology Transfer*

In 1976 the bulk of license requests for export of space-related hardware and technology processed by the Department of State's Office of Munitions

Control involved transfer under the United States-Japanese Space Cooperation Agreement and exports to Europe. The Department continued to emphasize the export of hardware rather than the technology to produce the hardware.

### *Remote Sensing*

The Department of State conducts and supports negotiations for agreements whereby certain countries provide facilities for reception and processing of Landsat data and pay a fee, in return for which the U.S. government provides Landsat data transmitted directly from the satellite while over the coverage region of the station. This region is a circle of about 3000 kilometers radius on the Earth's surface. The countries presently operating such stations are Canada, Italy, and Brazil. Agreements have been reached with Iran, Zaire, and Chile. During 1976 the renewal of a ground station agreement with Brazil was negotiated, as was an agreement with Canada for a second station in that country.

### **Satellite Services**

#### *Communications Satellites*

The definitive agreements establishing the International Telecommunications Satellite Organization (INTELSAT) entered into force February 12, 1973, and membership in INTELSAT reached ninety-five as of September 30, 1976, with the completion of membership requirements by Bangladesh, Mali, Qatar, and the United Arab Emirates. The agreements consist of an Intergovernmental Agreement and an Operating Agreement. The U.S. government is a party to the former, and the Communications Satellite Corporation (COMSAT) is the U.S. signatory to the latter. INTELSAT consists of an Assembly of Parties, a Meeting of Signatories, a Board of Governors, and an Executive Organ under the direction of a Secretary General responsible to the Board of Governors.

During 1976 COMSAT participated in the fifth session of the Meeting of Signatories and represented the United States at the meetings of the Board of Governors held approximately every two months. The Secretary General continued to provide financial, legal, and administrative support, and COMSAT provided certain technical and operational management services to INTELSAT under a contract that runs through February 11, 1979. Also during 1976, the United States government participated at the Assembly of Parties held in Nairobi from September 27 to October 1.

In July 1976, the Board of Governors, after reviewing several proposals, authorized COMSAT as

Management Services Contractor to negotiate with the Aeronutronic Ford Corporation for the Intelsat V program. The Board of Governors at the August meeting authorized COMSAT to contract with Aeronutronic Ford for the procurement of the Intelsat V spacecraft. These satellites will have a capacity of approximately 12,000 two-way voice circuits plus two channels for color television, almost doubling the capacity of the Intelsat IV-A satellites now being utilized. The first Intelsat V is scheduled for launch in 1979, and present plans call for using the Shuttle launch vehicle for the last three launches in 1980-1982. As of September 30, 1976, there were 150 Earth-station antennas providing full-time service at 119 Earth stations in 79 countries.

#### *Maritime Satellites*

For a number of years it has been realized that a communications satellite system might be the solution to the inadequacies of the present system of communications with and between ships at sea. To this end the United States participated during the past few years in a series of international meetings convened by the Intergovernmental Maritime Consultative Organization (IMCO) to consider a global maritime satellite system. The agreements establishing a new International Maritime Satellite Organization (INMARSAT) were completed in September 1976 at the third and final session of

the INMARSAT Conference. The agreements consist of a Convention and an Operating Agreement. The Convention has been opened for signature. The United States is in the process of developing domestic procedures that would be necessary for formal U.S. participation in the organization.

#### *Aeronautical Satellites*

Negotiations regarding the establishment of an experimental aeronautical communications satellite system (AEROSAT) culminated with the entry into force on August 2, 1974, of a Memorandum of Understanding between the Federal Aviation Administration (FAA), the European Space Research Organization (ESRO, now known as the European Space Agency, ESA), and the government of Canada. The program to be undertaken is designed to test the use of communications satellites for air traffic control and civil aviation purposes. ESA has selected the Communications Satellite Corporation (COMSAT), a United States company, to be co-owner with it and Canada of the space segment to be provided; COMSAT, in turn, will lease communications capabilities to the FAA. It is planned to launch two satellites in the late 1970s. These will be placed in geostationary orbit over the Atlantic Ocean. It is thought that an operational system could be in place by the mid-1980s. AEROSAT Council meetings have been held periodically in 1976.



# Arms Control and Disarmament Agency

## Introduction

The Arms Control and Disarmament Agency is concerned with implementation of the broad goals of U.S. space policy in three areas: first, maintaining space as an environment free of military forces and weapons; second, preserving the use of space for the purposes of peacekeeping, and crisis management; and third, ensuring that other countries will not use space technology and equipment to develop strategic offensive weapons. In each of these areas, ACDA participates in the formulation of U.S. policy, in the negotiation of international agreements, and in evaluating the effect of such policies and agreements on arms control and disarmament issues.

## Demilitarization

One of the most fundamental objectives of U.S. policy relative to space is to ensure that it is not used as an arena for the testing or deployment of military forces or weapons. Two treaties relate to this goal. The Limited Test Ban Treaty (Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water) prohibits nuclear weapon tests or any other nuclear explosion in outer space. The Treaty was opened for signing in 1963. As of the end of 1976, 105 countries had ratified it and 16 countries had signed but not yet ratified. The Outer Space Treaty (Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies) specifically bans the emplacement of weapons of mass destruction in Earth orbit, on celestial bodies, or elsewhere in outer space, and it forbids the establishment of military bases, the conduct of military maneuvers, or the testing of weapons on celestial bodies. The treaty was opened for signature in 1967. As of the

end of 1976, 72 countries had ratified it and 35 countries had signed but not yet ratified.

## Crisis Management and Verification

Using space for peacekeeping activities such as crisis management is an important ACDA interest and has been reflected in several international agreements. The 1971 Agreement on Measures to Improve the U.S.-U.S.S.R. Direct Communication Link and the technical annex to that agreement provided for a secure and direct "hotline" link between the U.S. and Soviet governments via space satellite for the transmission of urgent information and requests for information in situations requiring prompt clarification. The space-based communications link between the two governments, exploiting the capabilities of the Intelsat and Molniya communication satellite systems, became operational in 1976. This is a significant step in the continuing efforts by ACDA and the U.S. Government as a whole to reduce the risk of outbreak of nuclear war.

## Space Technology

Finally, ACDA is active in the formulation of U.S. policy on bilateral and multilateral international programs for the peaceful use of space. ACDA seeks to discourage other countries from utilizing space technology and hardware for the development of strategic offensive weaponry, and it participates in the reviews that precede the export of U.S. space technology and hardware as well as those concerned with the export of U.S. avionics systems. ACDA seeks to institute and maintain safeguards that will minimize the possible exploitation of such technology and hardware for military applications, while not curtailing legitimate trade or discouraging international cooperation.



## Introduction

The basic responsibilities of the Federal Aviation Administration (FAA) are to ensure the safe and efficient utilization of the nation's airspace, by both military and civil users, and to foster the development of civil aeronautics and air commerce. To support these responsibilities, the Administration conducts a wide range of research and development activities. These activities can be grouped into two categories: those concerned with enhancing aviation safety and those designed to increase the efficiency of air navigation and air traffic control facilities.

## Aviation Safety

FAA's research, development, and engineering programs in aviation safety include activities designed to demonstrate the technical, operational, and economic feasibility of improving the operational performance of aircraft, as well as efforts to raise the performance standards for pilots and other airmen. A program looking into means of deterring or preventing acts of terrorism or other violence aboard aircraft and at airports is being vigorously pursued. An applied research program in aviation medicine seeks to identify and eliminate biomedical factors in aviation accidents and to improve the performance, health, and safety of pilots, ground personnel, and passengers. The knowledge acquired in all of these programs enables the agency to improve contemporary and future aircraft and ensure the issuance of appropriate new standards, certification criteria, and regulations.

### *Conflict Alert*

Early in 1976 FAA completed the installation of its conflict alert system, which flashes a warning signal on the radar displays used by air route traffic controllers to alert them when aircraft are potentially in conflict with each other. By January, all 20 Air Route Traffic Control Centers (ARTCCs) in the contiguous 48 states had completed the initial step of the program, which pro-

vided conflict alert in the high altitude sectors above 5500 meters; at year's end, the system was operational at 19 centers from an altitude of 3800 meters and above. By the middle of 1977 all ARTCCs are expected to operate the ATC system with a conflict alert capability extending upward from the base of radar coverage.

The conflict alert system is a computer program that has been added to the centers' central computers, which provide service to aircraft flying under instrument flight rules. The system projects what the flight paths of aircraft will be in the next two minutes. When their paths are projected to be closer than the required horizontal or vertical minimums established by FAA, the data tags that identify the aircraft (which appear on the controllers' radar scope) begin to blink and the words "conflict alert" appear next to a separate display of aircraft identities. The controller is thereby alerted to the possibility of a conflict and radios one of the pilots to give him a new heading or altitude to keep the aircraft safely separated. FAA standards require a 9-kilometer horizontal separation or a 300-meter vertical separation between aircraft flying in controlled en route airspace in the contiguous 48 states.

### *Wind Shear*

Since early 1971, six air carrier accidents have occurred in which wind shear was a major contributing factor. Wind shear—the change in speed or direction of wind encountered by descending or ascending aircraft—can have an immediate and dynamic effect on an aircraft; at a low altitude, it can be extremely hazardous. During 1976, FAA collected data to define the hazard and to find ground-based and airborne solutions. Several promising methods were investigated in flight simulators; these methods will be employed during 1977 in flight tests. A ground based detection and warning system was installed at Dulles International Airport. In addition, the agency made arrangements with the National Weather Service to undertake the prediction of wind shear conditions at



several east coast airports during the 1976–1977 fall and winter seasons.

### *Fire Safety*

If the severity of postcrash fires could be reduced, the time for emergency evacuation would be increased. During 1976, FAA completed laboratory burn tests of materials currently used in cabin interiors. The gases generated by these materials were ranked according to degree of toxic hazard. Concurrently a fire management study established the relative merits of various methods of preventing or controlling post-crash fires. An attempt was made to determine the partition geometry required to interrupt the spread of fires (including flash fires) and determine the adverse effects of fresh air feeding a cabin fire. A mathematical model was developed to simulate cabin fire propagation on a computer; after refinement, this model will predict cabin flammability characteristics quickly without actual burn tests. Full-scale burn tests were conducted on a surplus C-133 transport fuselage to verify the concepts. The fire hazard potential of typical flight attendant uniforms was also tested to improve fire safety standards for these garments. At year's end, FAA was in the process of establishing a permanent full-scale fire-test facility.

In another fire-research project, FAA and the U.S. Navy conducted small-scale crash simulation tests using modified fuel to assess the range of crash conditions in which the crash fireball could be prevented.

### *General Aviation Safety*

FAA's research and development efforts are directed at a variety of general aviation safety problems—crash survivability, pilot competence, and flight safety. Primary emphasis is placed on improving the crash-worthiness of light planes, the need for flight safety improvements to prevent crashes, and reducing pilot-related causes of crashes. During 1975 and 1976, FAA developed a mathematical technique for analyzing the responses of light-aircraft airframes to the dynamic loads that occur during a survivable crash. The technique will be validated by full-scale crash tests in cooperation with NASA. Concurrently, a technique for predicting occupant, seat, and restraint-system responses to crash loads, which had been validated earlier, was integrated into the airframe model. This study is expected to provide the basis for revised structural standards for light aircraft; it is also expected to provide a method that can be used to demonstrate compliance with the new standards.

### *Aviation Security*

FAA's civil aviation security program is designed to prevent or deter acts of terrorism or sabotage—i.e., hijacking, bomb threats, and actual bombings—aboard aircraft and at airports. The objectives of the R&D phase of this program are to conceive, design, develop, test, and evaluate new devices and ancillary equipment, as well as evaluate and assess existing devices, that will detect dangerous objects—handguns, explosives, and other weapons. During 1976, FAA

- Conducted a one-year airport operational evaluation of an automatic device designed to detect handguns and explosives hidden in handcarried luggage. The device employed x-ray absorption technology. The development of a similar device for checked baggage is underway.
- Evaluated a personnel explosive detector based on vapor-sensing technology.
- Completed a laboratory determination of explosive vapor characteristics.
- Experimented with locker designs in an effort to determine how to minimize the exposure of people to explosions at airports.
- Studied the feasibility of a thermal neutron explosive detector system and a nuclear magnetic resonance explosive detector system and began the development of engineering prototypes.

### *Aviation Medicine*

The primary purpose of FAA's medical research program is to increase pilot and aircrew effectiveness. This is a high priority objective because human error or failure ranks as a major cause of aircraft accidents. An additional objective of the program, also of high priority, is the search for improved means for aircrew and passenger survivability during various emergencies.

Among the more significant aeromedical studies conducted during 1976 were the following:

- A study was conducted on the supplemental-oxygen needs of working flight attendants during decompression. Men and women flight attendants were exposed, both while at work and at rest, to the decompression profile reported for a DC-10 decompression in 1973 over Albuquerque, New Mexico. The study showed that even mild to moderate work markedly reduced the time of useful consciousness; this was equally true for males and females. The study further showed that to remain conscious during that decompression, attendants had to obtain supplemental oxygen within 15 seconds.

Recommendations for flight attendant procedures during decompression have been made.

- Computerized data from medical examinations of airmen were studied to determine the value of periodic medical assessments. Particular attention was paid to the frequency with which safety-significant medical information had been discovered for various age groups. The results of the study, and a companion review of medical literature dealing with periodic medical examinations, will be used in determining the optimum frequency for airman examinations.
- Studies of National Transportation Safety Board Data have shown that the greatest percentage of aircraft accidents occur during the approach-to-landing phase of flight operations. Misperception and incorrect judgments of distance and altitude are major factors. FAA conducted certain baseline studies on pilots performing approach and landing operations in a visual flight simulator. The results of this and similar studies will help in improving visual approach slope aids for airports.

### **Air Traffic Control and Air Navigation**

FAA's R&D is also directed at improving the Federal airways system by applying existing technology to air traffic control and air navigation problems. The aim is to keep the current system operating safely with maximum efficiency and to provide for the expansion of the system to meet foreseeable future needs.

### ***Flight Service Station Modernization***

In October 1976, FAA's Flight Service System (FSS) was composed of 292 stations in the contiguous 48 states with an authorized staffing of 4653 flight service specialists. The system was supported by 147 radio direction finder locations, 54 remote and 476 limited-remote air/ground communications outlets, and 861 VOR/VORTAC navigation facilities. In FY 1975, the system provided approximately 58 million flight services, of which 16 million were pilot weather briefings; 8 million flight plans were filed. These services were provided to all of the flying public including scheduled air carriers and the military; however, the largest customer by far for the FSS is general aviation, now approximately 161,000 aircraft.

Present operations are highly labor-intensive. In too many cases a pilot must be provided a weather briefing for his intended route of flight by a flight service specialist. The problem is compounded by the projected doubling of demand for flight ser-

vices by 1985 and a near tripling of demand in 1990. Much of the equipment now in use is deteriorating and/or obsolete. Although advanced technology has been successfully utilized to automate the en route and the terminal elements of the air traffic control (ATC) system, none of this available technology has been applied to flight service stations. Weather data are distributed by teletype and displayed on flight service specialists clipboards—a most awkward and inefficient operation.

The importance of accurate and timely weather reporting to the safety of general aviation flights should be stressed. One study has shown that from 1964 through 1972, 2026 weather-involved accidents killed 4714 persons. These fatal weather-involved accidents represent 36.6 percent of the total general aviation accidents for the period studied.

Simply stated, the major problem facing the FSS is to provide means to satisfy the demand on the system in a more efficient, less costly manner while at the same time enhancing safety.

Recognizing the growing urgency of the problem, the Department of Transportation in the fall of 1971 formed the joint Office of the Secretary (OST)/Federal Aviation Administration (FAA) Flight Service Station Evaluation Team to analyze existing and projected FSS functions and develop recommendations for an improved FSS design. The report of the OST/FAA team recommended a new FSS concept employing automation to replace the existing labor-intensive system. A key feature was flight plan filing through remotely located terminals with little or no assistance from a flight service specialist. Automation would disseminate the vast amount of weather data in a more efficient manner, improving service, safety, and cost.

Building on this conceptual base, FAA initiated a program of system design analyses backed up by selected experiments. A very significant step in this system development was the design, fabrication, and evaluation of a flight service specialist automation system designated AWANS (Aviation Weather and NOTAMs System). AWANS has two principal objectives: first, to improve the timeliness and usability of the weather and NOTAM (Notices to Airmen) information to the flight service specialist (and to the ultimate user, the pilot); second, to improve the productivity of the system by making all of the data necessary for a briefing readily available to the briefer. The system employs mini-computers to accept, process, and store the required alphanumeric information available in today's system. This information can be called up for immediate use on cathode ray tube video displays by flight service specialist. The system also accepts and provides a video display of weather radar in-

formation available from National Weather Service radars. This system is currently in operation at the Atlanta Flight Service Station and has received enthusiastic acceptance by the flight service specialists there. The installation is serving as a functional prototype for further system development.

The next step in system development was the co-location and consolidation of the Washington Flight Service Station at the Washington Air Route Traffic Control Center (ARTCC) at Leesburg, Virginia. The consolidation has two objectives:

- (1) demonstration of the operational concept of co-locating a flight service station with an ARTCC,
- (2) demonstration of the concept of performing the functions of several FSS facilities at a single site.

This project consists of several phases:

- (1) relocate and reestablish the Washington flight service station into existing space in the Washington ARTCC (completed),
- (2) install an interim (off-the-shelf) video display system (completed),
- (3) replace the interim video display system with an automated system identical to the Atlanta AWANS,
- (4) remote the functions of several adjacent flight service stations into the relocated Washington flight service station, all to be completed by the summer of 1977.

*Discrete Address Beacon System (DABS).* This system is a key element of FAA's plans for the evolutionary upgrading of its automated air traffic control system to accommodate the projected traffic loads of the 1980s and beyond. Essentially, DABS is an advanced version of the present air traffic control radar beacon system—also known as “secondary radar”—in which an airborne transponder signals aircraft identity and altitude when triggered by signals from ground interrogator antennas mounted on a radar reflector screen. This information is processed and displayed directly on the radar scopes used by air traffic controllers. The chief advantage of DABS is its capability to interrogate and receive a transponded reply from a specific aircraft rather than from all aircraft in the zone of coverage, as is the case with the present radar beacon equipment. This would help eliminate one problem in high-density traffic areas—the overlapping and garbling of transponder replies from aircraft flying close to one another.

Since DABS addresses aircraft on an individual basis, it provides a natural means for a data link between aircraft and the ground—a link that can be used for automatic communications. The data

link will be the basis for a ground-based collision avoidance service called Intermittent Positive Control. Air traffic control computers will track aircraft using transponder and other information and flash a warning when potential traffic conflicts are detected. Moreover, since DABS has a much higher address capacity than present radar units (16,777,216 versus 4096), it will permit the assignment of a permanent identity code to all aircraft presently in operation and to those to come in the foreseeable future.

In March 1976, FAA ordered \$11.9 million worth of DABS equipment, including three ground sensors and 30 airborne transponders. The ground sensors will be co-located with radars at FAA's National Aviation Facilities Experimental Center (NAFEC) at Atlantic City, New Jersey; Philadelphia International Airport; and at Elwood, New Jersey. The airborne transponders will be installed in air carrier and general aviation aircraft. Multi-site testing of the three engineering models is not expected to begin before 1978.

#### *Microwave Landing System (MLS)*

This system is one of the most important elements of FAA's Upgraded Third Generation ATC System. The present instrument landing system (ILS), which is based largely on the technology of the 1940s, has a number of drawbacks: it can provide flight path information for only one approach path; terrain, structures, and aircraft interfere with its signals; its limited number of frequency channels cannot meet future growth demands. The MLS, presently under development by FAA, overcomes all of these limitations. Development began in the early 1970s and is now in its third phase—prototype development and evaluation.

Over the last 24 months, FAA has been testing an experimental MLS configuration at NAFEC. In mid-1976, the agency took delivery of two prototype MLS configurations from each of two contractors. One configuration (the so-called Basic Narrow Configuration) is designed for use at air carrier airports; the other (the Small Community system) is designed for use at general aviation airports. One Small Community Configuration and one Basic Narrow Configuration were deployed at NAFEC; the second Basic Configuration was installed at Crow's Landing, California. The second Small Community system will be delivered to NAFEC early in 1977. The Configurations are being deployed to provide maximum participation in the testing and demonstration by both military and civil pilots.

Meanwhile, in December 1975, the United States submitted its adopted version of the microwave

landing system—a configuration employing a time-reference scanning beacon technique—to the International Civil Aviation Organization (ICAO) for consideration as the standard international system. During 1976 ICAO's All Weather Operations Panel witnessed demonstrations of the U.S. system. ICAO is expected to select an international standard during 1977.

### *Automated Radar Terminal System III (ARTS)*

In 1975, FAA completed the installation of ARTS III, its automated terminal system, at 61 major terminal areas in the contiguous 48 states. In 1976, the agency took the initial step in enhancing the capabilities of this system when it contracted to provide 29 of the higher density terminals with primary radar tracking and improved beacon tracking. In addition, all 61 ARTS III systems will be provided with continuous radar recording capabilities.

At present, ARTS III displays alphanumeric data tags on radar scopes only for those aircraft equipped with a transponder for automatic reporting of identity and altitude. The data tags show this information as well as the computed ground speed of the aircraft. The enhanced ARTS III will enable controllers to put data tags on the radar scope for aircraft without a transponder, permitting continuous identification.

At the same time, FAA contracted for the installation of an enhanced ARTS III system in the New York terminal radar control room (TRACON). The New York ARTS III will have all the enhanced capabilities mentioned above, plus the capability to process data from four radar and beacon systems. Ground-breaking for the New York TRACON building took place in July at Mitchel Field, Long Island. The new installation will replace the present Common IFR Room at John F. Kennedy International Airport, which controls aircraft approaching and departing Kennedy, La Guardia, and Newark Airports as well as several small airports in the New York area.

### *NAS En Route Stage A*

Steps were also taken to enhance the capabilities of the automated en route system, NAS En Route Stage A, which is operational at all 20 ARTCCs in the contiguous 48 states, by launching a long-term software development program. Several types of computer program developments were contracted for. One involves a redesign of the present computer program to improve efficiency and to increase computer storage and processing capacity. The additional capacity is needed to accommodate air traffic growth and allow addition of new automation functions. Other development activities involve software changes required to accommodate such upgraded features as DABS, collision avoidance, and FSS automation.

Additionally, the contractor will develop the following new ATC automation functions:

*Flight Plan Conflict Probe.* This will provide controllers with computer assistance in the long-range planning of conflict-free paths through en route airspace. The computer will update flight plans, check an aircraft's intended flight path, determine potential conflicts, and suggest alternatives to correct potential conflicts.

*Control Message Automation.* This will process two-way communications with aircraft using data link. The system will generate a variety of aircraft control messages such as ATC command, restrictions, and weather advisories.

*Conflict Resolution.* This is an extension of the Conflict Alert program (see that heading). It will use flight plan and tracking data to give the controller suggested resolutions to potential conflicts.

*En Route Metering.* This function will help regulate air traffic passing from en route to terminal airspace control. Because acceptance rates may be exceeded by many nearly simultaneous arrivals during bad weather, smoothing the traffic flow is needed to prevent overloads in the terminal area and to minimize fuel consumption. Metering will aid the controller in sequencing traffic en route and adjusting the rate of flow into the terminal airspace.



## Introduction

The Smithsonian Astrophysical Observatory and the National Air and Space Museum, as bureaus of the Smithsonian Institution, contribute directly to national goals in aeronautics and space science both through active research in geophysics and astrophysics and programs of public education and information.

### Smithsonian Astrophysical Observatory

The research programs of the Smithsonian Astrophysical Observatory are coordinated with those of the Harvard College Observatory in a cooperative venture known as the Center for Astrophysics. With over 140 scientists and 300 supporting staff members both in Cambridge, Massachusetts, and at field stations around the world, the center represents this nation's largest observatory. The joint scientific program includes investigations in most major topics of modern astronomy, with special emphasis on space science projects in the fields of high-energy astrophysics, optical and infrared astronomy, lunar science, solar and stellar physics, and geoastronomy.

### High Energy Astrophysics

The first detection of giant bursts of x-ray emission from the centers of globular clusters of stars was made by Observatory scientists working with data taken by an experiment aboard the Astronomical Netherlands Satellite (ANS). The sudden burst of energy, comparable to the 30-fold brightening of an optical object, was seen from a cluster in the constellation Sagittarius. Subsequently, at least another dozen of these so-called "x-ray bursters" were identified, primarily by a team from the Massachusetts Institute of Technology using data from the Small Astronomy Satellite (SAS-3), but also by Observatory scientists using ANS and Uhuru data.

Smithsonian scientists also participated in the reduction of data returned earlier from the Uhuru x-ray satellite. Some 50 new x-ray sources were

identified and an expanded map of the heavens as seen in x-ray range was prepared.

An x-ray experiment using a two-dimensional low-resolution mirror and imaging system was flown aboard a rocket. In addition to observations of extragalactic x-ray sources, the experiment obtained data that produced the first x-ray map of the Perseus cluster of galaxies, showing both extended emission regions and the galaxy NGC 1275. That galaxy is the most intense source of x-ray emission discovered.

Work continued on the experiments scheduled for flight aboard the upcoming NASA series of High Energy Astronomy Observatory (HEAO) satellites, the first of which is planned for late 1977. A major effort has been devoted to construction of the cosmic x-ray telescope aboard the HEAO-B, due to fly in 1978. This telescope will be capable of detecting tens of thousands of x-ray sources, some more distant than the most distant galaxies now seen from ground-based telescopes.

### Geoastronomy

The Observatory operates a worldwide network of tracking stations equipped with both optical telescopes and laser ranging systems to observe the precise positions of artificial satellites and uses the resulting data to extract information about the Earth's shape, gravitational field, and upper atmosphere.

Lageos, an extremely dense, mechanically and electrically inert satellite fitted with retroreflectors designed by Observatory scientists, was launched by NASA on May 4. The satellite, which has an orbital lifetime estimated in millions of years, will serve as a stable reference for ground-based laser tracking stations, including those of the Observatory, thus providing data on crustal movements, polar motion, and variations in the rotation of the Earth. At an altitude of 5900 kilometers and with a magnitude of 13, the Lageos satellite was thought too faint to be acquired by the network's cameras; however, the station at Hawaii photographed the satellite on its first orbit, just 90 minutes after

launch, and other network cameras photographed the object shortly thereafter. The Mt. Hopkins, Arizona, laser obtained returns within 3 days after launch, and, within two months, more than 16,000 range measurements were achieved by the Observatory's laser network. During the next four years, geophysicists hope to obtain range data (laser-to-satellite distance) accurate to 10 centimeters, with the distances between the ground stations measured to comparable accuracies. By the 1980s, this accuracy is expected to be 2 centimeters, or about the distance that Europe and North America are suspected of drifting apart annually.

On June 16, an Observatory-designed-and-built hydrogen maser clock, so accurate that it varies only 1 second in 10 million years, was launched by NASA on a 2-hour suborbital flight to test the equivalence principle, a cornerstone of Einstein's theory of general relativity. In the test, time aboard the spacecraft was measured against a duplicate ground-based clock to an accuracy of 1 part in  $10^{14}$ . According to theory, the space clock should run faster once free of the Earth's gravitational field. The payload reached an altitude of 10,000 kilometers with a flight time of 1 hour 56 minutes. The probe maser functioned properly throughout the flight, as did the ground-based equipment. Initial analysis of the data, considered some 100 times more accurate than any previous ground-based experiments, indicates that the principle of equivalence is correct to high accuracy.

In support of research in geodesy, geophysics, and the upper atmosphere, satellite-tracking operations were conducted in close cooperation with NASA, the Centre National d'Etudes Spatiales, and the Institut für Angewandte Geodäsie. As coordinator of all international laser networks, the Observatory provided orbital elements, scheduling, and general operational support for all the overseas lasers participating in the campaign to track the Geos 3 satellite. Laser data were also acquired on a number of other retroreflector satellites for use in the development of the gravity field and geodetic models of the Earth.

An analytical theory for determining the non-gravitational effects of solar radiation pressure, albedo pressure, and infrared pressure on artificial satellites was developed for the first time. The primary theory of satellite motion was carried to third order, with the potential development of an accuracy of better than 1 centimeter for satellite applications in geodesy and geophysics.

Ionospheric data collected by the Doppler tracking experiment on the Apollo-Soyuz Test Project (ASTP) of 1975 were reduced. This experiment was designed to detect large concentrations of mass in the Earth beneath the satellites. Work this year

was devoted to removing propagation errors from raw measurements of the relative velocity between the Apollo spacecraft and the ASTP docking module, with the resulting data to be inverted into gravity-field anomalies. These data also represent valuable horizontal sounding samples of the ionosphere at the 220-kilometer orbital height.

Raw data on thermospheric composition obtained by the gas analyzer on the polar-orbiting satellite Esro 4 were reduced for use in an analysis of upper atmosphere properties. In studies of the disturbed thermosphere, the increase of the exospheric temperature over quiet conditions was found to be a function of the planetary geomagnetic index  $K_p$  and of the magnetic invariant latitude. Local changes in temperature are accompanied by variations in the height of the homopause, which, in turn, caused large changes in composition. The atmospheric perturbation propagates toward the equator, where a density wave is observed 8 hours after a magnetic disturbance.

### *Solar and Stellar Physics*

Observatory scientists continued their analysis of solar data obtained by Harvard experiments aboard the Skylab satellite during the 1973-1974 flights. Thousands of photographs were taken by two different instruments—one sensitive to ultraviolet emissions, the other to x-rays. The analyses have resulted in detailed numerical models describing the physical mechanisms for energy flow in the Sun's corona and the acceleration of the solar wind. It has been found that the solar wind, which strikes the Earth, is controlled by a magnetic field deep within the Sun. This discovery has major implications for understanding physical processes and motions below the solar surface. Moreover, this discovery may allow Earth-bound investigators to predict periods of solar-wind activity through observations of changes in the Sun's surface.

Laboratory studies of atomic and molecular processes were used in theoretical studies of the thermosphere of the Earth, for comparison with the *in situ* measurements obtained by the NASA Atmospheric Explorer Satellite system, to obtain a quantitative understanding of the physical and chemical processes. The absorption of solar extreme ultraviolet radiation and photoelectrons in the atmosphere and the photochemical equilibrium in concentrations have been calculated. Using the satellite observations, information on the free oxygen concentration, the total ionization rate due to the solar ultraviolet flux, and the thermal budget of the ionosphere can be obtained. Some preliminary studies of the upper atmosphere of Jupiter and Mars have been carried out.

## *Lunar Science*

The Observatory continues its research on lunar and meteorite samples, with Observatory scientists instrumental in organizing two consortia to coordinate research in lunar geology. One of these, the Consortium Indomitabile, worked on samples from a large lunar boulder; the other, the Consortium Imbrium, was formed to study ejecta from the Imbrium basin. In addition, the analysis of solar-wind gases trapped in the lunar materials has placed an upper limit on the amount of tritium in the solar wind and has allowed a positive identification of carbon 14.

## *Optical and Infrared Astronomy*

Ground-based optical observations have been made in conjunction with x-ray data provided by satellites to study the properties of highly condensed objects interacting with normal companions in binary systems. An identification of these bodies and studies of their variability were made, both on short and long time scales. Intensive studies were made of the centers of globular clusters that emit x-ray bursts in a search for optical clues to this unusual phenomenon. A study of abundances in Sirius has been conducted to see whether mass transfer between it and its companion could have affected nucleosynthesis in this system. Ultraviolet studies of x-ray sources will be made with the International Ultraviolet Explorer satellite.

A 1-meter balloon-borne telescope program continues with support from NASA. Although both scheduled flights in 1976 were cancelled due to failure of the gyropointing control, future flights will carry a four-color far-infrared photometer developed by the University of Palermo and a high resolution Fourier transform spectrometer designed and constructed by the Observatory with NASA support.

## **The National Air and Space Museum**

July 1, 1976, marked the opening of the National Air and Space Museum building on the Mall in Washington. This new facility of the Smithsonian Institution was developed to present and exemplify to the public the technology, science, and history of flight. Its opening, on time and within budget, constituted a major bicentennial event.

The museum was developed around the national collections of aircraft and spacecraft which include the first airplane in the world, the Wright Brothers' Kitty Hawk Flyer; Lindberg's Spirit of St. Louis; the X-1, the first supersonic airplane; Friendship 7, which was the first American manned earth-

orbiter; and the Apollo 11 spacecraft, Columbia, which carried the first men to a landing on the Moon.

The National Air and Space Museum uses its collections in twenty-three major exhibition galleries to tell the story of flight. Gallery names include Exhibition Flight, the Hall of Air Transportation, World War I Aviation, Benefits from Flight, Space Hall, Flight Technology, and Life in the Universe, to cite a few.

The efforts of research and design leading to the new museum are believed to constitute by far the largest and most ambitious single museum development program ever mounted. The galleries have been developed to present the many dimensions of flight in ways understandable (and frequently enjoyable) to the visitor, and to supply much information about the technology, science, and history of flight never presented before to the general public.

Two major presentation centers augment the museum's exhibit complex, providing visual simulations of aeronautical and space flight not previously available. These are the Spacearium, a 21-meter domed chamber housing a planetarium and many additional projectors for astronomy and space travel presentations, and the Theater, in which a five-story-high motion picture is projected to convey the realities of flight. The automated planetarium was presented to the United States by the Federal Republic of Germany as their bicentennial gift.

Public acceptance of the new museum was instantaneous and dramatic. One million visitors were recorded during the first 3½ weeks; three million during the first 3 months; and between 5 and 6 million during the museum's first six months, breaking all records for museum attendance. The museum is in full operation, encompassing an aeronautical and space flight library, an education operation with programs directed at all ages, and a research program directed at studies and publications about the technology and history of flight.

## *Flight Experiments*

Museum scientists coordinated the analysis of both verbal descriptions and some 1400 photographs of terrestrial features made by crew members on the 1975 Apollo-Soyuz mission. These data were used to support research in the fields of geology, oceanography, hydrology, and meteorology. The analysis program was pursued in cooperation with USGS, NOAA, and several other research institutions in the United States and abroad.

### *Lunar Research*

Photogeologic studies of the Mare Smythii region on the east limb of the Moon continued. The Smythii basin is of geologic interest because it is located between the Moon's near and far sides and because it is only partially filled with basaltic lavas. Several unusual multi-ringed craters occur within the basin; and studies of the most well-developed crater, Haldane, indicate these features may have resulted from extensive modification by volcanism, with many aspects common to terrestrial calderas.

The Museum's extensive collection of lunar photographs and maps was also used to study sinuous rilles in the Harbinger Mountains region of the Moon. The data indicate a slope-controlled orientation and a genetic relation to volcanic features, thus lending support to the theory that the rilles formed as lava channels or tubes.

The southeastern Mare Serenitatis area of the Moon has been mapped at a scale of 1:250,000. Data sources included Apollo photographs, analyses of samples from the Apollo 17 site, and results of Apollo orbital geochemical and geophysical sensors. Based on structural relationships within this area, a geologic history of the Serenitatis basin was deduced. The resulting sequences of tectonic events

are also applicable to major basins elsewhere on the Moon as well as on Mars and Mercury.

Cooperation continued with NASA in the lunar mapping program, particularly through participation in the "Lunar Photographic and Cartographic Committee," to choose sites for future mapping. Museum personnel also contributed to the international program to name the Moon's surface features. Nomenclature proposals were presented at the 16th General Assembly of the International Astronomical Union. A computer program was devised for the lunar nomenclature file used by both government and private cartographers.

### *Comparative Planetology*

Studies of desert landforms were begun as the first step in a program of comparative planetary research. Specifically, a synthesis of photogeologic interpretations and ground-truth information was made on eolian landforms in the Western Desert of Egypt. Photographs of this desert display some dune shapes and wind-blown features reminiscent of dunes and streaks formed by wind action on Mars. Correlations between these similar features proved significant in understanding photographs returned by the Mariner and Viking spacecraft.





## Introduction

The United States Information Agency (USIA) maintains United States Information Service (USIS) posts in 112 countries with 253 information centers and libraries and domestic support facilities for press, radio, TV, and film. The Agency's Voice of America operates 113 transmitters with broadcasts in 36 languages. The agency also produces sixteen worldwide and regional magazines, TV programs, and major exhibits. USIA officers serving at posts abroad provide a link with local opinion leaders and promote contact between U.S. and local experts. Space and aeronautics are important matters in the Agency's public affairs mission, since they are a mark of U.S. expertise in science and technology.

In USIA programming the three most significant U.S. space events in 1976 were the NASA Viking landing on Mars, the AID demonstration in developing countries of satellite technology (AID-SAT), and the USIA worldwide, satellite-beamed, bicentennial TV program "Salute by Satellite." A review of foreign media reaction to the Viking landing showed that the world press gave prominent coverage of the landing. USIS posts advised and assisted on the AIDSAT project in countries in East Asia, the Middle East, and Latin America. As a demonstration of the benefits of satellites for surveying natural resources and for communication to remote areas, the project was a media success.

## Press and Publications

Fifty-three of the 92 space-related press stories sent to USIS posts via the Agency Wireless File were on Viking. Most were written by staff science writers, but some were commissioned articles from such authorities as Carl Sagan, Isaac Asimov, Arthur C. Clarke, and Wernher von Braun. The remaining items were on weather and communications satellite programs, other NASA space research, and the Space Shuttle.

Most Agency magazines carried Viking stories this year. Titles give some idea of the content: "Mission to Mars," "Viking on Mars," "Probing the

Secret of Mars," etc. Other space-related magazine articles focused on communications and weather satellites, Mariner and Pioneer space exploration, and the new Air and Space Museum in Washington.

Over 500 copies of a news packet, "Space: the New Frontier," were distributed to overseas posts and to foreign correspondents in New York and Washington. This packet contained articles and pictures, including a preview of the Viking project.

The AIDSAT demonstration program was another space event which received continuing support. In July a special new packet, "Satellite Technology Benefits Developing Nations," was sent to the 35 posts involved in the demonstration, and copies were distributed to foreign correspondents in the U.S. Agency articles on this project received excellent placement in the foreign press.

## Films and Television

Fifteen "Salute by Satellite" programs which covered bicentennial celebrations of various ethnic groups were produced and beamed in July as a part of the bicentennial. An introduction by President Ford was transmitted to 32 countries; Vice President Rockefeller hosted the Spanish-language programs for Latin America. These programs were carried by TV stations around the world and were seen by an audience of approximately 100 million.

Twelve monthly issues of the film and TV program "Science Report" were produced and distributed. Six of these had a NASA topic—the Apollo-Soyuz link-up, Mariner 10, Landsat satellites, preparations for the Space Shuttle, and an introductory story on the Viking project. The sixth report, on the touchdown of Viking 1 and the preliminary scientific results from Mars, was the first comprehensive TV account to be released worldwide. It was telecast in 81 countries and shown as a film in many others.

USIA produced special programs on solar energy, spin-offs from the space program, satellite communication, and the opening of the National Air and

Space Museum. These were distributed on video cassettes. One 60-minute cassette—"Satellites, Servants from the Sky"—was shown in the American Pavillion in Yugoslavia at the Zagreb Space Exhibit. In addition the Agency continued to distribute abroad documentary films such as NASA's "Mission of Apollo-Soyuz" and the National Science Foundation's "Invisible Universe."

### **Information Centers and Exhibits**

The U.S. crew of the historic Apollo-Soyuz mission traveled to North Africa and the Middle East under USIA auspices. In public appearances and private meetings the crew explained the scientific work accomplished during the flights and their observations from space of several of the nations they visited. The astronauts were received by heads of state and other high government officials, top scientists, and academic leaders. Dr. Farouk El Baz of the Smithsonian National Air and Space Museum explained the potential economic and scientific values of the Apollo-Soyuz mission.

A live demonstration was given in six countries in Southeast Asia on the educational use of modern communications technology for developing nations. In Zagreb, five U.S. specialists joined Yugoslav specialists to discuss applications of satellites and space technology in contemporary problems.

A satellite communications exhibit was part of the U.S. exhibit at the Zagreb Trade Fair. Two other exhibits, both entitled "Treasures of Space," were shown in ten cities in Africa and the Middle East. Six Moon rocks, astronaut equipment, and models of satellites were shown separately in various areas.

Skylab mission commander Gerald P. Carr visited East Berlin under USIA sponsorship. Other astronauts also lectured for USIA during the year. Alan J. Bean talked about his experiences as the fourth man on the Moon and about his preparation for the Space Shuttle. Ronald E. Evans spoke at the opening of the European Space Technology Center in the Hague, and at a meeting of the Swedish Space Board in Stockholm. Astronaut Karl G. Henize ap-

peared at the 25th anniversary observance of the Hermann Oberth Society in Bremen, Germany. Press conferences on Viking Mars explorations were arranged for Cornell University astronomer Carl Sagan in Paris and London.

### **Radio**

Voice of America (VOA) in 1976 reported on the here-and-now benefits and future directions of space research. Features, interviews, and discussion programs covered topics ranging from astronaut-type meals for the elderly to prospects for a space station; from the use of satellites for locust control in Algeria to their role in uniting the world through communications. During the year there were more than 800 different features and reports in various languages on U.S. space activities. Months before the Viking landings, VOA interviewed NASA officials who described the Viking spacecraft and mission. The landing of Viking I was described, live from Pasadena, on broadcasts in English, Russian, Chinese, and Spanish. Correspondents at the Jet Propulsion Laboratory (JPL) gave spot-reports on the progress of the search for life on Mars. As the first picture from the surface of Mars appeared strip by strip on the JPL screens, scientists explained for VOA listeners what was being seen by man for the first time. Millions of Central and South American listeners heard the VOA Spanish "simulcast" as relayed by their own local radio and television stations. Similar coverage was given to Viking 2. A special feature, "Martian Perspective," reviewed the results of the Viking mission with scientists Gerald Soffen, Michael McElroy, Carl Sagan, and Harold Klein.

VOA correspondents traveled to various locations to report on space activities in the U.S. Multilingual broadcasts covered conferences at the Ames Research Center, California, and at Philadelphia and Cape Canaveral. Michael Collins, former astronaut and Director of the new Air and Space Museum, acted as host in a special feature on the opening of the Museum in Washington.

# 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	1967	78	4	10	0
1958	5	8	0	4	1968	61	15	3	0
1959	9	9	1	2	1969	58	1	8	1
1960	16	12	1	2	1970	36	1	3	0
1961	35	12	0	2	1971	45	2	8	1
1962	55	12	4	1	1972	33	2	8	0
1963	62	11	0	0	1973	23	2	3	0
1964	69	8	4	0	1974	27	2	1	0
1965	93	7	4	1	1975	30	4	4	0
1966	94	12	7	1	1976	33	0	1	0
					Total	862	125	70	15

<sup>1</sup> This Earth escape failure did attain Earth orbit and therefore is included in the Earth-orbit success totals.

NOTES: The criterion of success or failure used is the 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.

"ESCAPE" flights include all that were intended to go to at least an altitude equal to lunar distance from Earth.

## 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	People's Republic of China	Australia	United Kingdom
1957		2						
1958	5	1						
1959	10	3						
1960	16	3						
1961	29	6						
1962	52	20						
1963	38	17						
1964	57	30						
1965	63	48	1					
1966	73	44	1					
1967	57	66	2	1			1	
1968	45	74						
1969	40	70						
1970	28	81	2	1	1	1		
1971	30	83	1	2	2	1		1
1972	30	74		1	1			
1973	23	86						
1974	22	81		2	1			
1975	27	89	3	1	2	3		
1976	26	99			1	2		
Total	671	977	10	8	8	7	1	1

<sup>1</sup> Includes foreign launchings of U.S. spacecraft.

NOTE: This tabulation enumerates launchings rather than

spacecraft. Some launches did successfully orbit multiple spacecraft.

## Successful U.S. Launches—1976

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period (minutes) Inclination to equator (degrees)	Remarks
Jan. 15 Helios 2 3A Titan IIIE-Centaur	<p>Objective: To investigate the fundamental solar processes and solar terrestrial relationships by the study of phenomena such as solar wind, magnetic and electric fields, cosmic rays, and cosmic dust. The basic mission extends from launch to the first perihelion (approximately 0.31 A.U. and 90 days after launch).</p> <p>Spacecraft: Spool-shaped satellite formed by two conical solar arrays attached to a 16-sided cylindrical central body; the central compartment is 1.75-m in diameter and 0.55-m high. Largest diameter of the solar arrays is 2.77-m and satellite height without antenna mast is 2.12-m; with the antenna mast protruding above the solar array, spacecraft height is 4.20-m. Two deployable booms attached to the central body measure 32-m tip-to-tip when extended and are used as antennas for a radiowave experiment; two other deployable booms, attached to the central body and perpendicular to the antenna booms, carry three magnetometer experiments. Solar cells located on the solar arrays above and below spacecraft body; second surface mirrors are interspersed among the solar cells to radiate excess heat; silver zinc batteries. Active and passive thermal control subsystem; attitude control subsystem; three antennas for communications and telemetry; carries 13 experiments. Weight: 370 kg.</p>	Helio-centric orbit	Second West German-built satellite successfully launched by NASA into elliptical solar orbit. Spacecraft orbit will take it closer to Sun than any man-made object has achieved to date (43 million km). Results will contribute more information on the solar corona, physical processes active on the Sun, and unexpected micrometeorite results observed on Helios 1. All 10 active experiments have been turned on and are functioning normally. First perihelion occurred April 17, 1976.
Jan. 17 CTS-1 4A Thor-Delta	<p>Objective: To advance the technology of spacecraft-mounted and related ground-based components and systems applicable to high-radiated-RF-power satellites. Specific objectives of two-way television and voice communication; wide-band data transmission and data relay to small, low-cost ground stations; maintain antenna pointing accuracy; and obtain 1-kw of useful power to the spacecraft from the unfurled solar-cell array.</p> <p>Spacecraft: Rectangular box-shaped spacecraft, two sides being curved, with a deployable 2-panel solar array. Overall height and outside diameter are 188-cm and 183-cm. Solar panels are mounted on curved panels on two sides of the spacecraft. The forward platform carries the super-high-frequency antennas and earth sensors. The aft platform consists of the reaction control system. The 2 extendible solar arrays are mounted on the north and south panels. The total span of the satellite is 15.8-m when the 2 solar arrays are fully extended. Earth-oriented satellite receives signals at 14 GHz and converts them to 12 GHz for retransmission to the ground. Weight in orbit: 347 kg.</p>	36,022 33,814 1392 0.7	Launched by NASA, the joint Canadian/U.S. satellite is the most powerful communications satellite to date. Apogee kick motor fired Jan. 20 and satellite stationed at 116° west longitude over Atlantic Ocean in slightly elliptical orbit. On Jan. 29 arrived on station and operations handed over to Communications Research Centre, Canadian Department of Communications.

## Successful U.S. Launches—1976

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period (minutes) Inclination to equator (degrees)	Remarks
Jan. 29 Intelsat IV-A F-2 10A Atlas-Centaur	Objective: To provide 6250 two-way voice circuits plus two television channels simultaneously or a combination of telephone, TV, and other forms of communications traffic. Spacecraft: Overall height of 6.99-m and 2.38-m in diameter. Consists of two main elements: rotating cylinder covered with solar cells contains power subsystem; positioning and orientation subsystem, apogee motor, and despin control subsystem; despun Earth-oriented platform atop rotating cylinder contains 20 communications repeaters (transponders), new antenna reflectors, and telemetry and command subsystems. Antenna reflectors are supported by a single tubular mast. 134.6-cm transmit and 88.9-cm receive quasi-square reflectors are constructed of a metallic mesh on an open web frame. Feed horn arrays and global horns are cantilevered from the base of the mast. Telemetry and command omnidirectional bicone antenna is mounted on the mast tip. Weight at liftoff: 1515 kg. Weight after apogee motor fire: 825.5 kg.	35,869 35,084 1420.2 0.1	Second in a series of improved Intelsat IV-A spacecraft has twice the communications capacity of Intelsat IV series. Launched by NASA for Comsat Corp., manager of Intelsat. Apogee motor fired Jan. 31 and satellite stationed at 29.5° west longitude over Atlantic Ocean. To serve as back-up for first Intelsat IV-A launched Sept. 25, 1975.
Feb. 19 Defense 16A Thor-Burner 2	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	355 90 89.0 98.9	Achieved only a low orbit and decayed Feb. 19, the day of launch. Though satellite fulfilled Cospas rules for successful orbit, DoD does not count it as successful.
Feb. 19 Marisat 1 17A Thor-Delta	Objective: To launch satellite into synchronous transfer orbit. Satellite to provide 24-hour real-time communications between ships and shore. Spacecraft: Cylindrical shape, 380-cm high and 215-cm in diameter; spin stabilized; 44 duplex teleprinter channels and one two-way voice circuit; cylinder covered with 7000 solar cells contains power subsystems, apogee motor, and despin control subsystems. Spacecraft has 3 UHF helical antenna array and quad L-band array antenna mounted on single pole extending from spacecraft body. Command and telemetry antenna located at end of antenna boom. Weight at launch: 654 kg. Weight after apogee motor fire: 327 kg.	35,867 35,703 1436.1 2.4	First in a series of maritime satellites. Launched by NASA for Comsat Corp. Apogee motor fired Feb. 21 and satellite stationed at 15° west longitude over Atlantic Ocean. During first two years the prime user of UHF will be U.S. Navy. Began telephone operation July 9 and telex operations July 29; Navy service began Mar. 25.
Mar. 15 LES-8 23A Titan IIIC	Objective: To evaluate advanced satellite communications techniques. Spacecraft: Communications satellite with protective hardening and radioisotope electric power source: Weight: 454 kg.	35,787 35,787 1436.1 25.0	Still in orbit.
Mar. 15 LES-9 23B Titan IIIC	Objective: To evaluate advanced satellite communications techniques. Spacecraft: Communications satellite with protective hardening and radioisotope electric power source: Weight: 454 kg.	35,787 35,787 1436.1 25.0	Still in orbit.
Mar. 15 Solrad HiA 25C Titan IIIC	Objective: To measure solar x-rays, ultraviolet light, and particle emissions. Spacecraft: Scientific instrumentation and four solar panels. Weight: 181 kg.	119,180 118,383 7344.3 25.7	Still in orbit.

## Successful U.S. Launches—1976

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period (minutes) Inclination to equator (degrees)	Remarks
Mar. 15 Solrad HiB 25D Titan IIIC	Objective: To measure solar x-rays, ultraviolet light, and particle emissions. Spacecraft: Scientific instrumentation and four solar panels. Weight: 181 kg.	116,645 115,720 7116.7 25.6	Still in orbit.
Mar. 22 Defense 27A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	347 125 89.3 96.4	Decayed May 18, 1976.
Mar. 26 RCA-Satcom-2 29A Thor-Delta	Objective: To provide television, voice channels, and high-speed data transmission to Hawaii, Alaska, and contiguous United States; to operate all 24 transponder channels at specified power throughout the minimum 8-year satellite lifetime. Spacecraft: Box-shaped 1.2-m x 1.2-m x 1.6-m high with two rectangular solar panels extending from the spacecraft on short booms. Hydrazine propellant tanks protrude from both east and west panels of spacecraft body; the two remaining main body panels support communications transponders and housekeeping equipment. During operation spacecraft is three-axis stabilized. Three nickel-cadmium batteries. Weight at launch: 868 kg. Weight after apogee motor fire: 463 kg.	35,882 35,642 1434.9 0.3	Second in a series of three RCA commercial satellites. Launched by NASA into transfer orbit. Apogee boost motor fired Mar. 29 and spacecraft placed in stationary orbit at 135° west longitude over equator. Commercial operations began June 7, 1976.
Apr. 22 NATO III A 35A Thor-Delta	Objective: To launch spacecraft into synchronous orbit over equator for use by NATO. Spacecraft: Drum-shaped 2.2-m in diameter, 2.23-m long, with overall length of 3.1-m, including antennas. Weight at launch: 720 kg. Weight after apogee motor fire: 310 kg.	35,794 35,782 1436.2 2.7	First of three planned NATO communications satellites. Launched by NASA for NATO. Apogee kick motor fired Apr. 24 and satellite stationed at 15.5° west longitude due south of the westernmost coast of Africa.
Apr. 30 Defense 38A Atlas F	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	1128 1092 107.5 63.5	Still in orbit.
Apr. 30 Defense 38C Atlas F	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	1129 1093 107.5 63.4	Still in orbit.
Apr. 30 Defense 38D Atlas F	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	1130 1093 107.5 63.4	Still in orbit.
Apr. 30 Defense 38J Atlas F	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	1139 1083 107.4 63.4	Still in orbit.
May 4 Lageos 39A Thor-Delta	Objective: To provide permanent reference point in orbit for precision Earth-dynamics measurement; demonstrate capability of laser satellite tracking techniques; and make accurate measurements of Earth's rotation and movement of the crust. Spacecraft: Aluminum sphere 60-cm in diameter with 426 laser retroreflectors mounted on surface of spacecraft. To obtain density for stable orbit, two aluminum hemispheres are bolted together around a solid brass core. Weight: 411 kg.	5944 5835 225.4 109.9	The Laser Geodynamic Satellite (Lageos) was launched successfully by NASA. Useful life of satellite estimated at 50 years, but will remain in orbit for more than 8 million years. Operations began May 6.

## Successful U.S. Launches—1976

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period (minutes) Inclination to equator (degrees)	Remarks
May 13 Comstar 1 42A Atlas-Centaur	Objective: To launch satellite into synchronous transfer orbit. Satellite to provide contiguous U.S., Hawaii, Alaska, and Puerto Rico with 14,400 two-way high quality voice circuits. Spacecraft: Cylindrical 244-cm diameter and 610-cm high; spin stabilized; solar cells are mounted on spacecraft exterior; 24 transponders, 12 horizontally polarized and 12 vertically polarized permit reuse of same frequencies by satellite, resulting in doubling the effective capacity of each spacecraft by making more efficient use of radio spectrum. Weight at launch: 1518 kg. Weight after apogee motor fire: 816.5 kg.	35,802 35,269 1423.3 0.1	First of planned three satellite network owned by Comsat and leased by American Telephone and Telegraph Company. Launched by NASA for Comsat. Apogee kick motor fired May 15 and spacecraft placed in stationary orbit at 128° west longitude over Pacific Ocean. Commercial operations began July 24.
May 22 P 76-5 Wideband 47A Scout	Objective: To evaluate certain propagation effects of disturbed plasma on radar and communication systems. Spacecraft: Box-shaped spacecraft with four deployable solar arrays. Experiment package of multiple antenna array. Weight: 72.6 kg.	1058 993 105.7 99.7	Launched by NASA for U.S. Air Force. Spacecraft operated as planned, mission objectives were achieved.
June 2 Defense 50A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	39,259 312 700 62.5	Still in orbit.
June 10 Marisat 2 53A Thor-Delta	Objective: To launch satellite into synchronous transfer orbit. Satellite to provide 24-hour real-time communications between ships and shore. Spacecraft: Cylindrical 380-cm high and 215-cm diameter; spin stabilized; 44 duplex teleprinter channels and one two-way voice circuit; cylinder covered with 7000 solar cells containing power subsystems, apogee motor, and despin control subsystems. Spacecraft has 3 UHF helical antenna array and quad L-band array antenna mounted on single pole extending from spacecraft body. Command and telemetry antenna located at end of antenna boom. Weight at launch: 654 kg. Weight after apogee motor fire: 327 kg.	35,807 35,788 1436.6 2.5	Second in a series of maritime satellites. Launched by NASA for Comsat Corp. Apogee motor fired June 11 and satellite stationed at 176.5° east longitude over Pacific Ocean. During first two years the prime user of UHF will be U.S. Navy. Began commercial operations Aug. 15, Navy service began June 28.
June 18 Gravity Probe A (Red Shift Experiment) sub-orbital Scout	Objective: To test Einstein's "equivalence principle", which is the foundation of relativity theory. Probe: 114-cm long, 96-cm diameter; extremely accurate hydrogen maser atomic clock; support equipment consists of S-band telemetry transponder, battery, and cooling system. Weight: 102 kg.		Launched by NASA into an elliptical flight of one hour and 55 minutes over Atlantic Ocean. Maximum altitude 10,000 km. Data substantially confirmed equivalence aspect of the theory.
June 26 Defense 59A Titan IIIC	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	35,860 35,620 1433.3 0.5	Still in orbit.
July 8 Defense 65A Titan IIID	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	242 159 88.5 97.0	Still in orbit.

## Successful U.S. Launches—1976

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period (minutes) Inclination to equator (degrees)	Remarks
July 8 SESP 74-2 65B Titan IIID	Objective: To measure the intensity, distribution, and effects of protons, electrons, and alpha particles in space. Spacecraft: Not announced.	8048 236 179.0 97.5	Carries five experiments for Air Force Geophysics Laboratory and three experiments for Office of Naval Research. Still in orbit.
July 8 Defense 65C Titan IIID	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	632 628 97.3 96.4	Decayed Dec. 13.
July 8 Palapa 1 66A Thor-Delta	Objective: To launch satellite into synchronous transfer orbit. Satellite to provide transmission of television, voice, and other data throughout Indonesia. Spacecraft: Cylindrical 1.8-m diameter and 3.3-m high; despun Earth-oriented antenna assembly affixed to top of spacecraft. Provides 12 RF channels, two of which will be protection channels for 10 traffic carrying channels; 23,000 solar cells. Weight at launch: 574 kg.; weight in orbit: 281 kg.	35,809 35,764 1436.1 0.0	Launched by NASA for Indonesia into transfer orbit. Apogee motor fired July 11 and spacecraft placed in stationary orbit above equator at 83° east longitude. First message sent via satellite by President Suharto on August 17, 1976.
July 22 Comstar 2 73A Atlas-Centaur	Objective: To launch spacecraft into synchronous transfer orbit. Satellite to provide contiguous U.S., Hawaii, Alaska, and Puerto Rico with 14,400 two-way high quality voice circuits. Spacecraft: Cylindrical 244-cm diameter and 610-cm high; spin stabilized; solar cells are mounted on spacecraft exterior; 24 transponders, 12 horizontally polarized and 12 vertically polarized, permit reuse of same frequencies by satellite. Weight at launch: 1518 kg. Weight after apogee motor fire: 816.5 kg.	35,747 35,388 1425 0.2	Second of three planned satellite network owned by Comsat and leased to American Telephone and Telegraph Company. Launched by NASA for Comsat. Apogee kick motor fired July 24 and spacecraft placed in stationary orbit at 95° west longitude below southwestern U.S. Commercial operations began Sept. 13, 1976.
July 29 Noaa 5 (ITOS H) 77A Thor-Delta	Objective: To place spacecraft in a Sun-synchronous orbit having a local equator crossing time of approximately 8:30 a.m., descending to permit regular and dependable daytime and nighttime meteorological observations in both direct read-out 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 102-cm by 102-cm and the overall height is about 122-cm. The total area of the array is 4.5 sq m with each of the 3 panels measuring 93-cm by 162-cm. 3-axis stabilized, Earth-oriented satellite carries primary sensor complement of 2 Very High Resolution Radiometer (VHRR) instruments and 2 Scanning Radiometer (SR) sensors for daytime and nighttime coverage, 2 Vertical Temperature Profile Radiometers (VTPR) which permit determination of the Earth's vertical temperature profile over every part of the Earth's surface at least twice daily, and 1 secondary sensor, the Solar Proton Monitor (SPM), which provides continuous measurements of proton and electron flux activity near the Earth. Thermal control system; 4 antennas. Weight: 345 kg.	1521 1505 116.3 102.1	Fifth operational satellite of a series of second generation meteorological satellites launched by NASA. Part of NOAA global weather watch program. Spacecraft functioning normally and was turned over to NOAA on Aug. 20, 1976, for operational use. Replaced Noaa 4 which became the back-up spacecraft.



## Successful U.S. Launches—1976

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (kilometers) Period (minutes) Inclination to equator (degrees)	Remarks
Aug. 6 Defense 80A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	39,315 380 703.8 63.3	Still in orbit.
Sept. 1 Transit Improvement Program (TIP) 3 89A Scout	Objective: To test a developmental satellite providing improved operational characteristics for the Transit navigation system; to be integrated into the operational Transit system. Spacecraft: Solar panels and accordion-like boom deploy from main satellite body after insertion into proper orbit; hydrazine-fueled motor. Weight: 166 kg.	787 341 96.0 90.3	Third in a series of improved Transit Navigation Satellites. Launched by NASA for the U.S. Navy into an elliptical transfer orbit. Solar panels failed to deploy as planned. Navy attempting to salvage mission.
Sept. 11 Defense 91A Thor-Burner 2	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	848 818 101.6 98.7	Still in orbit.
Sept. 15 Defense 94A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	330 135 89.2 96.4	Decayed November 5, 1976.
Oct. 14 Marisat 3 101A Thor-Delta	Objective: To launch satellite into synchronous transfer orbit. Satellite to provide 24-hour real-time communications between ships and shore. Spacecraft: Cylindrical 380-cm high and 215-cm diameter; spin stabilized; 44 duplex teleprinter channels and one two-way voice circuit; cylinder covered with 7000 solar cells containing power subsystems, apogee motor, and despun control subsystems. Spacecraft has 3 UHF helical antenna array and quad L-band array antenna mounted on single pole extending from spacecraft body. Command and telemetry antenna located at end of antenna boom. Weight at launch: 654 kg. Weight after apogee motor fire: 327 kg.	36,525 35,051 1436.2 2.6	Third in a series of maritime satellites. Launched by NASA for Comsat Corp. Apogee motor fired Oct. 16 and satellite stationed over Pacific Ocean for check out. Satellite was stationed over Indian Ocean at 73° east longitude in December 1976. To be used by the Navy as a spare in orbit should either Marisat 1 or 2 fail.
Dec. 19 Defense 125A Titan IIIB	Objective: Development of spaceflight techniques and technology. Spacecraft: Not announced.	530 244 92.3 96.9	Still in orbit.

## U.S. Applications Satellites 1972-1976

Date	Name	Launch Vehicle	Remarks
COMMUNICATIONS			
Jan. 22, 1972	Intelsat IV (F-4)	Atlas-Centaur	Third in new high capacity series. Positioned over Pacific.
June 13, 1972	Intelsat IV (F-5)	Atlas-Centaur	Fourth in new high capacity series. Positioned over Indian Ocean.
Oct. 15, 1972	Oscar VI	Thor-Delta (TAT)	Amateur radio relay.
Nov. 9, 1972	Anik 1 (Telesat 1)	Thor-Delta (TAT)	Launched for Canada.
Apr. 20, 1973	Anik 2 (Telesat 2)	Thor-Delta (TAT)	Launched for Canada.
Aug. 24, 1973	Intelsat IV (F-7)	Atlas-Centaur	Fifth in high-capacity series. Positioned over Atlantic.
Dec. 13, 1973	DSCS 2-3,4	Titan IIIC	Follow-on to DSCS 2-1,2.
Jan. 19, 1974	Skynet 2A	Thor-Delta (TAT)	Launched for the United Kingdom in response to an agreement to augment the DSCS program. Spacecraft failed to achieve the proper orbit.
Apr. 13, 1974	Westar 1	Thor-Delta (TAT)	Launched for the Western Union Co. to establish a domestic communications link.
May 30, 1974	ATS 6	Titan IIIC	Multipurpose experimental satellite especially designed for regional services in North America and later India.
Oct. 10, 1974	Westar 2	Thor-Delta (TAT)	Launched for the Western Union Co. as part of their domestic communications links.
Nov. 21, 1974	Intelsat IV (F-8)	Atlas-Centaur	Sixth in high-capacity series. Positioned over Pacific.
Nov. 23, 1974	Skynet 2B	Thor-Delta (TAT)	Launched for the United Kingdom in response to an agreement to augment the DSCS program. Spacecraft positioned over Indian Ocean.
Dec. 19, 1974	Symphonie 1	Thor-Delta (TAT)	First of two experimental satellites for France and West Germany. Spacecraft positioned over Atlantic.
May 7, 1975	Anik 3 (Telesat 3)	Thor-Delta (TAT)	Launched for Canada.
May 22, 1975	Intelsat IV (F-1)	Atlas-Centaur	Eighth in high-capacity series. Positioned over Indian Ocean.
Aug. 27, 1975	Symphonie 2	Thor-Delta (TAT)	Launched for France and West Germany. Positioned over the Atlantic.
Sep. 26, 1975	Intelsat IV-A (F-1)	Atlas-Centaur	First of a new series double the capacity of its predecessors. Positioned over the Atlantic.
Dec. 13, 1975	RCA-Satcom-1	Thor-Delta (TAT)	Launched for RCA as first of their communications satellite series. Positioned over the Pacific.
Jan. 17, 1976	CTS-1	Thor-Delta (TAT)	Canadian-U.S., most powerful experimental satellite.
Jan. 30, 1976	Intelsat IV-A (F-2)	Thor-Delta (TAT)	Positioned over Atlantic.
Feb. 19, 1976	Marisat 1	Thor-Delta (TAT)	For maritime use by Comsat, over the Atlantic.
Mar. 15, 1976	LES 8/9	Titan IIIC	Experimental satellites with radioisotope power sources.
Mar. 26, 1976	RCA-Satcom 2	Thor-Delta (TAT)	Second of three.
Apr. 22, 1976	NATO IIIA	Thor-Delta (TAT)	First of new series.
May 13, 1976	Comstar 1	Atlas-Centaur	Placed over Pacific for AT&T by Comsat.
June 10, 1976	Marisat 2	Thor-Delta (TAT)	For maritime use by Comsat, over the Pacific.
July 8, 1976	Palapa 1	Thor-Delta (TAT)	Indonesian domestic communications.
July 22, 1976	Comstar 2	Thor-Delta (TAT)	Placed south of the United States for AT&T by Comsat.
Oct. 14, 1976	Marisat 3	Thor-Delta (TAT)	Placed over Indian Ocean.

## U.S. Applications Satellites 1972-1976

Date	Name	Launch Vehicle	Remarks
<b>WEATHER OBSERVATION*</b>			
Oct. 15, 1972	NOAA-2 (ITOS D)	Thor-Delta	Second generation operational meteorological satellite.
Dec. 11, 1972	Nimbus 5	Thor-Delta	Provided the first atmospheric vertical temperature profile measurements through clouds.
Nov. 6, 1973	NOAA-3 (ITOS F)	Thor-Delta	Second generation operational meteorological satellite.
May 17, 1974	SMS-1	Thor-Delta	First full-time weather satellite in synchronous orbit.
Nov. 15, 1974	NOAA-4 (ITOS G)	Thor-Delta	Second generation operational meteorological satellite.
Feb. 6, 1975	SMS-2	Thor-Delta	Second full-time weather satellite in synchronous orbit.
June 12, 1975	Nimbus 6	Thor-Delta	To build numerical models for Global Atmospheric Research Program.
Oct. 16, 1975	Goes 1	Thor-Delta	First fully operational synchronous weather satellite.
July 29, 1976	NOAA-5 (ITOS H)	Thor-Delta	Second generation operational satellite.
<b>EARTH OBSERVATION</b>			
July 23, 1972	ERTS-1	Thor-Delta	Acquired synoptic multi-spectral repetitive images that are proving useful in such disciplines as agriculture and forestry resources, mineral and land resources, land use, water resources, marine resources, mapping and charting, and the environment.
Jan. 22, 1975	Landsat 2	Thor-Delta	Second experimental Earth resources technology satellite.
<b>GEODESY</b>			
Apr. 9, 1975	Geos 3	Thor-Delta	To measure geometry and topography of ocean surface.
May 4, 1976	Lageos	Thor-Delta	Laser geodynamic satellite.
<b>NAVIGATION</b>			
Sept. 2, 1972	Triad O1-1	Scout	First experimental station-keeping Transit navigation satellite.
Oct. 30, 1973	NavSat O-20	Scout	
Jul. 14, 1974	NTS 1	Atlas F	Navigation technology satellite.
Oct. 12, 1975	Tip-2	Scout	Transit Improvement Program.
Sep. 1, 1976	Tip-3	Scout	Transit Improvement Program.

\* Does not include Department of Defense weather satellites which are not individually identified by launch.

## U.S.-Launched Scientific Payloads 1972-1976

Date	Name	Launch Vehicle	Remarks
Jan. 31, 1972	HEOS A-2	Thor-Delta	Investigate interplanetary space and high latitude magnetosphere. (International cooperative payload.)
Mar. 12, 1972	TD-1	Thor-Delta	Seven ESRO experiments.
Aug. 13, 1972	MTS (Explorer 46)	Scout	Meteoroid penetration rate study.
Aug. 21, 1972	OAO 3	Atlas-Centaur	Precise astronomical observation from above the atmosphere.
Sep. 23, 1972	IMP 9 (Explorer 47)	Thor-Delta	Study cislunar space radiation environment, plus magnetic data.
Oct. 2, 1972	Radcat	Atlas-Burner II	Defense scientific experiment.
Oct. 2, 1972	Radsat	Atlas-Burner II	Defense scientific experiment.
Nov. 15, 1972	SAS B (Explorer 48)	Scout	Survey of high energy gamma radiation including point sources. (Italian launched.)
Nov. 22, 1972	ESRO 4	Scout	Polar ionosphere studies (ESRO payload.)
Dec. 16, 1972	Aeros I	Scout	Study of upper atmosphere and ionospheric F region. (German payload.)
June 10, 1973	Radio Astronomy 2 (Explorer 49)	Thor-Delta	Measure galactic and solar radio noise shielded from earth by the moon, by use of lunar orbit.
Oct. 26, 1973	IMP 10 (Explorer 50)	Thor-Delta	Study of interplanetary environment particle and fuel interactions in the distant magneto tail.
Dec. 16, 1973	Atmosphere (Explorer 51)	Thor-Delta	Photochemical processes in absorption of solar UV.
Feb. 18, 1974	San Marco 4	Scout	Diurnal variations in equatorial neutral atmosphere. (Italian payload and launch.)
Mar. 9, 1974	UK X-4 (Miranda)	Scout	Measure density of sun reflecting particles near the spacecraft, and test engineering systems. (United Kingdom payload.)
June 3, 1974	Hawkeye (Explorer 52)	Scout	Plasma properties of the magnetosphere over the north polar cap.
July 16, 1974	Aeros 2	Scout	Measure aeronomic parameters of upper atmosphere and solar UV. (German payload.)
Aug. 30, 1974	ANS	Scout	Study stellar UV and x-ray sources. (Netherlands payload.)
Oct. 15, 1974	Ariel 5	Scout	Study galactic and extragalactic x-ray sources. (United Kingdom payload.)
Nov. 15, 1974	INTASAT	Thor-Delta	Measure ionospheric total electron content, ionospheric irregularities and scintillation. Spanish payload.
May 7, 1975	SAS-C (Explorer 53)	Scout	Measure X-ray emission of discrete extragalactic sources. (Italian-launched.)
June 21, 1975	OSO-8	Thor-Delta	To study minimum phase of solar cycle.
Aug. 9, 1975	COS-B	Thor-Delta	Extraterrestrial gamma radiation studies. (ESA European satellite.)
Oct. 6, 1975	Atmosphere (Explorer 54)	Thor-Delta	Photochemical processes in absorption of solar energy.
Nov. 20, 1975	Atmosphere (Explorer 55)	Thor-Delta	Photochemical processes in absorption of solar energy. Measure spatial distribution of ozone.
Mar. 15, 1976	Solrad HiA/HiB	Titan IIIC	Measure radiation and particles at close to 120,000 km circular.
May 22, 1976	P-76-5	Scout	Plasma effects on radar and communications.
July 8, 1976	SESP 74-2	Titan IIID	Particle measurements up to 8000 km.

## U.S.-Launched Space Probes 1972-1976

Date	Name	Launch Vehicle	Remarks
May 30, 1971	Mariner 9	Atlas-Centaur	Mars orbital photographic mission. Entered orbit of Mars Nov. 13, 1971. Returned 6876 pictures and data on temperatures, elevations, and water vapor.
Mar. 3, 1972	Pioneer 10	Atlas-Centaur	Jupiter flyby mission. Passed Jupiter on Dec. 3, 1973, returned color pictures and data on radiation, temperatures, and magnetic fields. Accelerated toward solar system escape.
Apr. 6, 1973	Pioneer 11	Atlas-Centaur	Jupiter flyby mission. Passed Jupiter on Dec. 2, 1974, returning pictures and data and headed for a similar pass by Saturn before accelerating out of the solar system.
Nov. 3, 1973	Mariner 10	Atlas-Centaur	Venus and Mercury flyby mission. Passed Venus on Feb. 5, 1974, returning good quality pictures. Passed Mercury again on Sep. 21, 1974, returning 500-600 good quality pictures. Passed Mercury again on Mar. 16, 1975. Other data were also returned.
Dec. 10, 1974	Helios 1	Titan IIIE-Centaur	Investigate properties of interstellar space close to Sun. W. German payload.
Aug. 20, 1975	Viking 1	Titan IIIE-Centaur	Mars lander and orbiter mission, arrived in mid-1976, orbited, landed.
Sep. 9, 1975	Viking 2	Titan IIIE-Centaur	Mars lander and orbiter mission, arrived in mid-1976, orbited, landed.
Jan. 15, 1976	Helios 2	Titan IIIE-Centaur	Investigate properties of space close to Sun. W. German payload.

## 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 h 48 min.	First manned flight.
Mercury-Redstone 3	May 5, 1961	Alan B. Shepard, Jr.	15 min.	First U.S. flight; suborbital.
Mercury-Redstone 4	July 21, 1961	Virgil I. Grissom	16 min.	Suborbital; capsule sank after landing.
Vostok 2	Aug. 6, 1961	Gherman S. Titov	25 h 18 min.	First flight exceeding 24 h.
Mercury-Atlas 6	Feb. 20, 1962	John H. Glenn, Jr.	4 h 55 min.	First American to orbit.
Mercury-Atlas 7	May 24, 1962	M. Scott Carpenter	4 h 56 min.	Landed 400 km from target.
Vostok 3	Aug. 11, 1962	Andrian G. Nikolayev	94 h 22 min.	First dual mission (with Vostok 4).
Vostok 4	Aug. 12, 1962	Pavel R. Popovich	70 h 57 min.	Came within 6 km of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr.	9 h 13 min.	Landed 8 km from target.
Mercury-Atlas 9	May 15, 1963	L. Gordon Cooper, Jr.	34 h 20 min.	First long U.S. flight.
Vostok 5	June 14, 1963	Valery F. Bykovsky	119 h 6 min.	Second dual mission (with Vostok 6).
Vostok 6	June 16, 1963	Valentina V. Tereshkova	70 h 50 min.	First woman in space; within 5 km of Vostok 5.
Voskhod 1	Oct. 12, 1964	Vladimir M. Komarov Konstantin P. Feoktistov Dr. Boris G. Yegorov	24 h 17 min.	First 3-man crew.
Voskhod 2	Mar. 18, 1965	Aleksei A. Leonov Pavel I. Belyayev	26 h 2 min.	First extravehicular activity (Leonov, 10 min).
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	4 h 53 min.	First U.S. 2-man flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White, 2d	97 h 56 min.	21-min. extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	190 h 55 min.	Longest-duration manned flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	330 h 35 min.	Longest-duration manned flight to date.
Gemini 6-A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	25 h 51 min.	Rendezvous within 0.3 m of Gemini 7.
Gemini 8	Mar. 16, 1966	Neil A. Armstrong David R. Scott	10 h 41 min.	First docking of 2 orbiting spacecraft (Gemini 8 with Agena target rocket).
Gemini 9-A	June 3, 1966	Thomas P. Stafford Eugene A. Cernan	72 h 21 min.	Extravehicular activity; rendezvous.
Gemini 10	July 18, 1966	John W. Young Michael Collins	70 h 47 min.	First dual rendezvous (Gemini 10 with Agena 10, then Agena 8).
Gemini 11	Sept. 12, 1966	Charles Conrad, Jr. Richard F. Gordon, Jr.	71 h 17 min.	First initial rendezvous; first tethered flight; highest Earth-orbit altitude (1372 km).
Gemini 12	Nov. 11, 1966	James A. Lovell, Jr. Edwin E. Aldrin, Jr.	94 h 35 min.	Longest extravehicular activity to date (Aldrin, 5 h 37 min).
Soyuz 1	Apr. 23, 1967	Vladimir M. Komarov	26 h 37 min.	Cosmonaut killed in reentry accident.
Apollo 7	Oct. 11, 1968	Walter M. Schirra, Jr. Donn F. Eisele R. Walter Cunningham	260 h 9 min.	First U.S. 3-man mission.
Soyuz 3	Oct. 26, 1968	Georgi Beregovoy	94 h 51 min.	Maneuvered near unmanned Soyuz 2.
Apollo 8	Dec. 21, 1968	Frank Borman James A. Lovell, Jr. William A. Anders	147 h 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 h 23 min.	Soyuz 4 and 5 docked and transferred 2 cosmonauts from Soyuz 5 to Soyuz 4.
Soyuz 5	Jan. 15, 1969	Boris Volynov Aleksey Yeliseyev Yevgeniy Khrunov	72 h 56 min.	
Apollo 9	Mar. 3, 1969	James A. McDivitt David R. Scott Russell L. Schweickart	241 h 1 min.	Successfully simulated in Earth orbit operation of lunar module to landing and take-off from lunar surface and rejoining with command module.
Apollo 10	May 18, 1969	Thomas P. Stafford John W. Young Eugene A. Cernan	192 h 3 min.	Successfully demonstrated complete system including lunar module descent to 14,300 m from the lunar surface.
Apollo 11	July 16, 1969	Neil A. Armstrong Michael Collins Edwin E. Aldrin, Jr.	195 h 19 min.	First manned landing on lunar surface and safe return to Earth. First return of rock and soil samples to Earth, and manned deployment of experiments on lunar surface.

## History of U.S. and Soviet Manned Space Flights

Spacecraft	Launch Date	Crew	Flight time	Highlights
Soyuz 6	Oct. 11, 1969	Georgiy Shonin Valeriy Kubasov	118 h 42 min.	Soyuz 6, 7, and 8 operated as a group flight without actually docking. Each conducted certain experiments, including welding and Earth and celestial observations.
Soyuz 7	Oct. 12, 1969	Anatoliy Filipchenko Vladislav Volkov Viktor Gorbatko	118 h 41 min.	
Soyuz 8	Oct. 13, 1969	Vladimir Shatalov Aleksey Yeliseyev	118 h 50 min.	
Apollo 12	Nov. 14, 1969	Charles Conrad, Jr. Richard F. Gordon, Jr. Alan L. Bean	244 h 36 min.	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 h 55 min.	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 h 59 min.	Longest manned space flight to date, lasting 17 days 16 h 59 min.
Apollo 14	Jan. 31, 1971	Alan B. Shepard, Jr. Stuart A. Roosa Edgar D. Mitchell	216 h 2 min.	Third manned lunar landing. Mission demonstrated pinpoint landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir Shatalov Aleksey Yeliseyev	47 h 46 min.	Docked with Salyut 1, but crew did not board space station launched Apr. 19. Crew recovered Apr. 24, 1971.
Soyuz 11	June 6, 1971	Nikolai Rukavishnikov Georgiy Timofeyevich Dobrovolskiy Vladislov Nikolayevich Volkov	570 h 22 min.	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	Viktor Ivanovich Patsayev David R. Scott Alfred M. Worden James Bensen Irwin	295 h 12 min.	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 s was performed during return trip.
Apollo 16	Apr. 16, 1972	John W. Young Charls M. Duke, Jr. Thomas K. Mattingly, II	265 h 51 min.	Fifth manned lunar landing, with Lunar Roving Vehicle.
Apollo 17	Dec. 7, 1972	Eugene A. Cernan Harrison H. Schmitt Ronald E. Evans	301 h 52 min.	Sixth and final Apollo manned lunar landing, with roving vehicle.
Skylab 2	May 25, 1973	Charles Conrad, Jr. Joseph P. Kerwin Paul J. Weitz	627 h 50 min.	Docked with Skylab 1 for 28 days. Repaired damaged station.
Skylab 3	July 28, 1973	Alan L. Bean Jack R. Lousma Owen K. Garriott	1427 h 9 min.	Docked with Skylab 1 for over 59 days.
Soyuz 12	Sept. 27, 1973	Vasily Lazarev Oleg Makarov	47 h 16 min.	Checkout of improved Soyuz.
Skylab 4	Nov. 16, 1973	Gerald P. Carr Edward G. Gibson William R. Pogue	2017 h 16 min.	Docked with Skylab 1 in continuing long duration mission.
Soyuz 13	Dec. 18, 1973	Petr Klimuk Valentin Lebedev	188 h 55 min.	Astrophysical, biological, and Earth resources experiments.
Soyuz 14	July 3, 1974	Pavel Popovich Yuriy Artyukhin	377 h 30 min.	Docked with Salyut 3 and Soyuz 14 crew occupied space station for over 14 days.
Soyuz 15	Aug. 26, 1974	Gennadiy Sarafanov Lev Demin	48 h 12 min.	Rendezvoused but did not dock with Salyut 3.
Soyuz 16	Dec. 2, 1974	Anatoliy Filipchenko Nikolai Rukavishnikov	142 h 24 min.	Test of ASTP configuration.
Soyuz 17	Jan. 10, 1975	Aleksey Gubarev Georgiy Grechko	709 h 20 min.	Docked with Salyut 4 and occupied station during a 29-day flight.
Anomaly	Apr. 5, 1975	Vasily Lazarev Oleg Makarov	20 min.	Soyuz stages failed to separate; crew recovered after abort.
Soyuz 18	May 24, 1975	Petr Klimuk Valeriy Kubasov	1511 h 20 min.	Docked with Salyut 4 and occupied station during a 63-day mission.
Soyuz 19	July 15, 1975	Aleksey Leonov Valeriy Kubasov	142 h 31 min.	Target for Apollo in docking and joint experiments ASTP mission.
Apollo	July 15, 1975	Thomas P. Stafford Donald K. Slayton Vance D. Brand	217 h 28 min.	Docked with Soyuz 19 in joint experiments of ASTP mission.
Soyuz 21	July 6, 1976	Boris Volynov Vitaliy Zholobov	1182 h 24 min.	Docked with Salyut 5 and occupied station during 49-day flight.
Soyuz 22	Sep. 15, 1976	Valeriy Bykovskiy Vladimir Aksenov	189 h 54 min.	Earth resources study with multispectral camera system.
Soyuz 23	Oct. 14, 1976	Vyacheslav Zudov Valeriy Rozhdestvenskiy	48 h 6 min.	Failed to dock with Salyut 5.

APPENDIX D

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant *	Thrust (in thou- sands of lbs)	Max. dia. (ft)	Max. Payload (lb)			
					Height (ft)	300NM orbit	Escape	First launch
Scout .....	1. Algol IIIA .....	Solid .....	108.3	3.67	72.0	410 <sup>4</sup>	85 <sup>4</sup>	1972 (60)
	2. Castor IIA .....	Solid .....	63.2					
	3. Antares IIB .....	Solid .....	28.5					
	4. Altair III .....	Solid .....	5.9					
Thor-Delta 2900 series .....	1. Thor plus nine TX 354-5 .....	LOX/RP-1 Solid .....	205 99 <sup>2</sup>	8	116	3,900 <sup>4</sup>	1,050 <sup>4</sup>	1973 (60)
	2. Delta (DSV-3) .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	10.3					
	3. TE 364-4 .....	Solid .....	15					
Atlas F/TE 364-4 .....	1. Atlas booster and sustainer (Atlas F) .....	LOX/RP-1 .....	443	10	85	3,300 <sup>4</sup>		
	2. TE 364-4 .....	Solid .....	15					
Atlas-Agena .....	1. Atlas booster and sustainer (SLV/3A) .....	LOX/RP-1 .....	503	10	133	6,000 <sup>4</sup>	1,000 <sup>4</sup>	1968 (60)
	2. Agena .....	IRFNA/UDMH ..	16					
Titan IIIB-Agena .....	1. LR-87 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	520	10	159	7,100 <sup>5</sup>	1,500 <sup>5</sup>	1966
	2. LR-91 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	100					
	3. Agena .....	IRFNA/UDMH ..	16					
Titan IIIC .....	1. Two 5-segment 120-in diameter ..	Solid .....	2,600	10x30	133	26,500 <sup>4</sup>	7,000 <sup>4</sup>	1965
	2. LR-87 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	520					
	3. LR-91 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	100					
	4. Transtage .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	16					
Titan IIID .....	1. Two 5-segment 120-in diameter ..	Solid .....	2,600	10x30	154	6,500 <sup>5</sup>		1971
	2. LR-87 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	520					
	3. LR-91 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	100					
Titan IIIE-Centaur ..	1. Two 5-segment 120-in diameter ..	Solid .....	2,600	10x30	160		11,300 <sup>4</sup>	1974
	2. LR-87 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	520					
	3. LR-91 .....	N <sub>2</sub> O <sub>4</sub> /Aerozine ..	102					
	4. Centaur (Two RL-10) .....	LOX/LH .....	30					
Atlas-Centaur .....	1. Atlas booster and sustainer .....	LOX/RP .....	503	10	131	10,300 <sup>4</sup>	2,500 <sup>4</sup>	1967 (62)
	2. Centaur (Two RL-10) .....	LOX/LH .....	30					
Saturn IB .....	1. S-IB (eight H-1) ..	LOX/RP .....	1,640	21.6	181	34,000 <sup>4</sup>		1966
	2. S-IVB (one J-2) ..	LOX/LH .....	230					

<sup>1</sup> The date of first launch applies to this latest modification with a date in parentheses for the initial version.

<sup>2</sup> Set of 3.

<sup>3</sup> Propellant abbreviations used are as follows: Liquid Oxygen and a modified Kerosene—LOX/RP; Solid propellant combining in a single mixture both fuel and oxidizer—Solid;

Inhibited Red Fuming Nitric Acid and Unsymmetrical Dimethylhydrazine—IRFNA/UDMH; Nitrogen Tetroxide and UDMH/N<sub>2</sub>H<sub>4</sub>—N<sub>2</sub>O<sub>4</sub>/Aerozine; Liquid Oxygen and Liquid Hydrogen—LOX/LH.

<sup>4</sup> Due east launch.

<sup>5</sup> Polar launch.



## Space Activities of the U.S. Government

20-YEAR BUDGET SUMMARY—BUDGET AUTHORITY  
(In millions of dollars)

	NASA		Department of Defense	ERDA	Com- merce	Interior	Agriculture	NSF	Total space
	Total	Space <sup>1</sup>							
1959	305.4	235.4	489.5	34.3					759.2
1960	523.6	461.5	560.9	43.3				.1	1,065.8
1961	964.0	926.0	813.9	67.7				.6	1,808.2
1962	1,824.9	1,796.8	1,298.2	147.8	50.7			1.3	3,294.8
1963	3,673.0	3,626.0	1,549.9	213.9	43.2			1.5	5,434.5
1964	5,099.7	5,046.3	1,599.3	210.0	2.8			3.0	6,861.4
1965	5,249.7	5,167.6	1,573.9	228.6	12.2			3.2	6,985.5
1966	5,174.9	5,094.5	1,688.8	186.8	26.5			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	3,406.2	3,093.2	1,623.0	54.2	39.7	10.3	1.9	2.6	4,824.8
1974	3,036.9	2,758.5	1,766.0	41.7	60.2	9.0	3.1	1.8	4,640.3
1975	3,229.1	2,915.3	1,892.4	29.6	64.4	8.3	2.3	2.0	4,914.3
1976	3,550.3	3,226.9	1,983.3	23.3	71.5	10.4	3.6	2.4	5,321.4
T.Q. <sup>2</sup>	931.8	849.5	460.4	4.6	22.2	2.6	0.9	0.6	1,340.8
1977 Est.	3,749.8	3,372.5	2,291.5	22.6	89.8	9.5	4.7	2.4	5,793.0
1978 Est.	4,033.2	3,596.4	2,770.0	35.1	94.5	9.5	5.6	2.4	6,528.5

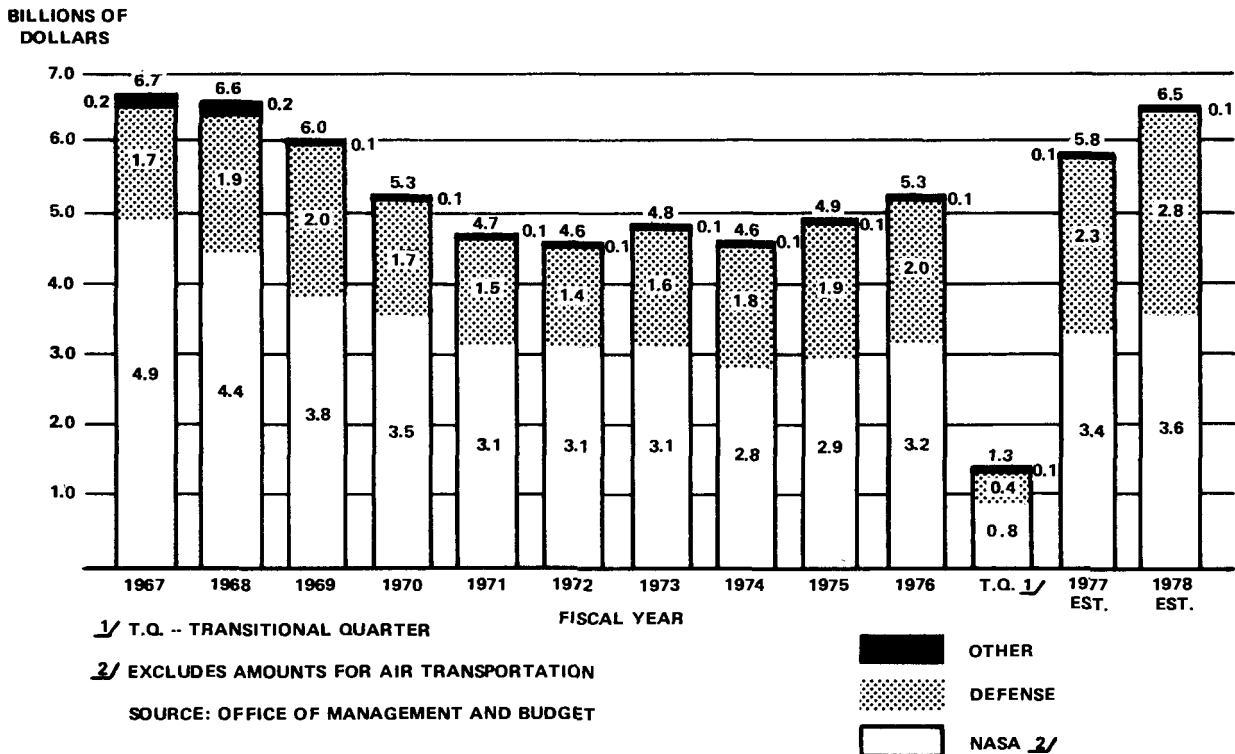
<sup>1</sup> Excludes amounts for air transportation.

Source: Office of Management and Budget.

<sup>2</sup> T.Q.—Transitional Quarter.

### U.S. Space Budget—Budget Authority 1967–1978

[May not add due to rounding]



APPENDIX E-2

**Space Activities Budget**

(In millions of dollars)

	Budget Authority				Outlays			
	1976 Actual	T.Q. <sup>1</sup> Actual	1977 Est.	1978 Est.	1976 Actual	T.Q. <sup>1</sup> Actual	1977 Est.	1978 Est.
<b>Federal space programs:</b>								
NASA <sup>2</sup> .....	3226.9	849.5	3372.5	3611.4	3336.3	868.6	3383.4	3523.2
Defense .....	1983.3	460.4	2291.5	2770.0	1864.4	458.1	2017.1	2543.3
ERDA .....	23.3	4.6	22.6	35.1	25.7	7.5	22.6	28.9
Commerce .....	71.5	22.2	89.8	94.5	71.1	23.2	92.5	96.5
Interior .....	10.4	2.6	9.5	9.5	10.9	2.2	9.5	9.5
NSF .....	2.4	0.6	2.4	2.4	2.0	0.5	2.4	2.4
Agriculture .....	3.6	0.9	4.7	5.6	3.5	0.9	4.7	5.6
<b>Total .....</b>	<b>5321.4</b>	<b>1340.8</b>	<b>5793.0</b>	<b>6538.5</b>	<b>5313.9</b>	<b>1361.0</b>	<b>5532.2</b>	<b>6209.4</b>
<b>NASA:</b>								
Manned space flight .....	1956.6	506.3	2066.2	2181.6	2000.2	524.6	2071.4	2155.8
Space science, appli- cations and technology .....	944.0	255.0	949.5	1038.8	980.3	251.5	960.1	968.2
Air transportation .....	324.9	82.6	378.8	423.4	332.7	82.8	349.4	391.6
Supporting operations .....	326.3	88.2	356.8	391.0	355.8	92.5	351.8	381.2
Less receipts .....	-1.5	-0.3	-1.5	-1.6	-1.5	-0.3	-1.5	-1.6
<b>Total NASA .....</b>	<b>3550.3</b>	<b>931.8</b>	<b>3749.8</b>	<b>4033.2</b>	<b>3667.5</b>	<b>951.1</b>	<b>3731.2</b>	<b>3913.2</b>

<sup>1</sup> T.Q.—Transitional Quarter.

<sup>2</sup> Excludes amounts for air transportation.

Source: Office of Management and Budget.

**Aeronautics Budget**

(In millions of dollars)

	Budget Authority			
	1976 Actual	T.Q. <sup>1</sup> Actual	1977 Est.	1978 Est.
<b>Federal aeronautics programs:</b>				
NASA <sup>2</sup> .....	324.9	82.6	378.8	423.4
Department of Defense <sup>3</sup> .....	1941.3	479.5	2245.2	2618.7
Department of Transportation <sup>4</sup> .....	84.8	21.8	93.8	103.4
<b>Total .....</b>	<b>2351.0</b>	<b>583.9</b>	<b>2717.8</b>	<b>3145.5</b>

<sup>1</sup> T.Q.—Transitional Quarter.

<sup>2</sup> Research and Development, Construction of Facilities, Research and Program Management.

<sup>3</sup> Research, Development, Testing, and Evaluation of aircraft and related equipment.

<sup>4</sup> Office of Secretary of Transportation and Federal Aviation Administration Research and Development.

Source: Office of Management and Budget.