

**Aeronautics and Space Report  
of the President**      *1974 Activities*

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

*1974 Activities*



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

# President's Message of Transmittal

*To the Congress of the United States:*

I am pleased to transmit this report on the activities and accomplishments of the United States in aeronautics and space in 1974. This is in accordance with Section 206 of the National Aeronautics and Space Act of 1958, as amended (42 U.S.C. 2476).

During 1974, the Nation's activities in aeronautics and space continued to produce significant benefits, to experiment with and develop new applications, to increase scientific knowledge, and to advance technology. The report shows:

The use of communications satellites continued to expand as a principal method of international communications. The first domestic privately owned communications satellites opened a new dimension in our tele-communications systems. Satellites continued to play an essential role in national defense activities—in communications, navigation, and other fields. Demonstration programs tested the use of satellite systems to improve delivery of health and education services.

Experimental uses of Earth observation satellites were tested in crop surveys, pollution monitoring, land use planning, water resources management, and other fields. Weather satellites continued to be our chief source of both global and local weather data; a new geostationary satellite began continuous observation of weather affecting the Western hemisphere.

The Skylab manned space station mission was successfully completed; it demonstrated that human beings can survive and work well in space for months or more at a time and provided a store of new scientific and technical data on the Sun, Earth resources, medical effects of space flight, and other fields. Development of the Space Shuttle progressed on schedule, and within costs, toward the goal of a versatile reusable vehicle for routine and economical use of space at the end of the decade.

Joint preparations and training with the Soviet Union proceeded for the 1975 Apollo-Soyuz manned docking experiment. Cooperative space activities with other nations continued on the basis of mutual benefits. Development by European nations at their expense of the Spacelab for use with the Space Shuttle got well underway.

Exploration of the planets continued with successful missions to Jupiter, Venus, and Mercury. The science of astronomy advanced with important new observations and discoveries using ground-based, high-altitude, and space telescopes.

In aeronautics good progress was made in developing technology to reduce energy requirements, noise, and pollution of civil aircraft. Modernization of the air traffic control system continued with the introduction of semiautomated equipment for air route traffic control.

Milestones in military aircraft development included the roll-out of the B-1 bomber, delivery of the first operational F-15 fighter aircraft, deployment to the fleet of the A-6E all-weather attack aircraft, and the successful testing of the new CH-53E helicopter.

Transfer of aeronautical and space technology to other fields continued with many beneficial applications in energy, materials, transportation, medical care, and other areas.

I believe that all Americans, and people of all nations, can be gratified with the accomplishments and the continued progress toward achieving the objectives of the National Aeronautics and Space Act of 1958 that are comprehensively described in this report.

The WHITE HOUSE,  
*Nineteen Hundred and Seventy-five.*

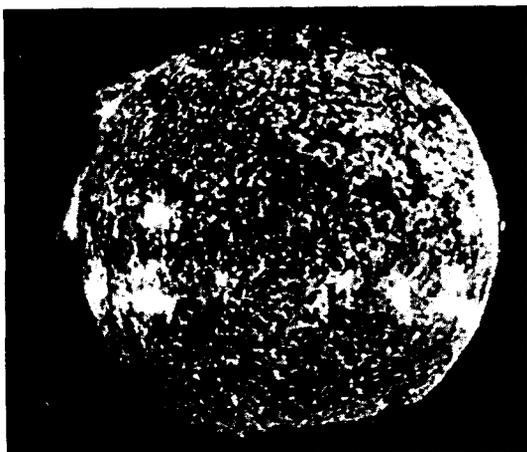


# Table of Contents

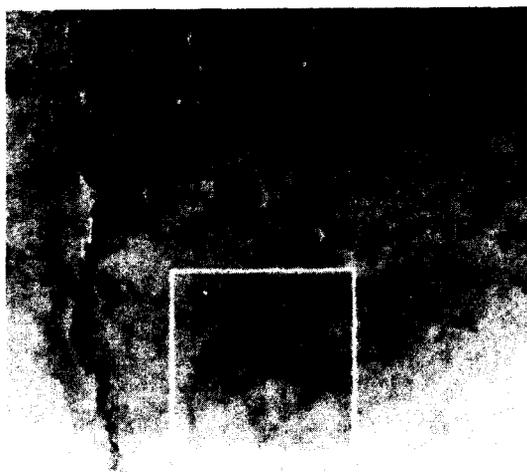
	Page		Page
I. Summary of U.S. Aeronautics and Space Activities in 1974	1	Introduction	91
Introduction	1	Aerospace Science	91
Space	1	Space Applications	93
Aeronautics	4	Aerospace Engineering	94
II. National Aeronautics and Space Administration	7	Education	95
Introduction	7	X. Office of Telecommunications Policy	97
Applications to Earth	8	Introduction	97
Study of Sun-Earth Interactions and Cosmic Processes	16	Aeronautical Satellite Experiment	97
Exploration of the Planets	19	Maritime Mobile Satellite Service	98
Analysis of Lunar Data	20	Proposed Amendment to Communications Satellite Act of 1962	98
Study of Man	21	Direct Broadcast Satellites	99
Space Transportation	24	Frequency Management	99
Tracking and Data Acquisition	26	Satellite Launch Insurance	99
Space and Nuclear Research and Technology	27	XI. Federal Communications Commission	101
Aeronautics Research and Technology	31	Introduction	101
International Affairs	37	Communications Satellites	101
Disseminating Technology and Benefits	40	Specialized Satellite Services	102
University Affairs	40	International Telecommunications Union	102
III. Department of Defense	41	Frequency Allocation and Coordination	103
Introduction	41	XII. The Smithsonian Institution	105
Space Activities	42	Introduction	105
Aeronautics	44	Smithsonian Astrophysical Observatory	105
Aircraft Research and Technology	48	National Museum of Natural History	106
Space Research and Technology	50	Center for Short-Lived Phenomena	106
Space Ground Support	51	National Air and Space Museum	107
International Cooperation	52	XIII. Environmental Protection Agency	109
Aeronautics and Astronautics Coordinating Board	53	Introduction	109
IV. Department of Transportation	55	Organization of Remote Sensing Activities	109
Introduction	55	Aircraft Oriented Research and Applications	110
Office of the Secretary Programs	55	Space Programs and Applications	111
Aviation Safety Research and Development	56	XIV. Atomic Energy Commission	113
Air Traffic Control and Navigation	58	Introduction	113
V. Department of Commerce	61	Jupiter Spacecraft	113
Introduction	61	Lincoln Experimental Satellite	113
Use of Satellites in Environmental Monitoring and Prediction	61	Viking Mars Lander	114
Other Satellite and Space Applications	64	Mariner/Jupiter Saturn	114
Space Support Activities	66	Generator Technology	114
Atmospheric and Solar Physics	67	Terrestrial Power	114
Aeronautical Programs	68	XV. Department of Agriculture	117
Environmental Data Programs	69	Introduction	117
VI. Department of the Interior	71	Remote Sensing Activity	117
Introduction	71	Providing Expertise to Other Nations	118
Space	71	XVI. Arms Control and Disarmament Agency	119
Aeronautics	74	XVII. United States Information Agency	121
International Cooperation	76	Introduction	121
VII. Department of State	79	Press and Publications	121
Introduction	79	Radio	122
Activities Within the United Nations	79	Motion Pictures and Television	123
International Cooperation	81	Information Centers and Exhibits	124
Satellite Services	82		
Support to Federal Agencies	83	<b>Appendixes</b>	
VIII. National Science Foundation	85	A-1 U.S. Spacecraft Record	125
Introduction	85	A-2 World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond	125
Astronomy	85	A-3 Successful U.S. Launchings — 1974	126
Atmospheric Sciences	87	B-1 U.S. Applications Satellites, 1970-1974	133
U.S. Antarctic Research Program	88	B-2 U.S.-Launched Scientific Payloads, 1970-1974	135
Engineering	88	B-3 U.S.-Launched Space Probes, 1970-1974	136
Materials Research	88	C History of United States and Soviet Manned Space Flights	137
Chemistry	89	D U.S. Space Launch Vehicles	139
Research Applied to National Needs	89	E-1 Space Activities of the U.S. Government	140
Education Activities	89	U.S. Space Budget—New Obligational Authority	140
IX. National Academy of Sciences, National Academy of Engineering, National Research Council	91	E-2 Space Activities Budget	141
		Aeronautics Budget	141

## Spacecraft Study Matters Vital to Earth

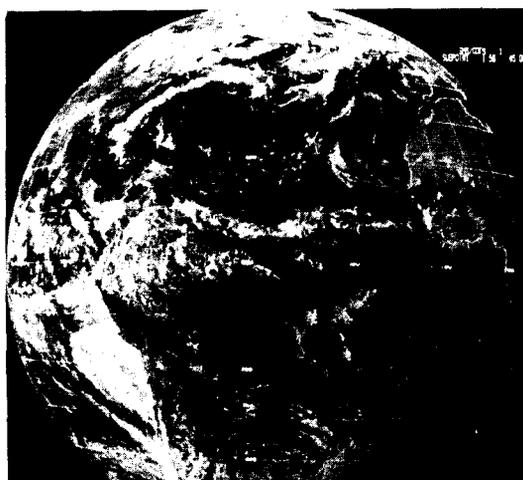
Life on Earth is dependent on the Sun, interactions between the Sun and Earth, and the changes induced by human activities. Space provides a unique vantage point to study such phenomena. In this sequence we observe the Sun, one region of severe interaction between the Sun and human food supplies, and finally how weather factors on one continent influence those on another.



This Skylab 4 image shows one of the most spectacular solar flares ever recorded. The flare spans more than 588,000 kilometers (367,000 miles) of the solar surface. We need to study the Sun because it is our primary source of energy, providing us with the heat and light needed for life; it influences our weather; and it can affect navigation instruments and disrupt radio communications.



The dark area of vegetation (outlined) stands out in this Earth Resources Technology-1 (ERTS-1) image of the parched, sun-drenched African Sahel which forms the border of the Sahara desert. The dark area was found to be ranchland where grass cover was maintained by controlled grazing. Thus, ERTS-1 pictured how encroachment of the desert can be slowed by controlled grazing. The drought in the Sahel is believed to be due to a change in climate—as yet unexplained—that is affecting world food supplies.



Imagery from the Synchronous Meteorological Satellite-1 (SMS-1) shows hot, dry, dust-laden air blowing off the Sahara desert across the Atlantic. Weather in Florida was influenced when the air reached there six days later. About half of the tropical storms, including hurricanes, originate when hot air from the Sahara meets cool air along Africa's Atlantic coast.



# Summary of United States Aeronautics and Space Activities in 1974

## Introduction

In 1974 the U.S. Government activities in aeronautics and space continued to make significant contributions toward the fulfillment of the nation's goals in space and aeronautics, including application of space systems and technology to beneficial uses on Earth, exploration of space and increase of scientific knowledge, development of improved space systems and technology, international cooperation, and advancement of civil and military aeronautics. Also in 1974, space activities in the private sector expanded to provide additional services to the public. The accomplishments in 1974 are summarized in this chapter and described in detail in the following chapters for each of the 16 Federal agencies having activities related to aeronautics and space.

## Space

In 1974, the United States launched 28 space payloads. Twelve were for Defense purposes and 16 were launched by the National Aeronautics and Space Administration (NASA). Of the NASA-launched payloads, eight were communication satellites with the balance being designed to secure weather, oceanic, atmospheric, or astronomical data or to advance satellite technology. The majority (nine) of the NASA-launched payloads were international in character, being launched with, or for, the United Kingdom, France, Germany, and the Netherlands.

### *Earth Resources and Environment*

During 1974, several Federal departments and agencies, as well as many State agencies, universities, and private institutions, continued experimentation on the use of remotely sensed data from space and aircraft in the study and monitoring of Earth resources and the environment.

The U.S. Department of Agriculture (USDA) continued its efforts in the development and evaluation of aerospace remote sensing technology for use in improving its agricultural and forestry programs. This involved additional research on the feasibility and operational utility of using aerospace-acquired data to

accomplish more accurate quantitative predictions of food and fiber resources, along with better evaluations of land productivity; and to monitor changes affecting the total production and quality of our natural resources and environment, including man-environment interactions.

NASA, the USDA, and the National Oceanic and Atmospheric Administration (NOAA) initiated a joint Large Area Crop Inventory Experiment (LACIE) to develop and demonstrate the capability to inventory wheat from space. The initial phase will be directed at the Great Plains wheat-producing region. The results of these investigations may lead to demonstrations of the feasibility of utilizing remote sensing technology for more accurate and timely worldwide inventories of major crops.

Both NOAA and the Environmental Protection Agency (EPA) continued to use satellite data for environmental monitoring. Information on oceanographic and hydrologic conditions in the form of analyzed maps depicting sea and lake ice conditions, thermal boundaries in the oceans, lakes, and rivers, and snow cover estimates in selected river basins was disseminated by NOAA to users via National Weather Service Facsimile networks. The information in these maps was derived from satellite data. Satellite data continues to play an important role in pollution monitoring, weather modification experiments, and meteorological and oceanographic research.

Satellite imagery, along with appropriate ground truth data, was used by the Department of Commerce to monitor urban development, to classify land areas, and to make population estimates in the United States and selected foreign countries.

The Department of the Interior participated with NASA and other agencies in a wide variety of activities involving remote sensing by aircraft and satellites for such uses as land management, preparation of environmental impact statements, and mapping.

Instrumental to all of these satellite-derived advances was the data acquired and transmitted to Earth by the Earth Resources Technology Satellite-1 (ERTS-1, redesignated LANDSAT-1 on January 15,

1975). Designed to last a year, ERTS-1 began its third year of operation on July 23, 1974, still providing valuable data for application to improved monitoring and management of Earth's resources and the environment. Data from the last Skylab mission, which ended early in 1974, also contributed greatly to the nation's capabilities in these disciplines, so important to satisfying the growing demands on the Earth's limited resources and the problem of its population's wastes.

### *Meteorology*

During 1974, satellites and aircraft played an increasingly important role in the low-cost gathering of meteorological data on a large scale. During the year, the United States, in cooperation with many other nations, made substantial advances toward obtaining an understanding of the dynamics of global weather and in the development of satellite systems to gather and use this knowledge. In time, these can lead to accurate long range forecasts with potentially vast economic benefits for agriculture, construction, transportation, recreation, and other industries.

From June 15 to September 23, the United States and 69 other nations monitored virtually every known meteorological factor along a 20-million-square-mile tropical area of land and sea stretching from the eastern Pacific Ocean across Latin America, the Atlantic, and Africa to the western Indian Ocean. Some 4,000 people using 41 ships, 40 buoys, 12 aircraft, and five United States satellites and one Soviet satellite probed from about a mile below the sea surface to the top of the atmosphere. Agencies of the U.S. participating included the Department of Commerce, the National Aeronautics and Space Administration, the Department of Transportation, the National Science Foundation, and the Department of State.

The study, part of the Global Atmospheric Research Program (GARP), is called GATE for GARP Atlantic Tropic Experiment. The tropics are believed to be a key to Earth's weather. Supporting GATE was the initial task of NASA's Synchronous Meteorological Satellite (SMS-1), launched May 17. SMS-1 is the prototype of the forthcoming U.S. Department of Commerce Geostationary Operational Environmental Satellite (GOES) System. From geostationary orbit, SMS-1 maintains a 24-hour weather watch on most of the Western Hemisphere, transmitting data to produce a picture every 30 minutes. It can also acquire and provide information from hundreds of instruments mounted on balloons, stream gauges, ocean buoys, merchant ships, and fire, weather, agricultural, and seismic stations. It thus contributes to our growing capability to provide long

range weather forecasts and predict climatic changes, both of which can contribute to efficient management of the nation's food and fiber resources as well as to the alleviation of the worst effects of severe storms.

### *Communications*

The application of communications satellite technology was broadened this year to provide vital services while keeping down costs. Improved communications through satellites have contributed to such wide-ranging areas as education and medical care in remote areas and toward increasing safety and speeding up day-to-day operations of ships and airliners, activities having large potential economic benefits.

Beginning operations in July 1974, the experimental Applications Technology Satellite-6 (ATS-6) has relayed graduate college courses from the University of Kentucky to teachers in 15 isolated Appalachian communities. It has enabled physicians and other health professionals of Veterans Administration hospitals in remote Appalachian regions to attend seminars and obtain medical consultations. This programming has been certified for continuing education credit by the American Medical and other professional associations.

The same satellite also was used to provide career education to junior high school students in remote areas of the Rocky Mountains. In addition, it has furnished communications links between medical aides in isolated Alaskan villages and physicians in regional Alaskan hospitals. This Health, Education Tele-communications (HET) experiment is participated in by NASA, the Department of Health, Education and Welfare, the Veterans Administration, the Federation of Rocky Mountain States, and various other organizations. In 1975, ATS-6 will be made available to the government of India for telecasting of educational programs to thousands of Indian villages.

ATS-6 has also demonstrated the feasibility of high quality ship-to-shore communication via satellite. The experiment is applicable to aircraft position location and other communications.

The Intergovernmental Maritime Consultative Organization has completed a study of a maritime satellite system to service merchant fleets at sea. In addition, the United States, Canada, and the European Space Research Organization have agreed on a program to test the use of satellites for air-traffic communication over the Atlantic.

The INTELSAT global communications satellite system continues to grow in capability and participation. At the end of 1974, it had 86 Earth stations in 62 countries and a membership of 86 countries.

Westar 1 and 2, the first two domestic communica-

tions satellites, were launched by NASA this year on a reimbursable basis for Western Union, which is using these satellites to provide commercial services. The Telesat Canada Anik satellites, launched beginning in 1973, are also being used by commercial U.S. organizations for domestic service on an interim basis. Additional domestic satellite systems are expected to begin operations in 1975 and 1976.

### *Space Operations*

Skylab, one of the world's most productive missions in terms of observations on humans, the Sun, and the Earth, came to a successful conclusion with the safe splashdown and recovery of the third manned mission on February 8, 1974. It demonstrated that man can perform work in space not only to conduct assigned tasks, but to overcome severe problems—saving and making “more than successful” a mission that appeared doomed after the failure of the Skylab micrometeoroid shield during ascent. The results of the Skylab missions show that we have not yet found a limit to the time people can successfully live and work in space.

Considering the need for a space rescue capability for future manned missions, and as an effort to increase international cooperation, the U.S. and the Soviet Union have scheduled a cooperative space docking experiment in 1975. During 1974, the two nations worked cooperatively preparing for the 1975 mission. This project will yield much valuable experience on the problems associated with working with another nation in space, including those problems related to dissimilar equipment, communications, tracking, launch sites, and language. In addition to the docking experiments, valuable experiments in space processing, pollution monitoring, and other areas will be performed by the American astronauts participating in the Apollo-Soyuz flight.

The large scale development effort on the Space Shuttle continued to grow in 1974 as design work approached completion and the program moved into the hardware test and fabrication stages. The Space Shuttle is the major element in the new Space Transportation System (STS) designed to reduce the cost of both civilian and defense space activities and make the full advantages of space available in the 1980's and beyond.

The STS consists of the Space Shuttle, the Interim Upper Stage (IUS) or Space Tug, and the Spacelab. The Space Shuttle will provide routine access to Earth orbit for placing, repairing, or retrieving satellites and for carrying the Spacelab to provide an opportunity for scientists and technicians to accompany and conduct their experiments in space. In 1974, NASA awarded the final major contract for the Space Shuttle. The Department of Defense will develop the

IUS. Spacelab is being developed by the European Space Research Organization (ESRO) at European expense as a component of the Space Transportation System. In 1974, ESRO awarded the contract for Spacelab development and work has started. This European contribution has established a new dimension in U.S.-European space cooperation.

### *Exploration of the Solar System*

Gathering information of interest to the world, of great scientific importance, and of significant relevance to problems we have on Earth, Mariner 10 (formerly known as Mariner Venus/Mercury '73) early in 1974 flew by Venus and Mercury and provided an immense amount of data, including the first close-up pictures of Venus and Mercury. A second pass by Mercury occurred on September 21, 1974. A remarkable third flyby is scheduled for March 1975.

Observations of Mercury revealed a lunar-like cratered surface, an unexpected faint magnetic field, a thin atmosphere, chiefly helium, and surface temperatures ranging from minus 160 degrees Centigrade (minus 300 degrees Fahrenheit) on the night side to 430 degrees Centigrade (800 degrees Fahrenheit) on the day side.

Mariner 10 ultraviolet photographs of Venus show vivid cloud bands rotating more than 60 times faster than the planet. Other results suggest dense cloud layers below the fast moving uppermost cloud deck, although no atmospheric storms have been found on Venus. Studies of the atmosphere of Venus have helped us assess potential problems of the effects of pollutants in the Earth's stratosphere, and are contributing to the analysis and understanding of them.

On December 3, 1974, Pioneer 11 successfully flew within 43,000 kilometers (27,000 miles) of Jupiter, survived the planet's intense radiation, and is now on its way to a rendezvous with Saturn in 1979, when it may return man's first closeup view of Saturn and its mysterious rings.

Data gathered by Pioneer 11 have supplemented the data obtained by Pioneer 10 (which flew past Jupiter in late 1973). The Pioneer 11 encounter was three times closer than Pioneer 10, and culminated a two-year, billion-kilometer (600,000,000-mile) journey from Earth. The spacecraft swept past the giant planet at a record speed of more than 160,000 km (100,000 mi.) an hour.

Pioneer 11 flew over Jupiter's North and South Poles, returning spectacular pictures of its turbulent cloudtops never before seen with such clarity. The apparently placid polar regions showed huge masses of air cells, spouting gases like bubbles in boiling water, becoming increasingly turbulent away from the poles and finally blending into the huge bands of colorful streaking gases that girdle the gigantic planet.

This new Pioneer 11 data will add to the knowledge obtained from Pioneer 10, which first gave us a new picture of the solar system's largest planet. Sifting through Pioneer 10 data, investigators have concluded that Jupiter is a whirling ball of liquid hydrogen, without any detectable surface. They also suggest that the Great Red Spot—a mystery since Galileo first turned his telescope on it—is a gigantic hurricane which has been raging along a 40,000 km (25,000 mi.) front for at least 400 years.

Helios A, launched in December 1974, is a cooperative mission with the Federal Republic of Germany which will fly closer to the Sun than any previous mission and will provide extensive new data on our basic energy source and the sustainer of all life on Earth. Using a variety of sensors, Helios will supplement the outstanding data gathered by the Skylab Solar Telescope.

### *Astronomy*

Using ground-based, rocket, balloon, and satellite measurements, research in astronomy, supported by NASA, the National Science Foundation, and the Smithsonian Institution, brought new discoveries during the year: the first-time verification of water molecules in comets, as comet Kohoutek streaked through our solar system; a 13th satellite of Jupiter; a pulsar that is a member of a double star system; and new data on the size and shape of the Crab Nebula. Even though Kohoutek did not live up to its predicted brightness, the fortuitous timing of it with Skylab enabled observations from space that greatly increased our knowledge of comets.

### *Defense*

Satellites continued to play an essential role in our national defense activities. During 1974 significant actions were taken to expand and improve the Defense Satellite Communications System to better serve the needs of the National Command Authorities and the World Wide Military Command and Control System. The NAVSTAR global-positioning satellite program also advanced significantly during the year. Contracts were let for the Phase I satellites and for user-equipment development. The Defense Meteorological Satellite Program continued to furnish weather data both to the military and to the civil-scientific community through NOAA.

### *Terrestrial Applications*

In addition to direct applications of space to human needs, a strong concerted effort is being made by NASA and the other agencies to apply space-derived technology directly to terrestrial use in such areas as energy, materials, transportation, and health care. Examples include solar heating and cooling, more

efficient automobile engines, and new medical technology.

### **Aeronautics**

Federal activities in aeronautics included research and development designed to improve civil air transportation, advance military capability, and through the export of superior aircraft continue to provide a positive input to the U.S. balance of payments.

### *Energy Reduction*

In the civil sector, NASA is conducting an aggressive program to reduce energy requirements for aircraft as a part of a broader effort to improve aircraft performance and economy. The program includes the development of more efficient propulsion systems; the reduction of drag by the use of novel concepts such as the super-critical wing and compliant aircraft skin panels; the reduction of aircraft structural weight through the application of lightweight composite materials to aircraft structures; the use of advanced active flight control systems; and investigations of the use of alternative fuels such as hydrogen and fuels derived from the liquification of coal.

During 1974, flight tests with an F-8 aircraft with a NASA-designed supercritical wing demonstrated a 15 percent increase in range without using any additional fuel. NASA also demonstrated a significant reduction in skin-friction drag using compliant aircraft skin concepts. This approach has a potential for a 50 percent skin drag reduction. A series of studies was initiated to explore opportunities for achieving major reductions in fuel consumption for subsonic commercial aircraft through improved propulsion systems and airframe modifications. Flight evaluation of composite wing midsections was begun under a NASA-U.S. Air Force program. Results of the July 1974 NASA-sponsored symposium on active controls indicates that their use to enhance aircraft controllability and reduce structural loads has a potential for a 25 percent reduction in aircraft gross takeoff weight, with an accompanying reduction in fuel requirements.

### *Reduction of Environmental Impacts*

A strong continuing effort was maintained by NASA and the Department of Transportation to reduce the undesirable environmental effects of aircraft. The noise-reduction program is concerned with propulsion systems, airframe noise, sonic booms, and enhancing the airport environment by using modified landing approach techniques. A steep approach landing procedure tested last year was further validated this year by a United Airlines DC-8 long-range transport equipped with a sophisticated navigation system

modified to accommodate this new procedure under routine scheduled-service conditions. The ground area subjected to objectionable noise was reduced about 50 percent. NASA ground tests of modified JT8D commercial jet engines indicated that the ground area affected by objectionable noise from current commercial aircraft using this engine could be reduced by 75 percent.

The engine-emission-reduction program is aimed at assessing the impact of high-altitude jet aircraft engine exhaust emissions on the stratosphere, and their contribution to atmospheric pollution; and on developing and demonstrating clean-engine technology to reduce emissions from current and future aircraft engines of all classes. During 1974, a United Airlines Boeing 747 equipped with an atmospheric-sampling instrument package commenced routine service on a commercial air route over the United States to Hawaii to measure the atmospheric effects of aircraft exhaust products along major intercontinental airline routes. Phase 1 tests were completed on several combustor concepts in the NASA Clean Combustor technology program, meeting 1979 EPA idle mode emission goals.

The Climatic Impact Assessment Program has fulfilled its congressional commitment by completing a three-year comprehensive international collaboration and scientific data exchange. Ten major countries including the U.K., France, and USSR, which now fly supersonic transports, have participated in this program. The report of findings is complete. Additional actions have been identified and some follow-on activity initiated. These results will be used as a basis for developing regulatory actions to prevent adverse environmental impact caused by aircraft operations in the stratosphere.

### *Air Traffic Control*

The Federal Aviation Administration (FAA) programs have stressed investigations, inhouse and at selected universities, relating to airport capacity and techniques of improved air traffic control and navigation. The new microwave landing system has been completed through Phase II of a three-phase development program.

Modernization of the air traffic control system by FAA has continued with the introduction of semi-automated equipment for the air route traffic control centers and for the radar terminals. At the end of the year, all 61 of the planned Automated Radar Terminal Systems were in operation at the high density terminals, and less complex systems are being installed at locations with lower levels of aircraft activity.

A long-term program has been initiated among the United States, Canada, and ESRO involving experiments with satellites in geostationary orbits over the

Atlantic. FAA was designated as the responsible United States agency and COMSAT was selected as the U.S. contractor to supply and support the satellites. The objective of this joint program is to evaluate the use of satellites to enhance communication and assist in controlling transatlantic air traffic.

### *Safety*

FAA, NASA, and other agencies are involved in research and development efforts to improve aircraft safety and increase the chances of survival in the event of an accident. During 1974, FAA placed particular emphasis on the investigation and development of means to reduce mid-air collisions. NASA's program conducted in cooperation with FAA focused on reducing flight accidents through improved inexpensive instrumentation for general aviation aircraft, increased safety in terminal-area operations, and increased aircraft and human survivability in case of accident.

During fiscal year 1974, several promising laboratory-developed techniques for minimizing the effect that one aircraft's wake can have on another aircraft were flight tested to determine their full-scale performance. Also, a prototype laser doppler system for detecting and tracking these wakes near airports so that other aircraft can be warned of their locations and take appropriate avoidance action began operational evaluation at John F. Kennedy Airport in New York. A new tire material which promises longer life and improved blowout protection for heavily loaded aircraft tires was developed by NASA chemists. A new brake compound which reduces brake wear and effects of brake heating was also developed and is currently being tested. Five full-scale general aviation aircraft were crash-tested to provide data for the design of more crashworthy aircraft in the future. NASA developed and tested during 1974, both in laboratories and full-scale fuselage tests, numerous new fire retardant materials for potential aircraft interior use which, in the event an aircraft should experience an in-flight or post-crash fire, could increase escape and survival time for passengers and crew.

Although these and other developments from the aviation safety program are intended primarily for aircraft use, many of these developments, such as the advanced tire, brake, and fire-retardant materials, can play a significant role in enhancing the safety of other modes of transportation.

### *Research on Future Air Transportation*

A significant part of NASA's aeronautics program continued to be addressed to advancing short haul, Short Takeoff and Landing (STOL), and Vertical Takeoff and Landing (VTOL) concepts to meet the specialized needs of the civil air transportation system

and the military services in the 1980's. The program includes the development of propulsive-lift aircraft technology, tilt-rotor aircraft technology, and advanced rotor-craft technology. Avionics and operating procedures technology are being developed for navigation, guidance, and control of both short-haul and conventional aircraft in the 1980's environment.

### *Defense*

Development of advanced aeronautical technology suitable for future military systems is a major goal of both DOD and NASA. Joint efforts in research, development, and test of experimental and prototype aircraft produced significant progress in 1974 toward the goal of achieving advanced systems of superior capability.

In 1974, the development of the A-10 Close Air Support Aircraft continued on schedule with over 1000 flight test hours being accumulated on the two prototype aircraft. Rollout of the Air Force B-1 bomber, under development since 1970, occurred in October and its first flight successfully took place in December. The A-6E All-Weather Attack Aircraft has been deployed to the U.S. Sixth Fleet, and is ready for deployment to the U.S. Seventh Fleet. The first two squadrons of the F-14 Carrier-Based Tactical Fighter were deployed on the USS Enterprise in September. The Navy has defined the requirements for a carrier-based strike fighter aircraft (NACF) which will complement the F-14 in maintaining maritime air superiority and beachhead air defense in the early 1980's. The Air Force F-15 Advanced Tactical Fighter continues on schedule, the first operational aircraft being delivered to Tactical Air Command in November 1974. Plans are underway to modify a significant number of the newer F-4's to incorporate the advanced Wild Weasel avionics system for use in search and destruction of hostile radar systems. The Air Force Lightweight Fighter Program will commence full scale development after source selection in early 1975, following the 1974 flight evaluation of prototypes.

The Utility Tactical Aircraft System (UTTAS) will be the Army's first assault helicopter capable of carrying a combat-equipped infantry squad. Prototypes by two manufacturers will participate in a com-

petitive fly-off during 1975-76. The widely used H-53 series helicopter has had its payload more than doubled (to over 16 tons) by the incorporation of a third engine in the new CH-53E. By the end of 1974, the first two prototype CH-53E's successfully accumulated well over 100 flight hours. First flight of the Advanced Attack Helicopter, being developed competitively, is scheduled for the Spring of 1975.

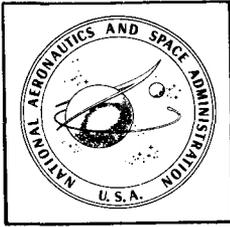
Initial deployment of the E-2C Carrier-Based Airborne Warning and Control System took place in September 1974. The E-3A Airborne Warning and Control System (AWACS) underwent a Systems Integration Demonstration from March through October 1974, as an aid to making a production decision. As of the end of 1974, a total of three 747 aircraft had been accepted by the Air Force for modification as E-4A interim National Emergency Airborne Command Posts.

The remote-piloted-vehicle (RPV) concept advanced substantially this past year through the use of very reliable and miniature electronic devices and more efficient configuration design. The RPV is unmanned, being flown by a pilot from a cockpit on the ground. This economical approach permits extended-flight-duration missions and releases personnel not only from tedious flights but from highly dangerous missions. RPV's also offer substantial savings for research and development through the use of scale models in place of more expensive full-sized aircraft.

A major success of the Army's aeronautical propulsion research and exploratory development program has been the development of efficient analytical methods for the design of small high-temperature combustors. Tests of the technique indicate a tremendous potential for weight reduction and lower emissions for this class of aircraft propulsion engines.

The NASA-U.S. Army Rotor Systems Research Aircraft program to test promising new rotor systems under actual flight conditions entered the initial fabrication phase with delivery scheduled for 1977. The NASA-U.S. Army Tilt-Rotor Research Aircraft program also reached the fabrication phase, with delivery of two craft expected late in 1975.

A Proximity Warning System to prevent aircraft collisions will soon become a reality at four major installations where the Army has its greatest concentration of aircraft.



# National Aeronautics and Space Administration

## Introduction

The National Aeronautics and Space Administration (NASA) is the civilian agency established by the National Aeronautics and Space Act of 1958 to plan, direct and conduct aeronautical and space research and exploration activities. Under the basic policy objective that activities in space shall be devoted to peaceful purposes for the benefit of all mankind, NASA's statutory goals include the expansion of human knowledge of phenomena in the atmosphere and space; development and operation of aeronautical and space vehicles and equipment; discovery and application of potential benefits of space activities; preservation of U.S. leadership in aeronautics and space science, technology, and applications; and cooperation with other nations on peaceful applications.

In NASA's early years, the focus of the space program was on the development of the technology required for space operations and on broad questions of space science, applications, and operations. In science, NASA began with the exploration of space around the Earth, then expanded its inquiry to determine the general nature of the Sun, Moon, solar system, and universe. Experimental communications and weather satellites demonstrated the feasibility of using space to improve critical services needed by modern society. The ability of man to live and perform useful work in space was demonstrated by a series of manned space flight programs of increasing complexity, duration, and productivity, culminating in the Apollo missions to the Moon and the Skylab experimental space station.

As experience and knowledge have accumulated, NASA has identified a growing number of Earth-oriented space applications, and non-space applications for space-developed technology. Its scientific inquiries are now focused not only on important scientific questions but also more directly on scientific questions related to urgent human needs back on Earth. Space operations have become almost routine and NASA's technology advances are now directed at reducing the cost of space operations as well as developing new capabilities for the future.

In *space applications* we are no longer just examining if certain things can be done, but are engaging in experimental demonstrations of practical uses having significant potential benefits. Experimental satellites are being used to demonstrate the use of satellite communications systems for education and health care purposes. Other experimental satellites are showing how to acquire and use various forms of remotely sensed data for mapping, inventorying, and monitoring Earth resources and atmospheric pollution.

In *space science* we are now asking more specific questions. For example, NASA is looking at the detailed structure of the Sun from space, seeking to understand better its energy processes, and the sunspots, flares, prominences, and other solar phenomena that interact with the Earth's atmosphere to affect our weather, climate, ecology, harvests, atmospheric pollution processes, and radio communications.

In planning the *exploration* of other planets, NASA is emphasizing studies of their atmospheric processes, geological formations, mineralization, and other factors that will aid us to understand better our own planet, the Earth. Investigators of distant stars are studying newly discovered energy sources so powerful that they are unexplained by present knowledge. Discovery of the physical laws that will unlock their secrets could eventually transform mankind's future here on Earth.

*Space operations* are a going business, much of which is directed at the routine employment of space flight capability to conduct scientific and applications programs. More than half of NASA's launches in 1974 were reimbursable launches paid for by commercial, other federal or foreign users of space.

In *space technology*, the Space Shuttle, NASA's largest project in the 1970's, is under development to provide the Space Transportation System for the 1980's for launch and recovery of science and applications payloads and the conduct of laboratory operations in space utilizing the Spacelab being developed by the European Space Research Organization. Besides opening up a whole range of new possibilities in space, the Shuttle is designed to permit the conduct of space missions at lower cost.

NASA's current space objectives, toward which its activities in 1974 were directed, include to:

- Pioneer and stimulate the employment of new space applications in such areas as meteorology, communications, Earth resources survey, pollution monitoring, navigation, space processing, and data collection and management.
- Provide launch services for a growing list of commercial users, other civilian federal agencies, and foreign nations.
- Assist federal, state, and local agencies and U.S. industry and small business in applying space-developed knowledge and technology directly to terrestrial civil applications in such areas as energy, medical technology, transportation, materials, remote delivery of education and medical care, and pollution-control technology.
- Explore the solar system to understand the formation and nature of other planets, which can help us better understand the dynamics and structure of the Earth and its atmosphere, and learn more about its resources and how to preserve its environment.
- Improve our understanding of the Earth-Sun interactions that affect almost every aspect of our existence.
- Seek to discover the nature of cosmic processes that can be of benefit to mankind.
- Use the unique environment of space to study the adaptive biological processes of humans and other living organisms, both to prepare for broader future participation in manned space flight and to develop medical understanding and techniques for use on Earth.
- Continue the search for evidences of the existence of life on other planets and elsewhere in the universe in order to gain new insights into the nature of life itself and into fundamental philosophical questions of man's place in the universe.
- Develop the Space Shuttle system within the projected cost estimates to provide an improved and economical means of conducting all space operations in the 1980's.
- Seek to reduce the cost of space activities generally by studying lower cost approaches and applying advanced technology to reduce the cost of payloads and equipment.
- Support United States policy in seeking better relations with the Soviet Union through the Apollo-Soyuz Test Project—a joint docking mission in 1975.
- Cooperate with other nations generally in space activities on the basis of mutual interests, without the exchange of funds.

In *aeronautics*, NASA serves as the principal agency for aeronautical research and technology for both

civil and military aviation. NASA's basic goal in aeronautics is to provide U.S. industry and the Department of Defense with advanced concepts and technology which will enable them to maintain the superiority of our aircraft over any competitor. On the civil side, technological advance is essential to preserve our position in aircraft exports, one of the major positive contributors to our balance of payments. On the military side, technological superiority is essential to an effective defense posture.

For civil aviation, the emphasis of NASA's continuing work in aeronautical research is on the technology required for improved, more efficient, more convenient, safer transportation, with special focus on reducing energy consumption and minimizing environmental impact. For military aviation, the emphasis is on improved performance and the specialized technological requirements of each of the military services.

NASA's current objectives in aeronautical research and technology, to which its activities were directed in 1974, include:

- Reduce the energy requirements of current and future aircraft and concurrently seek to improve their performance and economy of operations.
- Reduce noise, pollution, and other undesirable environmental effects of aircraft.
- Improve aircraft safety and operations through the application of advances in space and aeronautical technology.
- Advance the technology and explore new systems concepts for improved short haul, short takeoff and landing, and vertical takeoff aircraft.
- Continue to provide research and technical support to the aeronautical development programs of the military services.

This chapter summarizes NASA's 1974 activities in space, aeronautics, and the applications of aerospace technology.

### **Applications to Earth**

The primary objective of NASA's applications program is to employ space and its technologies to help in the solution of problems here on Earth. Applications programs employ remote sensing to conduct observations in Earth Resources Survey, Pollution Monitoring, Weather and Climate, and Earth and Ocean Physics. Space observations are already finding use at local and national levels, here and abroad, for such activities as weather forecasting, crop estimation, land-use determination, mapping, mineral exploration, resource determination, environmental monitoring, and hydrological management. Other program areas utilizing space systems and related technology to increase man's ability to deal with problems amenable to technological solutions

are Communications, Material Processing in Space, Technology Applications, and energy-related activities.

The program areas listed above and NASA activities to aid users in their application are individually reported upon in this section.

### *Earth Resources Survey*

The Earth Resources Survey Program involves the application of space or space-related remote sensing systems to the measuring and monitoring of parameters associated with agriculture, forestry, mineralogy, marine and inland water resources, cartography, land use and urban development, and geology. The experiments conducted within this program are designed to explore the technology that could permit, on an operational basis, the measurement, monitoring, and eventually management of the world's resources including food, fiber, timber, and water; the identification and the utilization of other resources, such as minerals and fossil fuels; and the wise planning for use of arable and habitable lands.

During 1974, the Earth Resources Technology Satellite (ERTS-1, now known as LANDSAT-1) continued to acquire much new data on resources' parameters and these data, along with extensive data from the Earth Resources Experiment Package carried on Skylab and those from the Earth Observations Aircraft Program, were used to further our measurement and monitoring capability. Planning for the initiation of new experimental and demonstration programs was continued.

*Earth Resources Technology Satellites.*—ERTS-1, launched July 23, 1972, has been a successful experimental mission and has provided data for more than 300 specific investigations. The data returned from ERTS-1 have proven to be of exceptional quality, and some of the applications that have been identified from the investigations are summarized below.

Agriculture investigation results indicate that use of ERTS-1 technology could result in more timely estimates of crop production and yield.

Land use inventory data obtained from ERTS-1 have been incorporated into some existing state and regional land use information management systems and have provided valuable updates of these systems.

In water resources, numerical water distribution models have been implemented by the U.S. Geological Survey in South Florida. These models combine data on the area of surface water from ERTS-1 imagery with data on water level obtained from ground measurements relayed to ERTS-1 by Data Collection Platforms, providing accurate and economical estimates of ground water available for irrigation and urban use. ERTS-1 data have also been utilized in the accurate prediction and management

of water coming from snowmelt. These predictions are particularly important in the Western United States where small increases in the accuracy of runoff predictions may have significant economic benefits.

In the coastal zones, ERTS data have been used to map variations in current circulation patterns and to infer sand transport due to offshore currents off the coast of California; to provide information on water circulation patterns within the Delaware Bay; and to reveal unexpected circulation patterns in the northern portion of Cook Inlet, Alaska.

*SKYLAB/EREP.*—The Earth Resources Experiment Package (EREP), which was flown on Skylab, included a complement of six advanced photographic and electronic sensors which acquired data in the visible, infrared, and microwave portions of the electromagnetic spectrum. These sensors were flown to gain information for the design of future automated systems and to explore the feasibility of using data with increased spatial resolution and data in other spectral bands such as in the microwave region for resource survey studies. These data will be correlated with information obtained about selected ground sites from aircraft and/or from on-site measurements. Particular emphasis is being placed on validating the utility of spectral signature identification from orbital altitudes. Investigations are being conducted in the areas of agriculture, range and forestry, geology, water resources, coastal zones, land use planning, and cartography.

*Applications Demonstrations.*—As a result of NASA's success in its remote sensing research programs, several experimental demonstrations of remote sensing capabilities are being planned. These programs are major efforts designed to demonstrate and transfer developed and proven technology to operational user agencies. They are designed to serve as the transition from the R&D remote sensing system to the operational system.

Presently planned demonstrations include: (1) a capability to inventory crops, (2) a system to extend the shipping season in the Great Lakes through ice monitoring, (3) the capability to generate or update environmental maps of a (predominantly) wetlands area, and (4) an automated natural resources system oriented to state or regional use.

*Earth Observations Aircraft Program.*—In 1974 the emphasis in the Earth Observations Aircraft Program shifted from obtaining complementary remote sensing data for the support of satellite missions to an integral part of NASA and interagency applications research and demonstration projects. The aircraft program now supports activities in meteorology, environmental quality, and earth and ocean physics research tasks in addition to those of Earth resources

survey which dominated flight activity in previous years. The primary objectives of the program continue to relate to the identification and development of sensors for future space missions, and the development of remote sensing and analytical techniques. During 1974 NASA operated one of the aircraft in support of other agency programs to measure pollutants and climatic impacts associated with the stratosphere. Also, another aircraft supported the Global Atmospheric Research Program's Atlantic Tropical Experiment. These activities are described in the following sections.

### ***Pollution Monitoring***

1974 marked the second year of existence of NASA's Pollution Monitoring Program as an entity. This program is aimed at developing and demonstrating the technology needed to monitor parameters associated with the pollution of the atmosphere and the waters of the earth. This technology is expected to contribute to an eventual national capability for operational systems capable of continually monitoring the environment and helping to maintain an acceptable environmental quality.

*Oceanographic and Air Pollution Observing Satellite.*—The Nimbus G Oceanographic and Air Pollution Observing Satellite planned for launch in 1978 is a major focus of the program; its nine experiments are designed to provide data on air and water pollution, oceanography, the atmosphere/ocean interface, and the Earth's energy balance. Although serving as a technology demonstration program, Nimbus G marks a first step towards eventual operational monitoring on regional, national, and global scales. Procurement for the design and construction of the spacecraft and associated experiments is underway.

In May, a successful major prototype demonstration test was conducted for the Lower Atmosphere Composition and Temperature Experiment designed to measure vertical profiles of trace stratospheric constituents on a global scale. A successful test, conducted under the Advanced Applications Flight Experiment (AAFE) Program, obtained data over a five-hour period on atmospheric constituents between 36 and 42 kilometers (22.6 and 26 miles). It was supported by 15 simultaneous correlation experiments using balloons, rockets, and aircraft-borne remote and *in situ* experiments as well as ground-based observations. Several universities, the Department of Transportation, the Department of Defense, and the National Center for Atmospheric Research participated.

*High Altitude Atmospheric (Stratospheric) Monitoring.*—Emphasis in stratospheric research is increasing, both to establish a national baseline of

stratospheric structure and composition and to monitor possible changes in stratospheric conditions resulting from natural phenomena and man's activities. Stratospheric processes are especially important because of their influence upon atmospheric temperatures and solar radiation reaching the earth's surface.

Data from high altitude (20 kilometers; 12.6 miles) aircraft surveys have indicated baseline upper atmosphere particle densities of about 15 particles/cm<sup>3</sup>, varying by a factor of two to three on a day-to-day basis. Up to 80% of the particles are in the size range of less than 0.1 micron diameter and are of sulfate origin. Flights to the north polar regions mark the beginning of quasi-hemispherical surveys of ozone, nitric oxide, and aerosols to determine regional variations. Recent transfer of an Air Force WB-57F aircraft to NASA, for use in support of the Department of Transportation's Climatic Impact Assessment Program and the NASA stratospheric research program, will enhance the capability for determining the baseline stratosphere and studying the effects of both natural and man-derived pollutants.

*Low Altitude Atmospheric (Tropospheric) Monitoring.*—Recent aircraft flights of two different carbon monoxide remote monitors in the Washington, D.C. area marked the initiation of a program to define the capability of remote sensors for satisfying urban/regional scale monitoring needs. Initial studies will concentrate on carbon monoxide and sulfur dioxide to support national requirements for ambient air monitoring of these pollutants. Remote sensor measurements, supported by computer models and *in situ* ground-truth measurements, are expected to demonstrate the capabilities of an integrated urban/regional system by 1980.

*Water Pollution Monitoring.*—Algae serve as biological indicators of water quality because of their response to nutrients (growth) or to toxic substances (disappearance). Remote measurement of algae bloom concentrations, distributions, and possibly algae type have been demonstrated through the use of infrared photography, multispectral scanners, and active laser systems. Continued analysis of studies in the upper Potomac River, in cooperation with the Environmental Protection Agency, have demonstrated the capability of making detailed maps of algae blooms with concentrations as low as about 30 micrograms per quart (or liter). Multispectral scanner studies of Clear Lake—a highly fertile lake in California—have shown highly complex algae distributions with distinctive spectral signatures apparently related to algae type. Research continues with a four-color laser system optimized to detect fluorescence from the red, golden, brown, green, and blue-green groups of algae.

## *Weather and Climate*

The Weather and Climate program has the longest history among U.S. programs to apply space techniques. These activities are primarily directed toward improving the accuracy of both the short and long-term weather forecasting.

Within the Weather and Climate program, basic and applied research is conducted to support space-related experiments, satellite development, and operations of the National Weather Program. Activities also include the development and demonstration of new sensing techniques and atmospheric modeling techniques in support of the Global Atmospheric Research Program (GARP). During 1974 the first Synchronous Meteorological Satellite (SMS) was launched and made significant contributions to the acquisition of near-continuous cloud cover imagery of the Western Hemisphere. SMS was a major component of the GARP Atlantic Tropical Experiment described below.

*Global Atmospheric Research Program (GARP).*—The GARP Atlantic Tropical Experiment (GATE) is a highly successful international atmospheric research experiment to gather data to contribute to the understanding of the behavior of the tropical atmosphere and its ultimate effect on global weather. The experiment began during the summer of 1974 and lasted 101 days. In this first large-scale international GARP experiment, NASA participated through data collection by the ship VANGUARD, a CV-990 aircraft, a direct-readout ground station, and the meteorological satellites, SMS-1, ATS-3, and Nimbus-5.

A second principal GARP activity was the May 1974 Data Systems Test (DST); primary responsibility was assigned to NASA for the DST, which produced the first real-time global data set. The observation system consisted of the Nimbus-5 atmospheric sounders, the operational satellite NOAA-3, ATS-3, and the conventional network of surface, upper-air, and aircraft observations. Processing of satellite sounding data from Nimbus-5 and procedures for determining wind fields from cloud-track images obtained by geostationary satellites highlighted the DST.

The DST provided a simulation of the observing data collection and data-processing system concepts and procedures under consideration for the First GARP Global Experiment (FGGE) currently planned for 1977-79. Further testing is planned for 1975 following the launch of Nimbus F. FGGE will concentrate efforts to utilize collected data in attaining the following goals: (1) A more realistic atmospheric model for extended range forecasting, general circulation changes, and climate prediction, (2) assess-

ment of the practical limits of weather systems predictability, (3) development of more efficient methods for assimilation of meteorological observations, and, in particular, usage of non-synoptic data as a basis for predicting large-scale atmospheric motions, and (4) design of an optimum composite meteorological observing system for numerical weather prediction of general circulation features.

*Synchronous Meteorological Satellite (SMS) Program.*—SMS-1 was launched into a geostationary orbit during May 1974. The Visible and Infrared Spin Scan Radiometer (VISSR) aboard offers full-Earth disk pictures of the Western Hemisphere every 30 minutes during the day or night. The VISSR has the capability of a visible-range resolution of about 0.56 miles (0.9 kilometers) and an infrared resolution of 5.6 miles (9 kilometers). The acquisition of such high-resolution data at frequent intervals in real-time will contribute significantly to efforts of identifying, monitoring, and tracking severe weather phenomena such as hurricanes and atmospheric conditions conducive to tornado formation. This added observational tool should aid short-range forecasting and promote more timely issuing of weather and disaster warnings. SMS-1 and SMS-B (to be launched in 1975) will comprise, in part, a geostationary satellite system which can fulfill the NOAA requirements for the National Operational Environmental Satellite System.

*ATS-6.*—Although this is primarily a communications satellite, its launch in May of 1974 marked it as the first geostationary three-axis stabilized satellite. Such stabilization ability will be of major importance in future geostationary Earth-oriented spacecraft because of the greater viewing time thereby afforded. The Geosynchronous Very High Resolution Radiometer aboard ATS-6 was designed to derive cloud-tracked winds and sea-surface temperatures in support of GARP as well as measure reflected solar energy and emitted infrared energy. This instrument produced about 600 very high quality color images before it was disabled due to a component failure.

### *Earth and Ocean Physics Applications*

During 1974, the Earth and Ocean Physics Applications Program continued its ground-based and flight activities in support of its primary goal, which is to identify, develop, and demonstrate relevant space techniques that may contribute significantly to the development and validation of predictive models for earthquake hazard alleviation, ocean-surface conditions, and ocean circulation.

GEOS-C, the Geodynamic Experimental Ocean Satellite is proceeding to launch readiness in March of 1975. Data from this program is expected to vali-

date the use of a radar altimeter for measurement of the ocean geoid, as well as to provide accurate information on wave height and sea state.

Two new projects were defined as part of the Earth and Ocean Physics Program in 1974. These are the Tectonic Plate Motion and SEASAT-A projects. The former is concerned with the physical motions of the Tectonic plates which make up the surface of the Earth while the latter is designed to acquire data on ocean dynamics. Both will contribute to a better understanding of Earth and ocean processes and their effect upon the environment in which we live.

### **Communications**

NASA has long been active in programs to develop the technologies for utilization of space systems in communications systems of vastly increased capability. A major segment of the communications industry, including established firms, new quasi-governmental corporations, and international organizations, is heavily involved in space communications.

The world-wide need for improved communications received added impetus. During 1974, a number of countries moved ahead with planning for communications satellite services. The United States will be a major supplier of subsystems, spacecraft, launch services, and ground-station equipment. Continuing our commitment to launch commercial communication satellites for international services on a reimbursable basis, another INTELSAT IV was launched on November 21, 1974, and additional launches are expected in 1975.

There was continued growth in domestic commercial communications satellite activities, as Western Union inaugurated its domestic satellite service. NASA provided launch services for Western Union's Westar A in April and Westar B in October 1974, on a reimbursable basis. RCA is continuing development and construction of satellites for its domestic system and anticipates a first launch in 1975. The American Satellite Corporation is leasing capacity on the Canadian communications satellite ANIK pending a decision to launch its own. The Comsat Corporation's Maritime Satellite—MARISAT—nearly completed in 1974 and a launch is planned for 1975. The result was a favorable outlook for growth in domestic telecommunications industry. In planning for the growth of existing services and the inclusion of new services over the next 10 to 15 years, NASA is assisting in preparations for the World Administrative Radio Conferences in 1977 and 1979.

In May 1974, NASA successfully launched the sixth in its series of Applications Technology Satellites (ATS-6). This spacecraft, employing the most powerful and versatile communications systems

launched in the series to date, has been employed in experiments in the use of satellites for health and education communications to remote areas.

With the launch of the ATS-6, NASA's activities in communications research and development are being refocused toward exploring more advanced elements of this technology, with further application of already developed technology being left to the private satellite and communications industry.

*Applications Technology Satellite.*—The Applications Technology Satellite 6 (ATS-6), the most versatile and powerful communications satellite yet developed, was successfully launched into synchronous orbit May 30, 1974. This satellite is distinguished by its 30-foot parabolic reflector antenna which can relay high quality signals, such as instructional color television, to small, inexpensive ground terminals. At the end of the first month of flight, all systems had been successfully evaluated with very few anomalies encountered, and the spacecraft was declared operational.

ATS-6 contains a total of 23 experiments covering a wide variety of useful applications and new techniques. One very important applications experiment explores continuous voice communication with and position determination for ships and airplanes in trans-oceanic travel. There are also experiments to investigate characteristics of newly allocated radio frequencies being considered for future communications use and to determine the power density levels, frequency distribution, and geographical location of sources of interference to presently used satellite communications frequencies. There is also an experiment to demonstrate a ground-based equipment approach to reducing the cost and complexity of controlling satellites and achieving a measure of commonality between satellites to reduce development costs. There are other experiments in day-night cloud-cover imagery and several experiments in space science. All of these have performed satisfactorily. The satellite mission was formally declared a success on September 25, 1974.

The ATS-6 Health, Education Telecommunications (HET) experiment, which investigates the practicability of satellites for broadcasting educational and health information to people in remote or isolated areas, began operations in July 1974 with the Appalachian Regional Commission (ARC) and the Veterans Administration (VA) components. The ARC components provided two summer courses for graduate college credit, relayed through ATS-6 from the University of Kentucky at Lexington, to teachers in 15 isolated Appalachian locations.

During these courses, the participants were able to initiate inquiries and provide responses to test questions through a spacecraft launched earlier,

ATS-3. Additional college credit courses with interactive capability will continue throughout the current academic year. The VA component of HET provide seminars and medical consultation for physicians and health professionals at 11 VA hospitals. This programming is certified for health professions continuing education credit by the American Medical Association. The Rocky Mountain component of HET started career education instructional television in September. As with the Appalachian component of HET, some of the reception terminals are equipped to utilize ATS-3 for interaction between participating junior high school students and instructors in Denver, Colorado. The Alaskan health component of HET, which experiments with provision of improved health care to isolated Alaskan villages, also started operation in September. In this component, audio and video medical data and teleconferencing can be transmitted between medical aides at remote locations and physicians located in regional hospitals in Alaska and at the University of Washington's School of Medicine.

Following the experiments in the United States, it is planned to move the ATS-6 satellite from the United States to India to support a Satellite Instructional Television Experiment (SITE) to be conducted by the Indian Government. Instructional television programs are planned to be provided to about 5,000 Indian Villages, 2,000 of them by direct broadcast to individual receivers. The Indian ground station is completed and ready for the SITE experiment. Television program production is underway and production of television receivers to serve the village sites is accelerating. In July 1976, following completion of SITE experiments, ATS-6 is planned to be moved back to the United States for additional experiments.

*Communications Technology Satellite (CTS).*—The Communications Technology Satellite is a joint development of the Canadian Department of Communications and NASA. This experimental satellite will be launched near the end of 1975 and is planned to begin experimental broadcasting to small low-cost terminals. This spacecraft pioneers the use of the 12 GHz frequency allocation which has been set aside for broadcast satellites. The United States is providing the super-efficient 200 watt output Transmitter Experiment Package for the satellite and the Thor/Delta launch vehicle. The United States will perform environmental testing and launch of the Canadian-developed spacecraft. During 1974 solutions were developed for problems associated with operating the Transmitter Experiment Package in a space environment. An engineering model of this package was delivered to Canada and integrated with

the Canadian spacecraft. With the CTS in geostationary orbit in view of the United States and Canada, NASA and the Canadian Department plan to conduct numerous communications experiments, sharing time on the spacecraft equally. Experiments to be performed range over a wide variety of potentially beneficial satellite applications. Included are experiments related to educational and health services to remote areas of the country and interchange of university curricula. In addition, scientific experiments associated with the transmission of digital television will be performed. In 1974 coordination with Canada and preparations for the launch continued.

*Advanced Communications Research and Technical Consultation Services.*—In 1974, emphasis was placed on conducting research needed to explore the higher regions of the radio frequency spectrum. Studies continued on frequency allocation and bandwidth and orbit requirements for future applications missions. Studies and investigations to open up new regions of the spectrum for applications research were continued as were efforts to develop or improve space systems components and technologies to facilitate increased efficiency in use of the geostationary orbit. Much of this effort is stimulated by increased crowding of the radio frequency spectrum and is designed to discover methods of alleviation. Technical consultation to the Federal Communications Commission, in the form of satellite systems evaluations, continued to expand as more and more new applications for domestic and international satellite services were filed. This consisted of numerous satellite system evaluations for the FCC. Spacecraft design reviews for INTELSAT and the United States domestic communications satellite applicants continued.

A major effort in 1974 involved the beginning of preparations for the World Administrative Radio Conferences to be held in 1977 and 1979. In this work NASA provides technical support to the Federal Communications Commission, the Office of Telecommunications Policy, and the Department of State, as they prepare the United States position for these two world conferences.

*Data Collection Via Satellite.*—Expansion of data collection activities using spacecraft continued in 1974. Interest in the use of Earth-based sensors to be interrogated by satellites continues to expand. Installation of a read-out station for data-collection platforms in the Gulf Coast region of the United States was initiated at the National Space Technology Laboratories in Mississippi.

*Disaster Warning System.*—In response to a request from the National Oceanographic and Atmospheric Administration (NOAA), a comparative study

of ground-based and satellite-based communications segments of a national disaster warning system was conducted. The concept would make it possible to transmit real-time warning alerts into U.S. homes, businesses, and institutions and providing communications links between ground-based components of the natural disaster control system.

*Data Management.*—In 1974, NASA initiated a concentrated effort in data management. The intent is to devise techniques to reduce costs and improve efficiency in handling experimental data and information. The objective of this effort was to define optimized data systems to satisfy identifiable needs of data users and to improve performance and reduce costs of components used in sensor data formatting, processing, storage, and dissemination. The improved and optimized components, in turn, are planned to be integrated into an optimized overall system. Initially addressing only the data and information activities associated with Applications programs, it is envisioned that in time these new techniques will be employed elsewhere in NASA and in other data management programs.

### *Space Processing*

Space Processing Applications has as its primary goal the identification, development, and demonstration of processing techniques that are designed to take advantage of the unique qualities of the space environment to produce materials which might be more economical to process in space or impossible to produce on Earth, but which could be of great value if available.

Research begun in 1973 was continued in order to further analyze the results of Skylab and to develop concepts for new processes. On November 4, 1974, the Massachusetts Institute of Technology presented President Ford with a crystal of indium antimonide that was grown aboard Skylab in January 1974 as part of the space-processing experiments on the Skylab missions. An example of the potential in space processing, this crystal was the purist and longest yet produced by man. Such crystals could make feasible substantial reductions in the size of the components in computers, television sets, and other electronic devices.

### *Non-Space Applications of Space Technology (Technology Applications)*

Many of the problems and difficulties facing the nation today in areas such as housing, transportation, public safety, and pollution control could be reduced or eliminated by new technological developments. Toward this goal, NASA, through its Technology Applications program, is bringing together teams of experienced scientists and engineers to work with

other federal agencies, state, and local governments in developing technology systems for use in hospitals, police departments, ground transportation, etc.

One such system originally developed in this program is the Modular Integrated Utilities System, a concept to integrate all community utility functions into a single, energy-efficient, environmentally benign package. This ongoing program being conducted by NASA's Office of Energy Programs for HUD was detailed in last year's report.

Another system is the Activated Carbon Treatment System, developed by NASA's Jet Propulsion Laboratory. This system, which uses technology developed for the production of solid-fueled rockets, relies on activated carbon to treat municipal sewage or industrial wastes. The removed organic material is then "pyrolyzed" to produce more activated carbon. The system was demonstrated this year at a treatment facility operated by Orange County, California.

This process eliminates the problem of sludge disposal and may result in substantial savings in new plant construction and operating costs. The U.S. Environmental Protection Agency has approved a grant for the County Sanitation Districts of Orange County to construct a 1,000,000 gallons per day plant which would use this process.

In a related area, NASA is developing a Water Quality Monitoring and Control System for use in municipal sewage treatment facilities or smaller "package" sewage treatment plants. This system will use many of the advanced sensors developed for future long-duration manned space flights.

### *User Affairs*

During 1974, NASA's Office of Applications made significant strides in improving its understanding of the many needs of the various "user communities," and at the same time progress was made in exposing to those communities the potential application of space technology and systems to help meet their needs. These activities have been focused in the Office of User Affairs of the Office of Applications. NASA is working closely with such mission-oriented agencies of the Federal Government as the Departments of Agriculture, Commerce, Interior, Health, Education and Welfare, Housing and Urban Development, and Transportation, and the Corps of Engineers and the Environmental Protection Agency. In addition, NASA also expanded its active dialogue with state government agencies and regional organizations in such areas as resources and land use management, energy, communications, and the environment.

*Environmental Applications.*—NASA jointly sponsored (with the Environmental Protection Agency)

two major regional meetings to identify EPA problem areas which are conducive to solution by applications of NASA-developed technology. These conferences were attended by technical experts from various NASA field installations, by representatives from EPA National Environmental Research Centers, and by representatives of EPA regional offices. These conferences resulted in the identification of a large number of significant environmental problems to which NASA technology and expertise can be applied. Work plans are in progress toward developing specific projects to implement solutions to the problems on a jointly funded basis.

*Summer Study of Space Applications.*—A major activity of the User Affairs program involved representatives of the user community in reviewing NASA's applications programs at a Summer Study of Space Applications held at Snowmass, Colorado. This study was formally sponsored by the National Academy of Engineering's Space Applications Board and took place from June 30 through July 13, 1974.

The study was focused on 14 multi-disciplinary panels and a staff which together totaled more than 100. Senior officials from industry, academia, state and local governments, federal agencies, and representatives of the applications program user communities participated. These were well known experts from a variety of fields, many of whom had little previous knowledge of the ongoing and future activities of the NASA applications program. The Director of the Summer Study was Jack M. Campbell, President of the Federation of Rocky Mountain States, and former governor of New Mexico.

The working panels were organized into the following disciplinary areas: Weather and Climate; Uses of Communications; Agriculture, Forest and Range; Environmental Quality; Materials Processing in Space; Land Use Planning; Marine and Maritime Uses; Extractable Resources; and Inland Water. Additional panels of an "overview" character addressed the subjects of Institutional Arrangements, Information Services and Processing, and Costs and Benefits. These panels provided perspective regarding cost and institutional inhibiting and driving factors. These panel activities were supported by inputs from a Panel on Space Transportation and a NASA Technology Support Team.

*Establishment of the National Space Technology Laboratories.*—Effective June 14, 1974, the National Space Technology Laboratories (formerly the Mississippi Test Facility) was created at Bay St. Louis, Mississippi. This step was taken in recognition of capabilities that exist there for conducting remote sensing, environmental, and related research and

technology activities, which have been enhanced in recent years by the co-location at NSTL of research and technology activities of several other government agencies.

### *NASA Energy Program*

To provide a focus for the application of its advanced aerospace technology to energy needs, NASA has established an Office of Energy Programs. This office will manage NASA energy programs and will coordinate NASA support to other Federal agencies conducting energy research and development.

*Solar Energy Electricity Generation.*—NASA has pioneered in the development of solar energy collection and conversion systems. The Skylab space station and the upcoming Viking Mars Lander spacecraft are among the many spacecraft utilizing solar arrays to produce electricity. In cooperation with the National Science Foundation, NASA is conducting a program to reduce the cost and improve the efficiency of solar cells. Promising progress has been made in the growth of high-quality, single-crystal silicon ribbons for application to mass-produced, low-cost solar cells.

*Microwave Energy Transmission.*—Transmission of electricity via microwave radiation is also being investigated as a vital component of possible large satellite power stations. In a recent NASA demonstration at the Venus test site at Goldstone, California, a record was set for wireless transmission of power. A one-square-meter receiving-and-rectifying antenna (rectenna) delivered approximately one kilowatt of power at a range of 1.6 kilometers. The efficiency of the rectenna in converting the incoming microwave power to direct current power was slightly over 75 percent.

*Solar Heating and Cooling.*—The use of solar energy for heating and cooling of buildings is being investigated as a potential alternative to current methods. Under the 1974 Solar Heating and Cooling Demonstration Act, NASA has initiated program planning in conjunction with the Department of Housing and Urban Development and several other Federal agencies to demonstrate the residential and commercial feasibility of solar heating and cooling units and to develop the capability within private enterprise for the widespread application of this abundant source of energy.

In June, an experimental solar house was completed at the Marshall Space Flight Center in Huntsville, Alabama, which will ultimately derive up to 85 percent of its heating and cooling energy from the sun. Ground was broken in July for a 50,000-square foot office building at the Langley Research Center in

Hampton, Virginia. This building should be able to derive up to 90 percent of its heating and 50 percent of its cooling from a field of solar collectors.

These facilities will provide test beds for new components, as well as aid in understanding the day-to-day problems associated with solar heating and cooling.

*Wind Energy Program.*—Wind-energy systems have been used for centuries for pumping water, grinding grain, and in limited cases, generating electricity. Wind-driven electrical generating systems, however, have thus far not been cost-competitive with fossil-fueled plants.

NASA has many years of experience in airplane and helicopter technology involving blade designs incorporating advanced materials, structures, rotating machinery, etc. As a result of this program, the NSF, as a part of its Five-Year Wind Energy program, has assigned NASA the responsibility for design, fabrication, and testing of windmills. The intent of this effort is to determine if such systems are technically feasible and if they can generate electrical power reliably and cost-effectively. At the present time, design and construction of a 100 Kilowatt Wind Generator is underway at the NASA Lewis Research Center. Initial testing is scheduled for July 1975.

*Transportation Systems Aerodynamic Drag Studies.*—NASA, in cooperation with the Department of Transportation, is conducting two studies designed to reduce the drag and correspondingly increase the fuel economy of transportation systems. At the Flight Research Center, trucks are being tested to determine the drag reduction possible through changes in their basic aerodynamic shape. In addition, an assessment is being made of selected commercially-available drag reduction "add on" devices.

At the Jet Propulsion Laboratory in Pasadena, California, scale models of automobiles (sub-compact, compact, and full size) are undergoing wind tunnel tests. Aerodynamic changes such as the addition of front and aft spoilers, vehicle underpanning, etc., are being evaluated, both in the wind tunnel and in full-scale road tests

*Low Pollution/Low Fuel Consumption Automotive Engines.*—A relatively recent discovery has shown that small quantities of hydrogen-rich gas introduced into the internal combustion engine, along with the normal gasoline/air mixture, permit operation with increased efficiency and greatly reduced pollutant emissions. The Jet Propulsion Laboratory, in cooperation with the Environmental Protection Agency and the Department of Transportation, is conducting tests using bottled hydrogen. Results indicate that fuel economy improvements of nearly

25 percent and emissions below the 1977 Federal standards can be obtained.

A major accomplishment during this year was the development and demonstration of a generator which produces a hydrogen-rich gas directly from gasoline and is of a sufficiently small size to be packaged on board a normal automobile. Such a device may permit essentially the same economical and low-pollution performance as was previously demonstrated for bottled hydrogen.

*Energy Conversion Alternatives Study.*—Currently over 60 percent of the heat generated in an electric power plant is wasted. Many alternative approaches are possible for reducing this wasted energy. NASA is conducting a study to obtain a comparative evaluation of the merits of various energy conversion systems utilizing coal or coal-derived fuels. The study is jointly funded by the National Science Foundation, the Department of the Interior, and NASA. The final report from the study should be available by the end of Calendar Year 1975.

*Advanced Coal Energy Extraction.*—To help meet the Nation's energy needs, the Department of the Interior is expanding its research and development effort to increase coal production with enhanced mine safety. NASA was requested early in 1974 to assist with that effort by selective application of its background and experience in engineering and physical sciences.

NASA is now working with the Bureau of Mines to select mutually agreeable technology advancement projects that build on expertise unique to NASA and will be complementary to the Bureau of Mines research and development program. Both near term (1978) and intermediate term (1985) technology advancement projects are under consideration.

### **Study of Sun-Earth Interactions and Cosmic Processes**

NASA's Physics and Astronomy programs are directed toward the investigation of the Earth, the Sun and the solar system, the galactic and extragalactic phenomena, and how they interrelate. These programs also seek to discover new physical and energy principles by studying the awesome processes that abound in this gigantic cosmic laboratory. As most of the radiations from these processes are screened from the Earth's surface, it is advantageous to place our instruments above the Earth's atmosphere—in space.

To achieve these program objectives, NASA uses techniques ranging from theoretical and laboratory research through aircraft, balloon, and sounding rocket flights to small explorer spacecraft, large

automated observatories, and manned spacecraft. Research teams involved in this program are located at NASA field centers, other government laboratories, universities, and industrial laboratories. Foreign participation is encouraged with the participating country providing its share of the costs.

### *Study of the Sun*

The Orbiting Solar Observatory (OSO-7), launched in September 1971, attained an impressive list of achievements prior to reentry in July 1974. Achievements include detection of nuclear reactions in solar flares, the discovery of oscillations in the Sun's transition region between the chromosphere and corona, and the development of improved techniques for forecasting the appearance of active regions. Particularly significant are the excellent observations taken by OSO-7 in conjunction with the Skylab Apollo Telescope Mount experiments.

Development of the last spacecraft in the series, OSO-I continued in 1974, pointing towards a planned launch for May 1975. OSO-I is designed to offer the best combination of high spectral, spatial, and time resolution ever obtained in many important UV and EUV lines. From these data, the detailed structure, dynamics, and heating of the chromosphere and transition region will be studied. OSO-I also contains several advanced X-ray instruments for studying solar, stellar, and cosmic X-ray sources.

The Apollo Telescope Mount (ATM) deployed aboard Skylab from May 1973 to February 1974 was a new "second generation" space observatory, where the skill of an on-board manned observer was added to the largest observatory yet placed in orbit.

The data acquired by the six major ATM instruments, together with those obtained by the worldwide program of complementary ground-based and rocket-borne observations, form the most comprehensive set of simultaneous high-resolution solar data ever collected. An analysis of these data promises to produce substantial growth in man's knowledge of the structure and dynamics of the solar atmosphere, and of the coupling between the solar atmosphere, the solar wind, and the terrestrial atmosphere. For example, ATM data indicate that most of the solar wind may be "blowing" from the mysterious coronal holes. Similarly, the observation of flares—the cataclysmic events that have dwarfed the world's total power consumption for thousands of years at the present rate—has shown that there are different mechanisms at work in different flares.

### *Sun-Earth Interactions*

An important objective of the Magnetospheric Physics program is to understand the processes by which the Sun influences the entire near-Earth

environment and the upper atmosphere, thereby producing climatic and other variations. The region of maximum solar absorption is near 100 miles (160 km) altitude and this region is now being systematically investigated on a global scale for the first time by the Atmosphere Explorer (AE)-C (Explorer 51) launched in December 1973.

Data from AE-C have already demonstrated the importance of large-scale dynamic atmospheric motions which have a direct bearing on the distribution of pollutants. The complicated chemical processes which accompany the absorption of sunlight are being investigated in this program. These processes must be understood before we can predict the long-term effects of man-made contaminants on our atmosphere.

Another important objective of the Magnetospheric Physics program is to understand the processes which occur in the outer magnetosphere where the solar wind interacts with the Earth's atmosphere and magnetic field. The Hawkeye satellite, launched June 3, 1974, was placed in the region of the magnetic neutral point, at an altitude of about 77,000 miles (124,000 km). This is where the Earth's magnetic field is neutralized by the solar wind, and where solar-wind particles can enter the Earth's atmosphere to produce the polar auroras.

The International Sun-Earth Explorer program (ISEE) (formerly International Magnetosphere Explorer (IME) program), which is a cooperative venture between NASA and the European Space Research Organization (ESRO) is proceeding on schedule. The ISEE will consist of three spacecraft: an A/B pair to be launched in late 1977 into a highly elliptical orbit about the Earth to study detailed time-space variations of particle population and electric and magnetic fields; and an ISEE-C spacecraft to be launched in late 1978 into a halo orbit around one of the libration points between the Sun and the Earth to study the solar wind impact to the magnetosphere and to measure cosmic rays.

### *International Cooperative Study of the Sun*

Helios is a cooperative space project between the Federal Republic of Germany and the United States which has the general scientific objective of providing increased understanding of fundamental solar processes and solar-terrestrial relationships. The Helios-A spacecraft, launched by a Titan-Centaur on December 10, 1974, and Helios-B, to be launched a year later, are to go in over two-thirds the distance from the Earth to the Sun, closer than any previous spacecraft, during the three-month period after launch. Germany built the spacecraft and seven of the experiments; the U.S. provided three experi-

ments, the launch vehicles, launch and flight operation support, and technical support.

### *Orbiting Astronomy Observatory (OAO)*

The Orbiting Astronomical Observatory-3 (OAO-3—Copernicus), launched in August 1972, is continuing to obtain scientific data. The primary objective of OAO-3 is to obtain high-resolution ultraviolet spectra of stars necessary to investigate the composition and physical state of matter in interstellar space and of stellar sources.

In its first two years of operation, OAO-3 obtained over 9,800 observations of 243 unique celestial objects with the Princeton University experiment, and over 1,400 observations of 234 celestial objects with the University College London X-ray experiment.

### *High Energy Astronomy Observatory (HEAO)*

The basic scientific objective of the High Energy Astronomy Observatory program is to explore the previously inaccessible regions of celestial X-ray and gamma-ray sources and of cosmic-ray flux. This program has the potential to enhance our understanding of newly discovered energy processes and of the creation of matter. It should also greatly improve our understanding of observed phenomena such as quasars, pulsars, novae, and supernovae, the most intense energy phenomena yet discovered.

During 1974, primary emphasis was placed on the detailed design of the HEAO-A spacecraft and scientific payload. Design of the HEAO-B instruments has begun and definition of the HEAO-C payload is continuing. In addition, long-lead items are being procured. The design of a facility to calibrate the large X-ray telescope on HEAO-B was completed and construction started.

### *International Satellites*

In addition to the previously mentioned ISEE, work continues on the International Ultraviolet Explorer (IUE), a joint project between NASA, UK, and ESRO. This project's goal is to place a 45-cm astronomical telescope into a modified geosynchronous orbit and operate it as an international observing facility. The satellite, planned for launch in FY 1977, is designed to obtain ultraviolet spectra of stars from 1200 to 3200A.

In continuing the high scientific priority given to X-ray astronomy, two international cooperative Explorer-class missions were launched in 1974. ANS, a cooperative satellite with the Netherlands, was launched on August 30 from the Western Test Range. The UK-5 Satellite, fifth in the series of cooperative programs with the United Kingdom, was launched in October 1974 from the San Marco Range off the

coast of Kenya, Africa. This mission was the first three-sided cooperative program as, in addition to the US/UK effort, the launch was conducted by Italy at their launch site.

### *Scientific Investigation of Comet Kohoutek*

A bright, long-period comet, Comet Kohoutek, was discovered in March 1973, and was the basis of an intensive scientific campaign to study the origin and structure of comets and their relationship to the early formation of the solar system. The combination of aircraft and space observations with ATM, and ground-based studies organized in NASA's Operation Kohoutek, yielded a substantial breakthrough in the knowledge of the composition and morphology of comets and indicated the great effectiveness and flexibility of space instruments for such special events. The detection of a cloud of hydrogen surrounding the nucleus and the improved data on the upper limits of the abundances of many other elements will measurably enhance the validation of various cometary theories.

### *Spacelab Science Payloads*

Several studies have been undertaken related to planning science payloads for the Space Shuttle. Initial studies pertained to facility-class payloads that would be flown from once to several times per year and would have an operational life comparable to traditional ground-based facilities. The spacecraft science payloads program builds upon the experience and accomplishments of both previous and on-going flight projects including the extremely successful Skylab.

In Atmospheric and Space Physics a preliminary payload design for an Atmospheres, Magnetospheres, and Plasmas-In-Space Spacelab (AMPS) has begun. This facility concept capitalizes on the commonality of instrumentation required for dynamic investigations of the near-Earth environment in the several disciplines represented.

In Astronomy, similar definition studies have begun for a meter-class, cryogenically cooled, infrared telescope facility; a meter-class, high-resolution optical/ultraviolet telescope facility; and a solar physics telescope cluster facility.

### *Large Space Telescope (LST) Definition*

A LST placed in Earth orbit could be used for observations not possible from Earth-based telescopes due to the atmospheric veiling effects on many wavelengths in the electromagnetic spectrum.

Preliminary systems definitions and advanced technological development on selected elements of the LST were carried out this year. These studies show that the design of a telescope of 2.4 to 3 meters (8 to

10 feet) in diameter is feasible. Such a telescope could make possible astronomical observations ten times deeper into space, possibly to the edge of the cosmos, with more detail than has ever before been possible.

### *Sub-Orbital Program*

As a link between theoretical and laboratory research and orbiting spacecraft, NASA uses jet aircraft, sounding rockets, and balloons to test and qualify new instrumentation for future space missions, to make scientific measurements not possible from Earth, and to acquire short-term physics and astronomy data from the upper reaches of the atmosphere in a more economical and timely manner than attainable from satellite instrumentation.

*Airborne Science Program.*—The initial data obtained with the new 91-centimeter infrared telescope carried by a C-141 aircraft to above 90 percent of the Earth's veiling atmosphere, has demonstrated the potential for infrared astronomy. This program also simulated the interaction between the experimenter, the scientific instrumentation, and the flight platform as might take place on a Space Shuttle flight.

*Sounding Rocket Program.*—Sixty-eight Physics and Astronomy sounding rockets were launched this year at locations in the United States, Canada, Sweden, and Norway by diversified research teams from universities, industry, foreign governments, and NASA Centers. A significant accomplishment was the launching of 54 rockets from Wallops Island, Virginia, within a period of 24 hours in support of a joint Air Force/NASA-sponsored investigation of the atmospheric layering and density distribution of ions and neutrals. Observations of colored luminescent clouds caused by the release of chemicals from several rockets provided a large amount of correlative data and created considerable public interest, as reported by visual sightings from as far as Connecticut and South Carolina.

Other firsts included the acquisition of ultraviolet spectrum data of a planetary nebula with a prototype instrument developed by NASA astronomers, and the first ultraviolet photograph of a star cluster.

*Balloon Program.*—Balloons continue to be an important platform for large, heavy telescopes required to conduct infrared, gamma-ray, and cosmic-ray astronomy. During the past year, 45 scientific payloads were launched from the United States and Canada. One significant observation was of the strongest source ever seen in the far infrared. The source is one-tenth as bright as the Moon, and its origin is still a mystery. Important observations were also made of the Crab Nebula in high energy X-rays as this strong source was occulted by the Moon. In addition,

hundreds of cool clouds in our galaxy, previously unknown, were detected using a new telescope of radical design.

The further development of the balloon itself showed satisfactory progress with the successful flight of the largest balloon ever flown, with a diameter of 450 feet—half again as long as a football field.

The application of the super-pressure balloon, developed to increase the length of flight time from several days to several months at constant altitude, will provide for future, long-duration Earth-orbital flights with astronomy and high-energy astrophysics payloads.

## **Exploration of the Planets**

Progress was continued in 1974 toward a better understanding of the planets, their satellites, and interplanetary space in the solar system. In addition to the contribution to science and basic knowledge, better comprehension of the formation and composition of other planets helps us understand the processes that affect the composition and mineral properties of our own. Similarly, improved understanding of the atmospheres and magnetic fields of other planets such as Mercury, Venus, Mars, and Jupiter, helps us to discover and test out theories about the Earth's atmosphere, magnetosphere, and weather.

### *Mariner Venus/Mercury 1973*

Mariner 10, the Mariner Venus/Mercury '73 spacecraft, was launched on November 3, 1973. Within hours following planetary injection, a near-Earth science phase commenced consisting of Earth photography and ultraviolet spectrometer scans. While passing through the lunar orbit on November 5, new photography of the Moon's polar region was obtained. These hundreds of new lunar photographs were utilized to calibrate the TV system.

Venus encounter occurred on February 5, 1974, when the spacecraft passed the planet at an altitude of 5760 km. The first closeup pictures ever taken of Venus revealed clearly the high-speed circulation of the upper atmospheric clouds. These circulation patterns, photographed in ultraviolet, displayed properties of the Venusian atmosphere not previously known to planetary scientists.

The Mercury encounter on March 29, 1974, marked man's first close-up look at the smallest and innermost planet of our solar system. High-resolution photography of the surface revealed a lunar-like terrain that was densely cratered but with a well-developed crust, covering what could be an Earth-like interior. The pictures revealed a surface morphology that showed large circular basins and scarp ridges that reflect a unique period of planetary evolution.

Additional science findings included a surprising planet-related magnetic field, a sparse helium atmosphere, and unexpected streams of high-energy electrons and protons in the shadowed region behind the planet.

Following completion of the Mercury encounter sequence, Mariner 10 was placed on a trajectory for a second Mercury encounter which took place on September 21, 1974. During this second encounter, "a space first," Mariner 10 flew by on the sunlit side to obtain photography of the South Polar region not possible during the first encounter. A remarkable third fly by is scheduled for March 1975.

### *Viking Mars Mission*

The Viking project is designed to begin a new phase of Mars exploration in mid-1976, when two Viking Landers reach its surface and begin their detailed scientific investigations. The scientific objectives of this mission are to obtain data concerning the search for life on Mars and to gather information which will help us understand the evolution of Mars and the solar system. The two Viking spacecraft are planned to be launched in August 1975.

During 1974, qualification testing of Viking science instruments, engineering subsystems, and the complete Orbiter and Lander spacecraft was completed. A major accomplishment in the qualification testing was the exposure of a complete Lander to multiple heat sterilization cycles.

### *Exploration of Jupiter*

The close-up exploration of the outer planets started when Pioneer 10 flew past Jupiter late in 1973. Objectives of Pioneers 10 and 11 were to conduct the first exploratory investigations of the interplanetary region out beyond the orbit of Mars, the Asteroid Belt, and the planet Jupiter. Pioneer 10 was launched in March 1972, and Pioneer 11 in April 1973.

During this year, much of the data obtained while in the encounter period has been analyzed with interesting results. As examples:

—The interior of Jupiter is even hotter than previous estimates. As a result, the planet must be composed largely of liquid hydrogen;

—The familiar circular cyclones and anti-cyclones of the Earth are stretched completely around Jupiter. The grey-white zones are rising cloud ridges that extend 20 km above the orange-brown belts;

—The strong tilted magnetic field plus the rapid rotation rate and large diameter of Jupiter provide an immense outer magnetosphere that is unique in the solar system, a beautiful "space lab" for the study of plasma/energetic particle physics.

### *Outer Planets Mission*

The Mariner Jupiter/Saturn 1977 (MJS'77) project, warmly endorsed by the Space Science Board of the National Academy of Sciences, was approved in 1973 as part of the outer planets exploration program. Two identical spacecraft are planned to be launched in 1977 to Jupiter where they will be accelerated by Jupiter's gravity and orbital velocity for the trip to Saturn, thus enabling attainment of valuable encounter data on both Jupiter and Saturn. In addition to obtaining information on the planets themselves, on the interplanetary medium, and on interstellar cosmic rays, these spacecraft should yield close-encounter data on Saturn's rings and on the massive satellites of both planets. These Mariner-class spacecraft are planned to encounter Jupiter about one and one-half years after launch and Saturn in approximately three and one-half years after launch.

During 1974, the detailed spacecraft system design was essentially completed, and most of the subsystem and science instruments preliminary designs were completed. A major effort was carried out to arrive at a satisfactory approach for protecting the spacecraft from the strong radiation at Jupiter measured by Pioneer 10.

### *Pioneer Venus Project*

The Pioneer Venus project, started in FY 1975, is aimed toward two of the major goals of planetary exploration: improving our understanding of the origin and evolution of the solar system, and improving our understanding of dynamic processes on Earth. This project's primary goal is to obtain a detailed characterization of Venus' atmosphere, which in turn, is expected to provide information that will be beneficial toward understanding the Earth's atmosphere.

The project has two flight missions: one to make *in-situ* measurements at multiple locations on Venus with atmospheric entry probes; and the other an orbiter mission to provide data on a planetary scale.

A systems contractor and scientific instrumentation were selected during 1974 to maintain a schedule leading to two Atlas Centaur launches in 1978.

### *Analysis of Lunar Data*

In 1974, the effort was continued to carefully extract and analyze the information available from lunar flights, Earth-based observations, and laboratory experiments. A Lunar Data Analysis and Synthesis program was initiated to support nearly 50 Principal Investigators in their efforts to correlate existing data and improve our knowledge of lunar origin, history, composition, and present environment, as well as the

Moon's relationship to the Earth and solar system.

In June 1974, about 40 U.S. and 75 U.S.S.R. scientists participated in a four-day conference in Moscow on the cosmochemistry of the Moon and planets. Agreement on basic lunar mapping principles was obtained during the second joint U.S.-U.S.S.R. cartography meeting.

Continuing analysis of the Apollo 15-17 metric photography is providing increasingly accurate positioning and detailing of surface features. In 1974, the first large-scale maps were produced and distributed to lunar investigators for intensive study.

Geochemical measurements made from the orbiting Apollo spacecraft are allowing us to extend the detailed knowledge of lunar surface composition at the landing sites to the approximately 25 percent of the Moon's surface that was flown over by the Apollo orbiters. Chemical elements initially measured from orbit included aluminum, silicon, magnesium, uranium, potassium, and thorium. Recent refinements in data-processing techniques are now permitting measurements of iron and titanium from orbit to be added to this list. This proven technique is now available for future planetary missions.

The five Apollo Lunar Surface Experimental Packages (ALSEP's) placed on the Moon are still returning useful scientific data.

Over the long term, the most valuable scientific result of the lunar program may well be an increased knowledge of our Earth and the entire solar system. A second laser telescope, being completed on Mount Haleakala in Hawaii, will complement the existing telescope at the McDonald Observatory in Texas, which is now ranging on the three laser ranging retroreflectors placed at the Apollo 11, 14 and 15 landing sites and also on the U.S.S.R.'s Lunokhod II reflector. As a result of this laser program, scientists have now determined to a high degree of accuracy the path of the Moon around the Earth and the motions of the Moon around its own axis. With these results, and the new Hawaiian station, it is planned to begin the determination of minute variations in the Earth's rotation rate and the wobbles or wanderings in the Earth's polar axis of rotation.

These irregularities are thought by some scientists to be associated with large earthquakes and perhaps even to precede them. These phenomena are being studied for their possible implications for earthquake prediction.

Studies initiated on Apollo 17 samples of large lunar boulders are revealing important relationships between lunar rock types that were not obtainable from the small rocks and soil grains returned previously. The age of one Apollo 17 rock is the oldest yet determined. At 4.7 billion years, it is nearly a billion years older than the oldest known Earth

rocks. Since the Moon and the Earth are currently thought to have formed as near neighbors in space, study of these oldest lunar rocks provides data bearing on the earliest years of the Earth. The original crust of the Moon, presently believed preserved as the lunar highlands, resembles a relatively lightweight, light-colored volcanic Earth rock known as anorthosite. Previously considered of minor significance, the role of this rock in Earth's history is now being reassessed by geologists.

In its first billion years, the Moon experienced intensive bombardment by asteroid-like bodies as large as several miles in diameter. Although the Earth must have undergone similar bombardment, subsequent erosive processes have erased much of the record. As a result of this current interest in meteoritic impacts and their contributions to planetary surface topography, an impressive number of more recent Earth features have been restudied and reidentified as the modified remnants of small meteoritic craters. Some of these Earth craters have associated mineral deposits of large economic value, hence, the better the understanding of their origin, the better the chances of finding new deposits of similar genesis.

Analyses of the lunar minerals reveal that they were formed under conditions in which free oxygen and water were much scarcer than when terrestrial minerals and rocks were formed. If, as the majority of scientists now believe, the Earth and Moon originated as near neighbors in space, these compositional differences must reflect different conditions prevailing at the time of formation. The discovery of rusted Moon rocks has been particularly exciting as it indicates that water and oxygen vital to life may be derived from the Moon's surface.

### Study of Man

NASA's Space Biomedical Research Program is an integrated program of research into the effects of space and space flight environments on living organisms, their components, and functions. It focuses on the living system, from man on down to the simplest cell. Space Biomedical Research provides for the conduct of a ground-based and space-flight research program designed to elucidate and enhance man's ability to function effectively, efficiently, and safely during space flight, and to conduct life-sciences research using the unique environment of space to support and advance Earth-based science.

#### *Skylab*

Skylab, a multi-faceted mission, produced the most complete medical study of man in space. For the first time, an extended medical study of man in space, with a doctor on board, was accomplished.

The Skylab flight program came to a successful conclusion on February 8, 1974 with the safe return of astronauts Gerald P. Carr, Edward G. Gibson and William R. Pogue. This last Skylab crew spent 84 days in orbit, establishing a new record for long-duration manned space flight. The last Skylab mission met or exceeded all of its planned objectives.

The analysis of the scientific data collected during the three missions will continue over the next several years. However, most of the data collected by Skylab should be in the public domain by mid-1975 and be available to interested parties for independent studies.

Skylab demonstrated that a multidisciplinary manned space station is not only practical but can be highly productive. The men worked well in space, actively enjoying the experience of living in orbital weightlessness. It was possible to maintain essentially normal operations of the immensely complex vehicle even in the face of a number of equipment malfunctions. Also, the crew produced large volumes of very high-quality data in many scientific and engineering fields, more than fulfilling the expectations on which the experiment program was based. The observations and data taking of the Comet Kohoutek resulted in the greatest advance in cometary research since Halley's time.

### *Medical Results of Skylab*

With the successful completion of the third manned Skylab mission, the most significant series of inflight medical studies on man's adaption to and performance in space flight came to an end. The three manned missions of 28, 59 and 84 days, respectively, provided medical data from a series of studies of the time course of adaptive changes which occur as a result of the weightless environment inherent in space flight. All of the observed changes returned to the preflight values during the postflight observation period, indicating that the changes were reversible.

All of the medical-experiment equipment launched in Skylab performed throughout the entire Skylab Flight Program with no major failures. This permitted the scheduled performance of all medical experiments as planned and provided reliable and repeatable data.

The significant adaptive changes occurring in man during the Skylab missions are summarized as follows:

1. There is an apparent redistribution of body fluids within the first few hours of exposure to the weightless environment of space flight, followed by a complementary adaptive change of the cardiovascular system which ultimately plateaus in three to five weeks. The underlying physiological mechanisms in-

involved in these related changes are not completely understood as yet. The current Space Life Science Research Program is preparing, through ground-based studies, inflight investigations on man and his biological surrogates which will be conducted in the Shuttle/Spacelab era.

2. All three crewmen of the second manned mission experienced varying degrees of "stomach awareness," nausea, and, in one crewman, vomiting which is currently believed associated with a response of the vestibular system. However, none of the crewmen of the first manned mission had such a response and only one of the three crewmen in the third manned mission experienced nausea and vomiting. When such responses did occur, they were alleviated within two to three days and all symptoms were totally absent in five days. The use of an anti-motion sickness medication (Scop-dex) as a preventive measure may explain the absence of any problem in the two crewmen in the third manned mission. It is also possible that they may not have had a problem without medication. This condition is being vigorously studied in the Life Sciences ground-based research program.

3. The Skylab medical-experiments program showed that at the end of the 84 days mission, a gradual and small loss of calcium was still taking place. The calcium loss observed in all the Skylab crewmen paralleled the loss of calcium observed in bed rest studies conducted in the Space Life Sciences Research Program. Although it is suspected that the calcium loss originates from selected bones in the body, current ground-based research studies are being conducted in order to identify the actual source. However, it will then be necessary to conduct medical experiments in the Shuttle/Spacelab Program to ascertain if the same physiological mechanisms are at play in the weightless environment of space flight.

4. Prior to Skylab, it was believed that the 100 percent oxygen environment was the basis for the observed red blood cell mass loss that occurred in the Gemini and Apollo crews. A special pressurized chamber ground-based study proved that a 100 percent oxygen environment would cause such a change. However, a drop in red-cell mass was observed in Skylab with a mixed gas atmosphere of 30 percent nitrogen and 70 percent oxygen. Since the red-cell mass loss became less with each succeeding manned mission, it is believed that the change is due to some adaptive mechanism associated with red-cell production within the blood-forming organs of the body. Not only did the red blood cell mass loss decrease with extended mission duration but the recovery time to preflight values was quicker following the longer missions. This further supports the theory that these changes in red-cell mass are related to an adaptive process at the red-cell production level of response.

In summary, the medical results of the Skylab missions have added confidence to the potential commitment of man to long-duration space flight. These are no foreseeable, unresolvable problems which would limit the commitment of man for long duration space flight missions. The Space Life Sciences program ground-based research efforts and subsequent Shuttle/Spacelab medical experiments are focusing on the key issues learned from Skylab with the ultimate objective of insuring that preventive or corrective measures will be available well in advance of a long-duration manned space flight.

### *The Impact of Space Medical Research On Health in the U.S.*

NASA is one of the few agencies that concentrates its research on the study of normal healthy body systems; most other medical research involves the study of diseased systems. This unique approach promises to provide needed insight into the basic physiology of man, and through this knowledge diseased conditions could be better identified, understood, and treated. NASA's diverse research has provided or promises to provide (1) a means of early identification of disease, (2) the necessary biological quantification of radiation doses for the use of accelerator-produced radiation in human cancer therapy, (3) an understanding of the loss of bone and muscle tissues from immobilized limbs, (4) a rapid means of measuring and interpreting human respiratory functions and condition, and (5) an increased understanding of and ability to diagnose cardiovascular disease.

*Import of Skylab Medical Results.*—As an example, Skylab inflight medical investigations of physiological adaptive processes found that the weightless environment produced changes which cannot be explained on the basis of current theories of fluid/electrolyte balance, cardiovascular dynamics, and neurophysiology of the vestibular system. The Skylab medical experiments provided data under unique conditions (near zero-G) which portend new vistas for the study of basic physiological functions underlying the observed adaptive changes. Subsequent studies should provide better understanding and knowledge of these systems which could ultimately lead to improved preventive and therapeutic measures for the delivery of health care.

*Medical Information Computer System (MEDICS).*—The Life Sciences Directorate at the NASA Johnson Space Center (JSC), has been developing a low-cost multiuser minicomputer system to meet a variety of space-related operational medical needs. The system, called MEDICS, is flexible, quickly learned, easy to operate, relatively inexpensive, and

capable of yielding instantaneous information for as many as 16 users simultaneously. MEDICS can also be used in applications other than the space program; for example, MEDICS is planned to be used to support the joint NASA-HEW remote health care delivery project described below.

MEDICS represents a significant advance in the application of minicomputers. MEDICS computer programs enable the operation of a time-shared generalized storage and retrieval system on a minicomputer, rather than the usual expensive large-scale computer required for those types of operations. With the MEDICS software package, a hospital or regional medical center could make a relatively small equipment investment and put into operation a flexible time-shared management information system to meet diverse medical and administrative needs.

*Space Technology Applied to Rural Papago Advanced Health Care (STARPAHC).*—In April 1973, the Papago Indian Reservation near Tucson, Arizona, was selected as the site for the Integrated Medical and Behavioral Laboratory Measurement System (IMBLMS) field test. In this joint NASA-HEW project, NASA is providing the design, assembly, installation, and two years of operations of a telemedicine system, and HEW is providing the medical and paramedical personnel to use the system. Health care on the reservation was already a responsibility of HEW, administered by the Indian Health Service (IHS). Shortly after site selection, the program added a new designation, STARPAHC, reflecting the involvement of the Papago reservation.

The IMBLMS/STARPAHC remote health care delivery system, scheduled to begin test operations in early 1975, makes optimum use of advanced medical instrumentation; video, voice, and data communications; modern data-management techniques; and physician's assistants and other paramedical personnel functioning independently and under the remote supervision of a physician. The specially trained paramedics, called Community Health Medics (CHM) by the IHS, may examine a patient, transmit medical information to a physician in a control center miles away, and consult via two-way TV with the physician who may diagnose the problem and prescribe treatment.

*Other Medical Technology.*—Materials, analytical techniques, computers, and communications systems originally developed for the exploration of space have been valuable to medical research and health care delivery. The examples which can be cited are many. High-purity carbon materials originally developed for rocket nozzle liners have proven to be very biologically compatible. They are now used in heart valves, and development of their use for direct

skeletal attachment of artificial limbs is progressing rapidly. Computer-assisted image processing and enhancement techniques originally developed for the Pioneer and Mariner planetary exploration programs are now used to analyze chest x-rays and human chromosome patterns, to study possible countermeasures against atherosclerosis (hardening of the arteries), and even to visualize chemical molecules. Communications satellites are already helping to deliver health care in Alaska, and medical instrumentation developed for Skylab is being used in emergency medical systems.

A device developed for medical studies of astronauts who are on long space missions is the basis for a miniaturized medical diagnostic system capable of performing 12 different blood analyses. Another attribute of the system is that it uses approximately one-tenth cubic centimeter of blood to do its work. This is about a fiftieth of the blood sample required for most conventional analyses. The system is especially attractive for use with infants, the elderly, and emergency room cases where minimum blood samples are available.

Hospital patients can move about freely and yet provide the medical staff with continuous readings of their heartbeats and body temperatures because the patients wear space-age wrist radios that transmit these readings to a hospital central station. This radio system is derived from equipment developed and used in the Mercury and Gemini-manned space flight programs.

From a machine to conduct eye examinations on astronauts has come the Automated Visual Sensitivity Tester (AVST). With the AVST, a technician can in 10 minutes check a patient for such eye disorders as glaucoma, cataract, and scotoma (a blind spot in the field of vision). Such tests usually take 25 minutes with conventional manual techniques.

The NASA biochemical machine process for detection of extraterrestrial life has been adapted to human health uses in FLASH (Fast Luciferase Automated Assay Specimens for Hospitals), which analyzes bacteria in urine samples.

EPIC, a machine for measuring human coordination, is another device developed from NASA technology. It is expected to find many uses not only in biomedicine, rehabilitation, and the physiology of muscular coordination, but also in job-aptitude testing, law enforcement, and highway safety. In rehabilitation work, for example, test results can show progress or indicate need for remedial help.

By swallowing a one-inch by half-inch bugged tablet, patients can keep medical personnel continuously informed about temperatures deep within their bodies. Local temperature increases can reveal infections.

A greatly improved pacemaker for heart patients uses many electronic and electrical components first developed for NASA spacecraft. This pacemaker uses a rechargeable battery rather than nuclear generated power, and therefore emits no radioactivity.

These examples are illustrative of ways in which space-developed technology is being utilized for human betterment.

## Space Transportation

In January 1972, the President formally proposed to the Congress that the United States initiate the development of the Space Shuttle. The Space Shuttle is the major component of the new Space Transportation System (STS) conceived for the 1980's and beyond. Later in the 1970's and early 1980's, the United States plans to also develop the upper stage Space Tug which will boost satellites to synchronous orbits. In the meanwhile, it is planned to use an Interim Upper Stage to be developed by the USAF. In addition, the Europeans have agreed to develop the Spacelab that will be compatible with the Space Shuttle and will be taken into orbit and operated in the Shuttle's payload bay. The new STS will be used to transport NASA and non-NASA payloads in communications, navigation, traffic control, meteorology, Earth observations, and space science. A stable of unmanned expendable launchers is available to meet current needs. The reusable launch system is being developed under NASA direction. This section describes the progress made in developing the STS as well as the activities of the current expendable launch systems.

### *Space Transportation System*

The STS consists of a reusable Space Shuttle orbiter, Spacelab, and an upper stage Space Tug. The system is designed to provide economical and versatile space transportation for future decades. As discussed under the international affairs section, a manned laboratory (Spacelab), which can be housed in the Shuttle cargo bay, is concurrently being developed and funded by the European Space Research Organization to provide the user community with a ground-type laboratory which can take advantage of the unique environment of space.

The STS is expected to be an economical and reliable transportation system for placing a wide variety of payloads (weighing as much as 29,000 kilograms (65,000 lbs.)) into orbit and retrieving certain of these for return to earth. Because it utilizes a reusable orbiter vehicle and reusable booster rockets, the cost of each flight is anticipated to be less than most present launch techniques which expend the

launch vehicle. This feature is one of the prime motivation factors for the STS.

In the 1980's, the STS is planned to permit the elimination of the rather large stable of launch vehicles that are used today. The STS is expected to be used to place almost all our satellites into orbit and have the capability of rendezvous with malfunctioning satellites to provide for repair on-orbit or for return to Earth. This capability assumes particular importance with the predicted growing future requirements for additional weather, Earth resources, communication, and navigational satellites.

*Space Shuttle.*—The size and weight-carrying capacity of the Shuttle orbiter will free spacecraft designers from constraints that have made payloads very difficult and costly to build. With the Shuttle, it will be possible to use relatively inexpensive, more nearly standard laboratory equipment in place of specially constructed, highly miniaturized parts which are expensive to develop and test. It will also eliminate test articles and back-up hardware.

The design effort on all of the major elements of the total shuttle orbiter system has now been initiated. Rockwell International/Space Division was selected to build the orbiter vehicle. Procurement to support this activity was initiated and 19 subcontracts, each exceeding \$10 million, have been authorized. Approximately half of the orbiter vehicle funds will be subcontracted to other firms throughout the country. This widespread use of the nation's technical base is typical of the other major elements as well.

The external tank for carrying the liquid cryogenic propellants for the orbiter main engines is being designed and built by Martin-Marietta Corp. in Louisiana. The main engines, which are the prime power plants for the orbiter, are being constructed by Rocketdyne in California. Hardware components of the engines, the long lead time element of the Space Shuttle system, are already being tested. The fourth major element of the flight vehicle is the booster, consisting of two solid rocket motors strapped to the external tank to provide additional thrust during the initial launch phase. The motor for this element will be built by Thiokol in Wasatch, Utah.

The Congress appropriated \$475 million in FY74 and \$800 million in FY75 for the design, development, test, and evaluation to be accomplished during this period. These funds have been utilized to take advantage of the skills available throughout the United States and has allowed the development to proceed at a good pace.

The first orbiter test flight scheduled for 1977 will be an unpowered flight after release from a carrier aircraft. This carrier aircraft, a commercial 747, was

obtained in July and preliminary flight testing, prior to initiation of modification to accommodate the orbiter, has started. The first manned orbital flight will occur in 1979 and the Shuttle is expected to be operational in 1980.

*Interim Upper Stage/Space Tug.*—A large number of the payloads expected to be flown on the Space Shuttle during the 1980s will require a Shuttle Upper Stage to deliver these payloads to orbits beyond the capability of the Shuttle alone. In 1973 the Department of Defense and NASA agreed to a two-phase Upper Stage Program. Concurrent plans call for the USAF to develop an Interim Upper Stage (IUS) capable of delivering payloads to high energy orbits; no payload retrieval capability will be built into the IUS. NASA will be responsible for the planning of a full-capability reusable Tug, which will have the capability to deliver, retrieve, and, if economically desirable, service payloads in high energy orbits. The Interim Upper Stage is planned to be available in 1980; the Tug is expected to be operational about three years later.

*STS Mission and Payload Integration.*—The Mission and Payload Integration Office continued its activities of studying the utilization of the STS and assuring hardware and operational compatibility between payloads and the STS.

In 1974, primary efforts were directed toward formalizing early Shuttle mission plans and conducting economic analyses for the continuing development and updating of the Payload and Flight Summaries that comprise the NASA Mission Model.

#### *Current Launch Vehicles*

While awaiting the deployment of the STS, NASA is continuing to rely on expendable launchers to fulfill its launch obligations. The physical characteristics of these launchers are given in Appendix D, while the details on their 1974 launch activities are given below.

*Scout.*—During 1974, the four-stage solid-propellant Scout launch-vehicle system placed six-satellites in orbit, five of which were cooperative or reimbursable international missions. In addition, standby readiness was maintained to support further launches of the U.S. Navy Transit Satellite Navigation System.

*Delta.*—The first Delta mission in 1974—its 100th launch, was the first Delta launch utilizing surplus Saturn IB H-I engines adapted to Delta.

The vehicle was unsuccessful in attempting to place the British military communications satellite in geosynchronous orbit, due to a failure in the second stage electronics package. Appropriate corrective actions were instituted and the vehicle placed six satel-

lites in orbit including the first domestic commercial communications satellite, Westar-A; the important Synchronous Meteorological Satellite (SMS) to provide the initial operational capability to monitor severe storms; a second Western Union satellite (Westar-B); the seventh in a series of operational meteorological satellites for NOAA; the British military communication satellite; and an experimental communications satellite for a joint French and German Government consortium.

Also, during 1974, contracts were signed for seven additional reimbursable launches including three for RCA; two for the French/German Government consortium; two for ESRO; and an initial agreement was made with the Japanese Government for three launches in 1976-1977.

*Atlas Centaur.*—One Atlas Centaur launch took place during the past year. An Intelsat IV spacecraft was successfully placed in a synchronous transfer trajectory on November 21, 1974. Five launches are planned for the coming year to support reimbursable missions: four INTELSAT IV and IV A launches and one Comsat Domestic Communications Satellite launch.

*Titan Centaur.*—A proof flight of the new Titan Centaur vehicle on February 11, 1974, was only partially successful due to a failure of the Centaur stage boost pump. Corrective action was taken resulting in a successful launch of the German Helios-A solar probe in December.

The Titan Centaur vehicle has been chosen to launch the dual Viking missions in 1975, as well as the second Helios spacecraft in 1976.

### *Advanced Studies*

Advanced Studies provide a foundation for new manned space flight programs. These studies explore various potential program options to arrive at technical, cost, and schedule data which can be used by management in the decision-making process. Factors investigated include extension of existing capabilities, new modes of operation, or new concepts. During 1974, the last of the studies and related activities were completed relative to the Space Tug and Interim Upper Stage (IUS) of the Space Shuttle. They supported a decision for the USAF to develop the IUS and for NASA to defer the full-capability Tug until a later date. During this year an effort was initiated to perform integrated long-term planning for manned space systems during the '80's and '90's. This may ultimately result in a series of identified potential program options with first estimates of costs and schedules, as well as an identification of critical technologies needed.

One study initiated is of the Manned Orbital Systems Concept, with investigation of the feasibility of the modules, transported to orbit in the Shuttle, being docked together to form an Earth-orbiting facility. Another is to analyze propulsion requirements of missions currently identified in the Mission Model Analysis and potential future missions. An investigation may then be performed to determine whether existing systems, uprated systems, or new propulsion systems would be most cost-effective.

An investigation is being performed to determine the feasibility of assembling in orbit some of the very large structures that have been proposed, such as the Solar Satellite Power Station, or a large radiotelescope. Also being investigated is maintaining and servicing satellites in orbit, perhaps thus extending many-fold the lifetimes of a multitude of unmanned satellites as well as manned facilities.

### **Tracking and Data Acquisition Program**

The objectives of the Tracking and Data Acquisition Program are to provide responsive and efficient tracking, data acquisition, communications, and related support to meet the requirements of all NASA flight projects. Such support is essential for achieving the scientific objectives of all flight missions, for executing the critical decisions which must be made to assure the success of these flight missions, and, in the case of manned missions, to insure the safety of the astronauts. During the past year the Tracking and Data Acquisition Program met the requirements of all flight projects on schedule and with excellent reliability.

The majority of the support rendered the flight projects is provided through the facilities of two worldwide tracking networks—the Spaceflight Tracking and Data Network (STDN) and the Deep Space Network (DSN). The STDN furnishes support to all Earth-orbiting missions; the DSN supports the other major class of NASA's flight programs, that is, the planetary and interplanetary missions.

#### *Spaceflight Tracking and Data Network (STDN)*

The operational activities of STDN remained at a high level during 1974 with support being provided to an average of 40 individual flight projects. In addition to supporting all of NASA's Earth-orbital missions, the network supported space projects conducted by other Government agencies, private industry, and foreign countries through cooperative international programs.

*Communications.*—One of the major missions launched during the year and supported by the network was the Applications Technology Satellite.

This satellite, named ATS-6, is the most complex, versatile, and powerful communications spacecraft launched to date.

*Meteorology.*—In late May, the network supported the launch of the first in a new series of weather satellites—the Synchronous Meteorological Satellite (SMS). The spacecraft, in near-synchronous orbit, is in a relatively fixed position above the Equator and is providing meteorologists with an updated picture of temperatures and clouds over the U.S. every 30 minutes. NASA's tracking and data acquisition support to SMS is completed after the spacecraft is in orbit and its on-board systems operational. At that time the National Oceanic and Atmospheric Administration (NOAA) will assume the control of the satellite.

### *Deep Space Network*

The Deep Space Network (DSN) continued to provide excellent support to NASA's planetary and interplanetary missions. In addition to the substantial operational activities of last year, good progress was made in modifying and augmenting the network systems for support of future missions, such as the 1975 Viking missions to Mars.

*Venus-Mercury.*—The Mariner 10, launched in November 1973, required a high level of network support throughout 1974. The mission imposed many "first-time" support requirements on the network, the most critical being the requirement to conduct multiple midcourse trajectory changes. These changes were needed to achieve a precise flyby of Venus to take advantage of that planet's gravity to obtain the necessary velocity to fly by the planet Mercury. The ability of the network to precisely track the Mariner spacecraft resulted in successful encounters of both planets, and the network received outstanding photographs of the planets.

The receipt of a large number of these photographs, of excellent quality, was possible only through the 64-meter diameter antennas. The DSN has three of these large antennas evenly spaced around the world: Canberra, Australia; Madrid, Spain; and Goldstone, California. The capabilities afforded by the huge antennas and ultra-sensitive receiving systems have permitted NASA to conduct missions at ever-increasing distances from Earth and to maximize the science data return.

*Jupiter.*—The Pioneer 11 spacecraft required near continuous support throughout the year as it completed its journey to Jupiter, more than 900 million kilometers (560 million miles) away. When the spacecraft encountered Jupiter on December 3, the network began acquiring data on the planet from the three 64-meter antenna stations. The network

support for Pioneer 11 is essentially the same as was provided Pioneer 10 one year earlier.

The network is continuing its support of Pioneer 11 as the spacecraft is now on a trajectory headed for Saturn. The spacecraft should encounter Saturn in mid-1979 and at that time the network will be acquiring data from a distance of over one and one-half billion kilometers from earth. Without the advanced capabilities of the large 64-meter antennas, it would be impossible to conduct a mission over such extreme distances.

### *Tracking and Data Relay Satellite System*

A major objective in the longer-range plan for the Tracking and Data Acquisition Program is the introduction of the capabilities of a Tracking and Data Relay Satellite System (TDRSS) into the Spaceflight Tracking and Data Network. The TDRSS is planned to consist of two satellites in synchronous orbit to relay data between low-altitude mission spacecraft and a single ground station located in the United States. The TDRSS is planned to provide nearly full-time, realtime contact with Earth-orbiting spacecraft and replace a number of the present ground stations of the STDN, leading over the longer term to overall reductions in tracking and data acquisition support costs.

Good progress toward achieving the TDRSS objective was made in 1974 when Congress authorized (FY 1975 Authorization and Appropriation Acts) NASA to proceed with the needed procurement activities. The authority to implement the TDRSS is subject to further Congressional review of the economic tradeoffs between obtaining the services on a long-term leased basis from the private sector versus a NASA-owned system.

### *Space and Nuclear Research and Technology*

The NASA Space and Nuclear Research and Technology programs are directed at providing a technology base for support of current and future space activities by advancing the technology used in systems required to transport, power, control, and communicate with the spacecraft, and in scientific instruments needed to achieve the objectives of current and future NASA space missions. Some of the resulting technology has applications to terrestrial uses as well. The significant accomplishments of the program in 1974 are noted below.

#### *Space Propulsion Technology*

Every major space mission that NASA has performed has been preceded by extensive rocket propulsion technology efforts. Propulsion systems take years to develop, and the technology must be ready before development starts. This means that the

technology for NASA missions in the 1980's should be pursued in the 1970's. Propulsion systems are expensive to develop and they are usually the major component of a vehicle system and, considering fuel, comprise the majority of the weight at launch. Therefore propulsion technology improvements can substantially improve performance and/or reduce cost of a program.

NASA propulsion technology encompasses efforts in liquid and solid fuel chemical systems as well as electric-powered thrusters. In all cases the technology is aimed at expanding NASA's mission capability at lower cost. Costs can be reduced by using lower cost hardware (typified by simpler solid fuel motors), by reusing systems over and over (like the Space Shuttle), or by improving performance of a particular stage enough to allow use of a smaller, cheaper launch system.

Improved performance also opens the door to previously impractical missions such as out-of-the-ecliptic and close-to-the-Sun probes. A "new horizons" program has also been established to assure consideration of unconventional propulsion systems offering several times the energy levels now attainable. Selected program highlights are described below.

*Solid Propulsion Technology.*—The final motor in a series of high efficiency solid-fuel motors was successfully tested in a static condition. This motor combined several advanced features such as a light weight all-carbon nozzle and expansion cone, a special igniter which provides a several second thrust buildup to minimize shock to the spacecraft, and an unusually flexible propellant.

Planetary missions require propulsion systems which can withstand thermal sterilization cycling from about 295 degrees to 410 degrees Kelvin (70 degrees to 275 degrees Fahrenheit). The application of low-cost reliable solid motors to these missions has been prevented by the distortion tendencies and chemical instability of solid-fuels at these high temperatures. A significant step forward was taken this year with the successful static firing of a thermally sterilized solid-fuel motor.

The high atmospheric pressures of planets like Venus, Jupiter, and Saturn require extremely large weight penalties if conventional chemical rockets or aerodynamic surfaces are used for entry or control. A pulsed detonation mode concept was developed which meets this challenge by using the output of a high-powered laser to detonate a small explosive charge remotely. The resulting shock wave is then directed by means of an expansion nozzle to provide thrust. The nozzle is designed to allow expulsion of the atmospheric gases which fill it between pulses, adding to the energy of the propellant. Firings of

the proposed system were conducted in near vacuum conditions as well as at high pressure and in simulated atmospheres.

*Liquid Propulsion Technology.*—A major long-range goal of the chemical propulsion program is to discover new energy storage concepts capable of more than doubling the specific impulse of present chemical rockets. Theoretical and experimental studies are continuing in the areas of atomic hydrogen, hydrogen enriched solids, and electronically excited solid helium.

Experimental attempts to generate atomic hydrogen, by disassociating molecular hydrogen in a strong magnetic field and cooling the products to one degree Kelvin, have exhibited energy storage by the release of heat. Presses capable of developing pressures of 35,000 pounds per square inch are being developed to generate and study metallic hydrogen. An experimental effort on energy storage by hydrogen absorption in solids will study the promising hydrogen/deuterium palladium system.

In the reusable oxygen-hydrogen propulsion technology program, contracts were awarded to develop high-performance liquid oxygen and liquid hydrogen turbomachinery designed for 10-hour service life, and to develop a regeneratively cooled thrust chamber capable of completing 300 start/stop cycles.

Fluorinated oxidizer (FLOX) propellant combinations offer up to a 30 percent increase in engine specific impulse over currently operational propulsion systems. This makes them attractive for use in future planetary missions which require long life systems. Eighteen month storage tests of titanium and aluminum in cryogenic fluorine and FLOX were completed this year. The tests indicate that the compatibility of these materials with fluorinated oxidizers is more than adequate for missions in excess of 5 years.

*Electric Propulsion Technology.*—Electric propulsion is attractive as auxiliary propulsion for long-life station keeping and attitude control applications, and as primary propulsion for planetary/interplanetary and near-Earth applications requiring high specific impulse, reliability, and low mission cost. Tests of a one-thousandth of a pound (4.5 milli-Newtons) thrust (150 watt) ion engine aboard the ATS-6 satellite were initiated this year to demonstrate north-south station keeping. Endurance testing of small engines in ground facilities continued. In the area of primary propulsion, the endurance testing of a standardized 2.75 kilowatt ion engine was continued past the one year mark.

### *Space Power Technology*

Spacecraft depend on the Sun, batteries, fuel cells, and nuclear energy to supply the power needed to

operate instruments, computers, life-support systems, radios, and electric rocket engines. Due to weight restrictions, power for space missions has been limited, and the expansion of mission capabilities, therefore, requires improvements in existing kinds of space power systems and research on new concepts. Costs of power systems should also be reduced. For these reasons, NASA's research and technology program gives considerable emphasis to the area of space power and covers a wide variety of energy sources and end uses. While space missions will be the major use of this NASA power-technology program, it is possible to apply this technology to other energy related systems.

*Spacecraft Energy Systems Technology.*—A test panel of newly developed, high efficiency solar cells was flown on the IMP J satellite to verify predictions of up to a 20 percent increase in efficiency with no loss in radiation resistance. The technical feasibility of making solar cells from a silicon ribbon grown directly from the melt was demonstrated this year. This is one of the critical first steps in manufacturing low cost solar cells. A basic research effort has determined that the impurities that are introduced with the doping material degrade the performance of highly doped silicon solar cells. This problem has been holding up further improvements in efficiency.

Preliminary specifications have been developed for primary batteries having five-to-ten year shelf life. These lifetimes are required for future outer planet atmospheric entry probes. These batteries have potential Earth applications as well.

Recent progress in the regulation, distribution, and control of electric power in spacecraft was demonstrated by the flight qualification of a power-processing system for the CTS spacecraft. The system operates at 11,000 volts, exceeds 85 percent efficiency, and has a voltage ripple of  $\pm 0.01$  percent.

*Nuclear Energy Technology.*—An analysis was completed on gaseous fuel reactors which indicates that they could be operated, using uranium hexafluoride, at 1500 degrees Kelvin for high efficiency power generation. Gaseous fuel reactors could also be utilized for the destruction of certain radioactive waste products from other nuclear power plants by transmutation and fusion of the waste material in the gaseous fuel reactors. Plans and designs were prepared for conducting low-power tests of such gaseous fuel reactors.

Tests of a new thermionic energy converter designed to operate at lower temperatures with increased efficiency were successfully completed this year. Thermionic converters can be used to trans-

form the heat energy from radioactive sources to electrical energy to power spacecraft systems.

*Direct Conversion of Nuclear Energy into Laser Light.*—As part of the Nuclear Energy Technology Program, fission energy from a nuclear reactor was converted directly into laser light for the first time in an experiment this year. A helium-xenon laser was made to operate utilizing only the energy of fission fragments to energize the laser. This mechanism provides for the controlled conversion of nuclear energy directly into coherent laser light which could lead to major advances in energy conversion, long range communications, and power transmission over long distances.

*High Power Lasers and Energetics Technology.*—Two new test devices that can produce fusion-like plasmas began regular experimental operation as part of a research program on methods to use fusion energy for space power plants. In one test series, helium was heated under steady-state conditions to a temperature of 100 million degrees Kelvin.

Magnetohydrodynamic (MHD) power generators can make major improvements to power plant efficiency and can provide light-weight space power units. This year improved efficiency was measured in tests of an MHD generator system suitable for use with nuclear power plants. New efficient combustors were designed and tested in preparation for experimental testing of MHD generators powered by the burning of hydrogen and oxygen.

Large, powerful superconducting magnets are required for efficient confinement of plasmas and for generating electrical power. Progress was made this year in developing processes for commercial manufacture of a new form of wire (i.e., ribbon) which can make large and powerful superconducting magnets stable and practical.

NASA scientists invented a new technique for establishing laser action in metal vapors and developed a copper chloride vapor laser that radiates in the "Green Band." A new form of laser action was demonstrated this year which depends on control of the spin energy of the nucleus. This process holds promise for use in low-noise amplifiers and biomedical research.

In research on the transmission of power by laser light, the transmission of CO<sub>2</sub> laser power in a vertical direction was analyzed to include the changing composition of the atmosphere at various altitudes. It was determined that an increase of transmission efficiency of 70 percent could be realized by tuning the laser frequency so as to avoid the most important absorption lines in the atmosphere.

### *Atmospheric Entry Technology*

The objective of increasing our knowledge and understanding of the origin and evolution of the solar system and extending our knowledge of the Earth by comparative studies of the outer planets requires the in-situ measurement of the atmospheres of these planets. The Advanced Atmosphere Entry Technology program is designed to establish a base of information to permit the design of probes that can enter the atmospheres of the outer planets, Jupiter, Saturn, and Uranus, in a safe, reliable, and predictable manner. In addition, the program is designed to provide the aerodynamic characteristics for spacecraft entering the Earth's atmosphere. Selected highlights of the program are described below.

*Entry Aerothermodynamics.*—Methods were developed for estimating the very high heating expected during entry into the atmosphere of Venus, Uranus, Saturn, and Jupiter. This year, estimates were made for the Pioneer Venus Project of the heating to be expected by a probe entering the Venusian atmosphere.

*Entry Technology Flight Experiment.*—Fifteen flights have been completed in the Joint NASA/Air Force program which utilizes the X-24B research vehicle to help develop a technology base for advanced entry spacecraft and also for applications to hypersonic cruise vehicles. The vehicle's flight characteristics, performance, and handling qualities have been evaluated in the speed range from Mach 1.6 to landing.

### *Materials and Structures Technology*

Materials and structures are the building blocks of launch vehicles, spacecraft, and payloads for man's exploitation of space. Supporting research in materials and structures has the goal of providing increased payload capability, resulting from structural weight reductions of up to 25 percent, and low cost, energy conservative systems. Selected highlights of the program are described below.

*Polymerization of Monomeric Reactants.*—A new technique was developed for obtaining more processable, higher temperature resistant polymers for use as matrix materials in advanced resin fiber composites. These composites have potential for use in a variety of high performance applications. The composites are presently being evaluated to explore their use in advanced space transportation systems to achieve payload weight increases of 25 to 35 percent.

*Seal Technology.*—NASA has developed a hydrodynamic self-balancing or "lift pad" seal. The seal has demonstrated its ability to maintain close separa-

tion without solid-to-solid rubbing, so that both leakage and wear are minimized. The concept has a variety of potential applications both within and outside of the aerospace field, e.g., the LOX pump of the Space Shuttle main engine, main bearings of aircraft gas turbine engines, etc. In aeronautics alone, it is estimated that as much as ten percent of the 500 million barrels of crude oil used annually by the U.S. military and civil aircraft fleet could be saved through improved seal technology. Up to five percent savings are realizable from current advanced sealing concepts, such as the lift pad seal.

*Heat Pipe Technology.*—A feedback controlled heat pipe and a thermal diode heat pipe, which permits heat transfer in only one direction, were demonstrated in flight tests on board the ATS-6 satellite. The devices were used for thermal control of temperature-sensitive spacecraft components. This advanced technology for heat transfer provides a greatly enhanced capability for spacecraft thermal control, and has potential use for heating and cooling, without electrical power or moving parts, in industrial plants, hospitals, laboratories, and homes.

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

The increasing complexity of space missions has resulted in new instruments and components that have improved space exploration and operation capabilities. These instrument concepts can be applied to planetary as well as Earth-observation type missions, i.e., Earth Resources, Meteorology, Weather and Climate, etc. The applications of this new technology have imposed more stringent demands on the communication links between space vehicles and the user community. The reception, transmission, processing, and storage of information must be improved to satisfy these demands and must also be accomplished at lower cost and with increased reliability. The following paragraphs describe some of NASA's achievements in these areas during the past year.

*Microwave Power Tubes.*—A technique was developed for improving the efficiency of microwave power-amplifier tubes from their current 10 to 20 percent efficiencies to greater than 50 percent. The new tube will be used to transmit 200 watts of power at 12 gigahertz on the Joint Canadian/NASA Communications Technology Satellite in FY 1976.

*Solid-State Data Storage System.*—Tape-recorder type operations were demonstrated with a  $6 \times 10^4$  bit feasibility model of a no-moving-part solid-state replacement system for scientific tape recorders. Studies indicate that a  $10^8$  bit unit can be developed that will have 10 times the expected useful life of con-

vential satellite tape recorders, and will be smaller and require less power.

*Infrared Heterodyne Radiometer.*—An infrared heterodyne radiometer which is sensitive to and capable of measuring wavelengths around 10 micrometers was developed. The radiometer was used to map the infrared radiation of the Moon and Mars with extreme accuracy and sensitivity.

*Wideband Communications Receiver.*—The first Doppler tracking wideband receiver capable of operating with data rates exceeding 300 megabits per second and at a bandwidth of  $\pm 700$  megahertz was developed. In addition, a modulation system compatible with a carbon dioxide laser was operated this year. These two activities complete the development of the components for an optical data transfer system with a capacity capable of satisfying the requirements of future Earth resources missions.

*Solid-State Image.*—A solid-state imaging sensor consisting of a 100x160 array of Charge Coupled Devices (CCD) was fabricated and tested as the active element in a planetary imaging camera. The sensitivity of the CCD camera is 10 times that of the Mariner 10 camera, with a four-fold reduction in weight and power.

*Semiconductor Laser Diode.*—A breakthrough in laser technology was achieved with the development of the first continuous wave semiconductor laser diode that operates at room temperature in the visible part of the spectrum. A minimum of 2000 hours of stable operation was obtained with the emission of tens of milliwatts of power. The power required to operate the device is 100 times less than that required for a typical gas laser.

### *Space Shuttle Supporting Technology*

The Space Shuttle is a reusable, space transportation system essential for economical space exploration and exploitation. Since 1969, NASA has conducted a broad program to provide technology critical to the design and development of the Shuttle. This technology program was a multidisciplinary activity which involved aerodynamics, dynamics, structures, materials, propulsion, power, flight control, communications, operations, maintenance, and safety. Now that the Shuttle development program is well advanced, the Shuttle supporting technology program is confined to those areas, such as the evaluation of thermal-protection materials and flight performance, where significant contributions to the success of the Shuttle program can be made. Selected highlights of the program are described below.

*Shuttle Dynamics.*—Studies were completed which defined methods to allow a wider range for the location of the center of gravity of the orbiter so that a broader range of payload sizes and shapes can be accommodated.

*Thermal Protection Materials.*—Evaluation of the flight performance of Shuttle thermal protection materials is continuing in specialized test facilities. Results of tests on materials to be used as antenna windows indicate that no significant surface degradation or deterioration in the dielectric constant should occur.

*Propellant Gauging System.*—A gauging system was developed to determine the quantity of liquid fuels in tanks under zero "g" conditions. The system, which has a maximum error of 0.5 percent over the full range of tank capacity, is based on the absorption of gamma rays passing through the tank.

### *Low Cost Space Systems*

The Low Cost Systems Office was established last year to lead an Agency-wide effort to reduce the overall cost of space systems. A cost-benefit analysis activity has been established and several common spacecraft components have been identified for standardization. Contracts have been let to develop two types of standard spacecraft tape recorders. Also, work has been initiated that will lead to the development of a standard spacecraft attitude control propulsion system, a flight computer, an inertial reference unit, solar cells, NiCd battery cells and a transponder. In addition, NASA's business and program practices are being surveyed to identify opportunities for effecting cost savings in the administration and management of R&D programs. A study has been undertaken to identify those management techniques which were common to R&D projects that were accomplished at lower than estimated costs.

### **Aeronautics Research and Technology**

The NASA Aeronautics Research and Technology programs are directed at serving national needs by focusing on the objectives of developing technology to (1) reduce energy requirements and improve the performance and economy of aircraft, (2) reduce the undesirable environmental effects of aircraft such as noise and pollution, (3) improve aircraft safety and terminal area operations, (4) advance short-haul, short take-off and landing, and vertical take-off and landing system concepts, and (5) provide aeronautical technology support to the military. The significant accomplishments of the program in 1974 are noted below.

#### *Reducing Energy Requirements and Improving Performance and Economy*

Events of this past year have shown the vulnerability of our transportation system to interruptions

in the supply of petroleum fuel. Air transportation, although highly productive, requires a significant portion of the Nation's petroleum fuel. Relatively small reductions in drag and structural weight combined with higher propulsion system efficiencies can have a large effect on the overall fuel consumption and economic efficiency of the aircraft. Some highlights of the NASA programs for reducing energy requirements and improving performance and economy are described in the following paragraphs.

*Efficient Subsonic Wings.*—The NASA-developed supercritical wing technology allows for subsonic aircraft cruise speeds to be increased nearer to the speed of sound without encountering undesirable increases in drag. This means that aircraft speed and distance can be increased without any increase in fuel consumption. Flight tests with an F-8 aircraft with supercritical wing demonstrated a 15 percent increase in distance traveled without using any additional fuel. An advanced wing, the NASA GAW-1, was developed for general aviation aircraft and is planned to be flight tested on a light twin-engine aircraft.

*Transonic Aircraft Technology.*—More than one-third of the 50 planned test flights of the F-111 aircraft equipped with an advanced supercritical wing were completed in the Transonic Aircraft Technology (TACT) program. Preliminary flight data confirms wind tunnel model data predictions of improved performance.

*Skin Friction Drag Reduction.*—Preliminary tests were completed on compliant or flexible aircraft skin concepts which indicate a reduction of at least 16 percent in skin-friction drag. Application of the compliant-wall concepts to aircraft have the potential of significantly decreasing aircraft fuel consumption.

*Filamentary Composite Materials.*—NASA research has shown that the use of boron- or graphite-epoxy composite materials can reduce the structural weight of aircraft components by as much as 50 percent, resulting in reduced fuel consumption and increased performance and economic benefit. Although bench-level research has demonstrated the advantages of composites, application is dependent on verification of their durability in airline operations. A five-year flight durability program, which will amass more than two million component flight test hours, is in progress and will include two components on military aircraft and four secondary plus two primary structural components on commercial aircraft.

*Active Control Technology.*—The use of active control technology, together with improved aerodynamics, has been shown in analytical studies to have potential benefits in the areas of superior performance, increased aircraft life, reduced fuel consump-

tion, reduced noise, and greater passenger comfort. Last year, flight tests demonstrated the feasibility of digital fly-by-wire control of aircraft. This year the design of a triply redundant system was completed. A program was initiated to develop techniques for the design of aircraft using active control concepts. Studies were completed by Boeing and Lockheed which defined how existing aircraft could be used to demonstrate individual active control concepts.

*Gas Turbine Propulsion Systems.*—NASA and the Air Force initiated a long-range research program aimed at strengthening and expanding the technology base for aircraft gas-turbine propulsion systems. The Air Force will supply modern advanced technology engines to serve as research propulsion systems and NASA has the responsibility for planning and execution of the research programs.

*Fuel Consumption Reduction.*—A system design study was begun to explore fuel-conserving opportunities for subsonic transport aircraft. The study is intended to quantitatively establish sensitivities and trade-offs among fuel conservation, noise, engine emissions, schedule delay, and economics and identify the technology advances needed for the design of future aircraft. A series of studies was initiated to determine various approaches for reducing commercial subsonic jet engine fuel consumption. The studies will examine modifications to existing engines and engine design concepts based on unconventional approaches with the objective of achieving a 30 percent reduction in fuel consumption. Other studies were initiated to establish the feasibility of major airframe-modification fuel conservation technologies for commercial aircraft. Alternate fuels such as hydrogen and methane are being studied by NASA as a possible means of reducing aircraft petroleum demands. Combustor tests have been run which evaluated the engine emissions resulting from blends of hydrocarbons which simulate fuels that could be produced from the liquification of coal.

*Remotely Piloted Research Vehicles.*—Progress was made in evaluating the advantages of using unpiloted, scale-model aircraft for flight research involving hazardous or new high-risk aircraft concepts. A three-eighths scale F-15 fighter Remotely Piloted Research Vehicle (RPRV) was maneuvered into stalls and spins to investigate best means of recovery from spins. An advanced wing concept, the oblique wing, which has promise for reducing drag and sonic boom for high speed aircraft, was evaluated in low speed flight using the low cost RPRV approach.

*Highly Maneuverable Aircraft Technology.*—NASA has initiated the Highly Maneuverable Aircraft Technology program to promote and stimulate the application of new advanced (high-risk) technology in a

multidisciplinary manner to the design of future highly maneuverable military aircraft. The program plans to utilize the RPRV flight test technique to realize the RPRV benefits of safety (unmanned), flexibility (remotely piloted), and low cost (subscale models).

*Supersonic Cruise Aircraft Research.*—A shock stabilization system which optimizes inlet operation at very high speeds was designed and wind-tunnel tested this year. A cooperative airframe/propulsion control system, which minimizes undesirable interactions between airframe and propulsion systems, is being designed for flight testing on a Mach 3 aircraft. Flight and laboratory evaluations of various new structural concepts, suitable for the high Mach number environment, e.g., welded and honeycomb titanium panels, are in process.

*Aircraft Handling and Ride Quality.*—NASA's effort to provide passenger acceptance and ride quality criteria for future air transportation systems continues this year. Commercial aircraft motion data were collected in flight and the resulting data incorporated into simulation studies conducted in the Passenger Ride Quality Apparatus. Modified Boeing 727 approach and landing trajectories were used to provide subjective ride-quality data applicable to projected short haul take-off and landing operations.

In a cooperative program with Kansas University and Beech Aircraft Company, a split-surface stability augmentation system was designed and evaluated in the laboratory. This system may reduce pilot workload and provide better aircraft handling and ride characteristics. Flight tests will begin next year in a Beech 99 commuter airline aircraft.

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

Aircraft noise and exhaust pollution are two undesirable environmental effects. A major NASA responsibility in aeronautics is to perform the research and develop the technology to reduce aircraft noise and pollution in ways that are economically and operationally sound.

Data and technical understanding resulting from the NASA programs serve to enlarge the technology base the aviation industry uses to develop hardware modifications and new designs. They furnish the government realistic and credible technical information needed in deciding and promulgating future noise and exhaust emission regulations.

NASA's noise and pollution reduction program is quite broad. In noise reduction, it includes fundamental studies of acoustics and noise sources, acoustic suppression and reduction techniques and technology demonstrations, community noise-impact-pre-

diction methods, and techniques for assessing human response. In exhaust pollution reduction, the program includes combustion and pollution formation research as well as combustor design technology demonstrations. These activities include analyses and experiments to predict and measure the atmospheric impact of aircraft exhaust emissions.

Some highlights of the NASA programs for reducing undesirable environmental effects of aircraft are described in the following paragraphs.

*Reducing Engine Noise from Existing Transport Aircraft.*—NASA's Refan Program is a major effort involving the application of advanced technology to the quieting of the JT8D engine which powers a major portion of the Nation's narrow-body commercial air fleet. The noise-footprint areas of these aircraft can be reduced substantially, when the engine's two-stage fans are replaced with larger single-stage fans. During the past year, three refanned engines have been built and ground tested. To date, the refanned engines have met performance, endurance, and acoustic goals. Acoustically treated nacelles were fabricated, and the necessary airframe modifications determined to begin ground testing the engines on a Boeing 727 configuration and flight testing on a Douglas DC-9 aircraft in early 1975.

*Acoustic Composite Nacelle.*—Conceptual design studies were initiated to define the means of integrating various acoustic composite material concepts in engine nacelle construction to reduce aircraft noise footprint area, without increasing operating costs and fuel consumption.

*Propeller and Rotor Noise Reduction.*—Studies are underway to determine the potential for reducing the propeller noise of general aviation aircraft. Initial concentration is on the use of shrouds and ducts to reduce propeller noise. Full-scale wind tunnel tests of a modified airplane with a shrouded propeller have been completed.

Wind-tunnel tests were completed which demonstrate that low-speed propellers and rotors with serrated leading edges are quieter than conventional airfoils. Further tests are planned to determine whether the noise-reduction effects of serrations will apply to high-speed rotors, fans, and inlet compressors for jet engines.

*Airframe Noise Reduction.*—A program was initiated to determine the source, magnitude, and methods of reducing airframe noise for large transport aircraft in approach (i.e., flaps and landing gear extended) configurations. Preliminary noise-source measurements were made in conventional wind tunnels and anechoic chambers, and airframe noise-prediction techniques were developed using fundamental noise-source principles and data correlations.

*Noise Reduction Laboratory.*—The completion of the Aircraft Noise Reduction Laboratory at the NASA Langley Research Center this year provides a powerful new tool for research into the nature of aircraft noise and human response to it.

*Noise Reduction Flight Procedures.*—The two-segment landing approach was developed by NASA to reduce aircraft noise levels on the ground, in communities near airports, due to aircraft approaches for landing. A United Airlines DC-8 aircraft, utilizing the two-segment approach, achieved a 53 percent reduction in the ground area impacted by noise above desirable tolerance levels. This year, there was a major effort to develop avionics and flight procedures that will allow current jet transport aircraft to make two-segment approaches under instrument flight conditions during routine schedule service.

*Quiet, Clean, Short Haul Experimental Engine.*—NASA's Quiet, Clean, Short Haul Experimental Engine (QCSEE) program has as its objective the demonstration of high-bypass-ratio engine technology for very quiet, very clean, and efficient propulsion systems technology which might be used in economically viable and environmentally acceptable powered-lift short-haul aircraft. General Electric Company will design, build, test, and deliver two experimental powered-lift propulsion systems to NASA for extensive ground evaluation of acoustic and aerodynamic performance in appropriate wing/flap system installations. The preliminary design of the two QCSEE propulsion systems was approved this year. The first system is designed for application to under-the-wing propulsive lift configurations; the second system is designed for over-the-wing configurations.

*Global Air Sampling Program.*—The purpose of the global air sampling program is to determine the contribution of high-altitude jet aircraft engine exhaust emissions to atmospheric pollution. A United Airlines Boeing 747 equipped with an atmospheric sampling instrument package commenced routine service on a commercial air route over the continental United States to Hawaii. Subsequently, Pan American plans to fly a similar instrument package on a round-the-world commercial air route in the northern hemisphere.

*Stratospheric Jet Wake Measurements.*—The near wake constituents of a YF-12 aircraft exhaust are being measured to determine the impact of supersonic aircraft engine emissions on the stratosphere. A water dump system is currently being tested on the YF-12 aircraft to mark its exhaust wake to assist the probe aircraft in locating the wake.

*Clean Combustor Program.*—The NASA Clean Combustor technology program was expanded to de-

velop technology to reduce aircraft emissions to meet Environmental Protection Agency emission standards for 1979. The expanded program will include the application and demonstration of clean combustor technology on all thrust classes of commercial aircraft engines, including internal combustion and turboprop engines. Phase I tests on several combustor concepts of the Clean Combustor Program reported last year were completed and the 1979 EPA idle mode emission goals for the T-2 class (large) engines were met.

*Engine Cycles for Supersonic Aircraft.*—Engine cycle studies are underway that will lead to the selection next year of an optimum engine cycle for supersonic cruise aircraft to minimize noise and pollution.

#### *Improving Aircraft Safety and Terminal-Area Operations*

New aircraft types, changing operational environments, and revised flight procedures all have significant implications for aircraft safety and efficient airport operations. A continuing program of research is necessary to minimize the impact of these changes while at the same time providing a net improvement over the longer term. Airport terminal-area congestion and operational difficulties account for most flight and ground delays, with their waste of precious fuel and the travelers' valuable time. The population living and working near airports is heavily impacted by aircraft noise.

Safe and efficient terminal-area operations thus benefit the traveler, the aircraft operator, and the airport neighbor. Programs for improving aircraft safety and terminal-area operations continued to make progress this year; selected highlights are described below.

*Aircraft Wake Vortex Reduction.*—The wakes left by large aircraft pose a significant hazard to other aircraft if adequate spacing between aircraft is not maintained. The problem of trailing vortices curtails maximum use of our Nation's airports. Reduction of wake-vortex intensity would permit closer aircraft spacing in operations and thereby increase airport operational efficiency. Numerous techniques were evaluated for reducing wake vortices in wind-tunnel and water-channel tests. This year the most promising concepts were flight tested to determine their full-scale performance. Flight tests of techniques using wing-tip mounted splines and engine-induced turbulence verified the extent of wake vortex minimization predicted by model tests. Flight tests of another promising technique, varying spanwise lift distribution, were completed with a Boeing 747 late this year. Concurrently, in the event that aerodynamic reduction of aircraft wakes should be impractical

for retrofitting the current jet fleet, NASA is developing a laser doppler system for detecting and tracking aircraft wakes in the vicinity of airports. This system would also enable air traffic controllers to adjust aircraft spacing more closely. Tests of a prototype system were completed this year and the system is undergoing operational evaluation at JFK airport in New York.

*Aircraft Stall/Spin Characteristics.*—According to the National Transportation Safety Board, 35 percent of all general aviation accidents and resulting fatalities are caused by the stall/spin phenomenon. Stall/spin behavior is under investigation utilizing unique facilities, such as the spin tunnel at Langley Research Center, to determine design criteria for aircraft with vastly reduced stall/spin characteristics.

*Aircraft Landing Systems.*—This year NASA research on aircraft landing systems led to the development of a new polymer additive for tires which will substantially reduce aircraft tire wear and blowouts. A new brake compound was developed which should increase brake life and reduce brake fading. Tests were completed which resulted in a new understanding of the operation of aircraft anti-skid systems under tire hydroplaning conditions.

*Aircraft Crashworthiness.*—Five full-scale aircraft crash tests were performed this year as part of the General Aviation Crashworthiness program. Data from the program will be used to develop analytical methods for predicting structural collapse behavior under crash-impact situations, define a survivable crash envelope, improve restraint methods, and define design methods to improve crash survivability. A total of 32 airframes damaged in Hurricane Agnes have been acquired from Piper Aircraft Corporation for this purpose.

*Fire Retardant Materials for Aircraft.*—Each year aircraft accidents occur in which occupants survive the initial impact but succumb to the smoke, heat, and toxic fumes produced by post-crash fire. NASA research on developing fire-retardant materials for aircraft continued this year with the development of an improved fire-retardant window material. Tests were also made of fire-retardant fabrics, coatings, and other interior materials to determine their safety characteristics and effectiveness. Full-scale fuselage fire tests were conducted for preliminary assessment of nonflammable properties of new materials for aircraft interiors. The materials showed good fire resistance and lower smoke production than current materials, but still produced significant amounts of toxic by-products indicating that further research is needed.

*Human Error in Aircraft Accidents.*—Last year the results of a preliminary study to assess the human

error factor in aircraft accidents were reported. This work was continued to verify the significance of the previous findings and to define research studies that will provide solutions with special emphasis placed on the approach and landing flight phase. A comprehensive program was initiated to understand the requirements and roles of air crews and ground controllers in the automated air traffic control environment projected for 1985 and beyond. An oculometer, a device which unobtrusively provides accurate real-time data on where a pilot is looking during tasks, has been developed and put into operation. Use of the oculometer should provide an effective technique for use in the development of safe, efficient advanced flight-management systems.

*Terminal Configured Vehicle Operations.*—NASA's Terminal Configured Vehicle program has the objective of providing technology to enable future Conventional Take-Off and Landing (CTOL) aircraft to be totally compatible with advanced air traffic management systems. By 1982 this system should include such features as improved four-dimensional (position plus time) navigation, more flexible landing guidance systems, better communications, and more automation, such as for computer assisted separation of aircraft. To validate various airborne system concepts, extensive use is being made of simulators and flight experiments in a simulated high density terminal area. Flight research with a Boeing 737 aircraft, modified to include an advanced electronic display system, automatic guidance and control system, and aft flight deck, was initiated. The accuracies obtained give encouragement of attaining the goal of less than five seconds time variation from the flight program in routine operations. The program places emphasis on the human factor aspects of operations and the interactions of crew members.

#### *Advancing Short Haul, Short Take-Off and Landing, and Vertical Take-Off and Landing System Concepts*

The problems of airport congestion to the traveler, aircraft noise on the surrounding community, and new emphasis on fuel conservation, coupled with increased air traffic forecasts, are matters of national concern. Airport congestion in the high-density corridors especially detracts from the convenience of the shorter distance traveler, since a high percentage of total trip time is associated with ground operations. Introduction of new short-haul transports (vertical and short-take-off and landing aircraft) and systems might better utilize existing airports and airspace, provide precise touchdown times, and may contribute to reducing congestion and fuel consumption. These aircraft are expected to provide the means of containing noise within the airport boundaries because of

steep descent and ascent flight paths and the ability to maneuver around local population communities. Selected program highlights are described below.

*Propulsive-Lift Technology.*—Research emphasis continued on the upper surface blown flap and jet augmentor wing propulsive-lift concepts this year. These concepts are aimed at providing transport aircraft with short-field performance and acceptable noise levels, with minimum penalty to cruise performance and operating costs. Studies are in progress to refine and expand the technology base for the upper surface blown flap concept, emphasizing cruise performance and noise aspects. The first of a series of advanced augmentor wing concepts intended to provide improved lift augmentation and reduced noise was tested on a semispan wind-tunnel model this year. Proof-of-concept flight tests of the C-8 augmentor wing research aircraft, incorporating an early version of the augmentor concept, were completed, verifying the increase in lift indicated from previous wind tunnel model studies.

*Quiet Short-Haul Research Aircraft.*—A Quiet Short-Haul Research Airplane program was initiated to generate and verify, through flight research, a technology data base for design and certification criteria for practical and efficient quiet propulsive-lift short-haul transports. Preliminary design studies were completed and the selection made of the propulsive-lift concept to be used on the research aircraft. Next year an existing C-8 Buffalo aircraft will be modified to a swept-wing hybrid-upper surface blowing advanced propulsive-lift configuration powered by four Avco Lycoming AFL 502 series engines.

*STOL Crosswind Landing.*—A study of the problems associated with landing during extreme crosswinds in a typical Short Take-Off and Landing (STOL) aircraft was completed in 1974, resulting in follow-on research with a versatile tri-cycle crosswind landing gear system being planned for 1975.

*STOL Navigation, Guidance, and Control Systems.*—An effort is being conducted under a joint NASA/FAA agreement to help provide the technology required for the design and development of an effective STOL short-haul air transportation system that can operate unobtrusively into city centers and suburban facilities. An operating systems experiments program was formulated to aid in the choice of terminal area navigation, guidance, and control system concepts for STOL short-haul aircraft, and will evaluate operational procedures. A flexible digital avionics research system (STOLAND) was installed in the CV-340 short-haul transport aircraft, and 8 test flights were made to obtain preliminary avionics system performance. STOLAND investiga-

tions were initiated this year with a DHC-6 turbo-prop and the C-8 Augmentor Wing Research Aircraft to obtain performance data.

A control system for STOL and Vertical Take-Off and Landing (VTOL) aircraft, that uses optimal four-dimensional (position plus time) guidance techniques that can control touchdown time within  $\pm 5$  second along tightly curved approach paths, was flight tested this year. This precise touchdown capability can double maximum STOL landing rates, and reduces the danger of interference with conventional aircraft on adjacent approach paths.

*Lift Fan and Vectored Thrust Aircraft Technology.*—In the Vertical Take-Off and Landing (VTOL) aircraft research program, small-scale wind tunnel tests were completed on an advanced lift plus lift-cruise aircraft model and on a vectored-thrust combat VTOL configuration. Small-scale tests of two lift-fan configurations were completed in the V/STOL tunnel. These tests are aimed at providing part of the technology required for a VTOL civil transport having the speed range, operating costs, and capability of current medium range CTOL aircraft. Initial static tests of a thrust vectoring system, designed to have light weight and rapid response characteristics with small losses in thrust, were completed in 1974 as part of a joint NASA/Navy program. The program is expected to provide design information for future military aircraft having VTOL and high subsonic cruise speed capability. Flight dynamics research utilized the variable stability X-22 tilt duct V/STOL airplane to investigate requirements for making decelerating approaches to a vertical landing under instrument flight conditions.

*VTOL Navigation, Guidance, and Control Systems.*—An integrated navigation, guidance, and control system for VTOL aircraft is being developed as part of a joint NASA/Army program to improve the technology for short-haul aircraft. A CH-47 helicopter will be used for flight tests. A three-axis strap-down inertial navigation system, using ring lasers as low-cost, no-moving-part replacements for the conventional mechanical gyros, was developed; and accuracies of approximately one nautical mile per hour were demonstrated. Flight evaluation is planned next year.

A program is underway to provide technology to demonstrate the capability of VTOL aircraft to land and takeoff with optimized fuel consumption and safety under low visibility conditions or at unprepared sites.

*Rotorcraft Technology.*—In the rotorcraft technology program, the effort to reduce the noise and vibration due to vortices generated by the rotor blade tips continued with full-scale tests to examine the

effects of rotor blade tip shape on noise and lift performance; and with tower tests of a rotor concept using air mass injection near the tip. Studies of advanced rotor concepts included the completion of small-scale high-speed wind tunnel tests of the reverse velocity rotor designed for higher cruise speed application, tower tests of a large-scale variable geometry rotor designed for reduced vibration and noise, and aeroelastic analysis of the bearingless rotor designed for reduced drag and maintenance. Flight tests were completed on the CH-46 variable stability helicopter providing a quantitative comparison of several combinations of control and pilot display concepts evaluating trade-offs in pilot workload, task performance, and complexity.

*Rotor Systems Research Aircraft.*—The joint NASA/Army Rotor Systems Research Aircraft (RS-RA) program consists of the design and fabrication of two unique flight research vehicles incorporating special research measurement systems with the capability to test promising new rotor systems and to verify new analytical methods in a real flight environment, which cannot be simulated adequately in ground-based facilities. The program entered the initial fabrication phase this year with delivery scheduled for 1977.

*Tilt Rotor Research Aircraft.*—The joint NASA/Army Tilt Rotor Research Aircraft (TRRA) program, which consists of the design, fabrication and flight test of two tilt rotor aircraft, reached the fabrication phase this year with delivery scheduled late next year. The benefits offered by the tilt rotor concept result from combining the low disc loading hover efficiency of a helicopter with the good cruise efficiency and increased forward speed capability of a fixed wing aircraft configuration.

#### *Supporting the Military in Maintaining the Superiority of Military Aircraft*

NASA continues to assist the military by developing advanced technology suitable for future military systems. In addition to conducting these R&D programs, NASA has provided direct technical support to specific military aircraft programs, such as the F-15, B-1, YF-16 and YF-17 programs to enhance the success of their development.

#### **International Affairs**

Highlights of 1974 included joint testing and training for the Apollo-Soyuz test flight in July 1975, four cooperative satellite launchings, selection of foreign investigators for studies based on remote sensing data to be obtained by the ERTS-B satellite, and on-schedule progress in the development of Spacelab, the manned orbiting laboratory which our European partners are building to operate with the Space Shuttle.

#### **US/USSR Cooperation**

Joint NASA/Soviet Academy of Sciences Working Groups continued to implement the May 24, 1972 US/USSR Agreement Concerning Cooperation in the Exploration and Use of Outer Space. This agreement provides for the Apollo-Soyuz Test Project—a joint manned experimental flight in 1975 to test compatible rendezvous and docking systems—and for cooperation in space science and applications.

*Apollo-Soyuz Test Project (ASTP).*—ASTP is the joint US/USSR manned space flight provided for by the US/USSR Agreement Concerning Cooperation in Space which President Nixon and Chairman Kosygin signed at the Moscow Summit in May 1972.

This experimental flight, on schedule for July 1975, has as its primary objective the conduct of space experiments to test the technical requirements and solutions for compatibility of systems for rendezvous and docking of future manned spacecraft and stations. A successful mission will contribute to a rescue capability for future manned space flights and broaden opportunities for US and USSR space cooperation in the years ahead. The Apollo Spacecraft is also carrying 27 individual experiments on this mission, five of which are joint experiments with the Soviets. These experiments cover the fields of science, space processing and manufacturing, applications, and life sciences. Several of the experiments are completely funded, except for spacecraft integration costs, by foreign governments. For example, the Federal Republic of Germany is funding an electrophoresis experiment to four to five million marks (approximately two million dollars).

The ASTP mission plan calls for the Soyuz to be launched first from the Soviet launch site at Baikonur. The first Apollo launch opportunity will occur about seven and one-half hours after Soyuz liftoff. Once in orbit, the Apollo will perform the necessary rendezvous maneuvers and then dock with the Soyuz. For about two days, the astronauts and the cosmonauts will exchange visits between vehicles and carry out joint activities, including experiments in space science and applications. There will be additional tests of the compatible docking mechanisms and, after final separation, the Apollo spacecraft will conduct further independent activities before re-entry.

The docking mechanisms to be used in the mission are separately developed and manufactured by the two nations but are based on a single set of agreed design specifications for components which must be compatible. US and Soviet engineers are closely engaged in the solution of common problems.

With design and development essentially complete, major progress in 1974 included joint compatibility tests of communications and docking systems and the

start of intensive US/USSR joint flight crew and flight-controller training. During the year, the Soviet side conducted two unmanned flights of the Soyuz spacecraft to test new systems and equipment to be used in the joint mission and completed an additional test flight of a manned Soyuz modified to an ASTP configuration. Meanwhile, NASA and the Soviet Academy approved public information plans for both the pre-mission and flight phases of the project. Plans have been made for the conduct of pre-launch tests at the US and USSR launch sites, and a joint flight readiness review has been scheduled for May 1975.

*Space Science and Applications.*—In the space science area, a joint NASA/Soviet Academy Conference on the Cosmochemistry of the Moon and the Planets was held in Moscow in June. During the Conference, a detailed Soviet briefing on the results of their recent missions to Mars was provided for a team of US specialists associated with the NASA Viking Project. US and Soviet specialists, who are preparing the joint experiment involving the correlation of geomagnetic data through ATS-6, met in the US in October for technical coordination. The Space Biology and Medicine Working Group met in the USSR in late October to exchange biomedical results of the Soyuz 13 and 14 and Skylab space flights. The Working Group also made recommendations, subsequently approved, which provide for NASA to prepare life science experiments for flight on the next available Soviet biological satellite.

In the space applications area, the joint Working Group on the Natural Environment agreed to (1) continued analysis and exchange of Nimbus/Cosmos microwave data and (2) coordinated investigation of microwave methods to determine moisture. In addition, the Working Group agreed on actions looking to the definition of coordinated studies in (1) geology and geomorphology, (2) vegetation, soil, and land use, and (3) hydrology. In connection with the proposed coordinated studies of vegetation, soil, and land use, U.S. scientists visited the Kursk test site in the Soviet Union. Also, U.S. and U.S.S.R. experiment scientists met in Leningrad in May to present the results of the final analyses of the data obtained during the joint Bering Sea microwave sensing experiment. This was the first time two independent research groups have made microwave radiometry measurements of sea ice and the ocean surface under the same conditions of varying surface roughness and intervening atmospheric conditions with generally the same results.

### *Spacelab*

Spacelab, to be carried in the Space Shuttle cargo bay, received considerable attention during the year.

The objective of the Spacelab program is to provide the user community with a ground-type laboratory which can take advantage of the unique environment of space.

The development of Spacelab, undertaken by agreement with NASA by the European Space Research Organization (ESRO), proceeded on schedule with award in June 1974 by ESRO of the development contract to a European consortium headed by ERNO of Germany. Spacelab represents a major (approximately \$420 million) contribution by ten participating European countries to the Shuttle-based Space Transportation System. Delivery of the first Spacelab flight unit is planned for mid 1979.

Meanwhile NASA and ESRO continued and expanded their respective Spacelab-use planning efforts involving representatives of a broader variety of science and application disciplines including physics and astronomy, life sciences, communications and navigation, Earth observations, and space processing. A NASA/ESRO Joint User Requirements Group (JURG) met throughout the year to assure that European and U.S. communities' user requirements are provided on a timely basis for Spacelab design. In addition, a Joint Planning Group (JPG) was established in mid-year to recommend the experimental objectives of the first Spacelab flight, which will be a joint NASA/ESRO mission.

And looking further into the future, NASA, in coordination with ESRO, has initiated Spacelab mission-definition studies in three science disciplines: (1) atmospheric, magnetospheric, and plasmas-in-space (AMPS), (2) solar physics, and (3) ultraviolet astronomy. The AMPS Working Group, first to be established, includes 14 foreign scientists—from Canada, France, Germany, Japan, Sweden, and the United Kingdom.

### *Cooperative Satellite and Probe Projects*

*HELIOS-A*, the first of two solar probes developed in cooperation with Germany, was launched on December 10 from the Eastern Test Range. This is the largest cooperative project yet flown by NASA and is designed to take scientific data closer to the sun than any spacecraft has previously flown. The second *HELIOS* is scheduled for launch in early 1976. Each spacecraft will carry an array of 10 experiments (seven German and three U.S.) designed to measure magnetic fields, plasma and radio waves, cosmic rays, and other particle and radiation phenomenon in interplanetary space and near the sun. These are expected to yield new data on solar behavior which is important to understanding the Sun's effects on the Earth.

*Netherlands Astronomy Satellite (ANS)* was launched by NASA from the Western Test Range

(WTR) on August 27. It carried x-ray instruments and an ultraviolet telescope for the study of stars and stellar objects and was the first cooperative U.S./Netherlands scientific satellite.

*San Marco C2*, a joint Italian-U.S. cooperative spacecraft to measure upper atmosphere density in the equatorial region, was successfully launched aboard a Scout rocket from an Indian Ocean platform off the coast of Kenya, Africa, on February 18.

*UK-5*, an astronomy satellite developed as a cooperative project between NASA and the British Science Research Council, was launched on October 15 on a NASA Scout launch vehicle from the Italian San Marco Range on the equator off the coast of Kenya. The spacecraft, contributed by the U.K., is designed to continue the study of stellar X-ray sources and search for new X-ray emitters in the universe.

*INTASAT*, a cooperative spacecraft designed and developed in Spain, was launched as a secondary payload with ITOS-G on a Thor-Delta vehicle on November 15 from WTR. The satellite is an ionospheric beacon designed to permit measurement on the ground of the total electron content of the ionosphere as a function of latitude and time.

Work continues on other cooperative satellite missions: (a) the International Ultraviolet Explorer (IUE), being developed in cooperation with the U.K. and ESRO, is expected to provide in 1976 a telescope facility in synchronous orbit for high resolution ultraviolet stellar studies, and (b) the Communications Technology Satellite (CTS), a Canadian-U.S. cooperative spacecraft to advance the state of the art in communications-satellite technology and demonstrate low-cost broadcast capability in the millimeter wave frequency band to remote areas, is planned for launch in 1975.

### **Earth Resources**

*ERTS investigations.*—Investigators from 37 countries and two international organizations analyzed data obtained from the first Earth Resources Technology Satellite (ERTS-1, now redesignated LANDSAT-1) and the Earth Resources Experiment Package (EREP) on Skylab. ERTS follow-on studies were approved to analyze remotely sensed data in the form of imagery or on magnetic tapes collected by ERTS spacecraft. This will involve investigators from 42 countries and five international organizations.

*Ground facilities.*—Under an agreement reached in May, the Italian organization Telespazio will build a ground station designed to receive data directly from NASA experimental earth resources satellites. Located at Fucino, the new installation will be linked

to the growing network of earth resources data facilities. A data-processing facility for Brazil's ERTS data-acquisition station, established in 1973, became operational in September of this year. There is also an operating ERTS ground station in Canada. Several other countries have expressed interest in establishing similar facilities.

### **Reimbursable Launchings**

*AEROS-B*, a German aeronomy satellite was launched by NASA from WTR on July 12. Four German and one U.S. experiment on board will investigate the varied particles and fields processes that take place in the upper layers of the Earth's atmosphere.

*Symphonie*, a French/German experimental communications satellite, was launched from ETR on December 18 aboard a Delta vehicle.

*UK-X4*, an experimental technology satellite launched successfully on March 8, is the first cost-reimbursable launch by NASA for the United Kingdom. The five U.K. experiments on board the three-axis stabilized spacecraft demonstrated some new approaches to small satellite subsystem design.

### **Broadcast Satellite Experiment**

*India.*—With the launching of the NASA ATS-6 satellite on May 30, 1974, an important milestone was passed in the preparation for the one-year NASA/Indian Space Research Organization (ISRO) cooperative Satellite Instructional Television Experiment (SITE). SITE, which is planned to begin in mid-1975, involves the broadcast of educational television programs from a station in India via the ATS-6 satellite to some 5000 remote Indian villages, more than 2000 of which will be equipped to receive the signal directly from the spacecraft on standard TV receivers augmented by a 10-foot antenna and associated equipment to convert the satellite signal into a TV picture. The remaining villages will receive the signals via conventional ground-relay systems. SITE will be the first large-scale experiment in satellite broadcasting to community receivers in an underdeveloped country. India, which is responsible for all ground equipment, is also producing all the necessary programs for the year-long experiment. NASA will provide the satellite time (four hours a day) and is providing technical assistance to the development of the ground hardware.

### **Lunar Samples**

37 Principal Investigators from outside the United States, representing participation by 11 countries, were selected to continue or begin new investigations under the NASA Lunar Sample Research Program.

## **Disseminating Technology and Benefits**

The prime objective of NASA's Technology Utilization program is to stimulate and organize the transfer of technology from aeronautics and space programs to the non-aerospace public and private sectors. The Technology Utilization program uses many means for the dissemination of new technology resulting from NASA's research and development efforts, when such technology is deemed to have commercial potential. Various publications issued include Tech Briefs—single-page summaries describing the technology; Technical Support Packages—in-depth elaborations of the technical aspects of the Tech Brief; Compilations—briefs on techniques or processes relating to a single field; and other NASA Special Publications, Case Studies, Profiles etc.

Other methods used in the Technology Utilization Program to disseminate NASA technology for secondary application include the sponsorship of six Industrial Application Centers and one Computer Software and Management Information Center (COSMIC). These centers are geographically situated throughout the Nation to serve as a network of technical assistance for both small businesses and large firms. In addition the Technology Utilization program sponsors Patent Licensing Conferences in prime geographical locations to encourage businessmen to make commercial use of NASA-owned patents. To expand its efforts towards assisting minority enterprises in utilizing NASA-generated technology for commercial applications, a full time staff member was assigned to concentrate on this work. One outgrowth of this effort was the assistance given by the Technology Utilization program in a minority-business conference and exhibition jointly sponsored by the Office of Minority Business Enterprise and NASA.

The successful Applications Engineering Program was continued during 1974 with the addition of

new projects in the areas of Biomedicine, Urban Construction and Safety, Environmental Pollution, Fire Safety, Transportation, and Law Enforcement. Some of the significant accomplishments resulting from these projects during 1974 included: the installation of the NASA-developed Flat Conductor Cable in an Urban Development Corporation of New York demonstration structure in New York; the increase in the number of implants of the NASA sponsored Rechargeable Cardiac Pacemaker to over 600 and the development and demonstration of a pediatric unit; the field test and evaluation by three major U.S. City Fire Departments of the NASA Fireman's Breathing System; the commercialization of Control Systems for the Handicapped developed under projects sponsored by this Program; and many others. In all aspects of these efforts, the Technology Utilization program continued its emphasis in sharing the technology developed under this program with other Government agencies and State and local governments, as well as private industry. As a result of these efforts, the amount of joint funding with other agencies has increased, thus enabling the Technology Utilization program to sponsor more projects as well as reduce the time for disseminating the technology to the private and public sector.

## **University Affairs**

Participation of the academic community in NASA programs continued during 1974. Some 1,632 projects totaling \$101 million were funded in support of research and space flight experiments in 258 universities. This represents an increase of 30 schools over last year, most of which are participating in a special effort to assure minority schools an opportunity of working with NASA. A total of 102 awards for \$2.4 million was made to 44 minority schools.



## Introduction

Space and aeronautical activities play a central role in enabling the Department of Defense (DOD) to carry out its mission—space in a supportive defense role in such activities as communications, navigation, meteorology and space surveillance, aeronautics in an active defense role in terms of tactical and strategic aircraft, air mobility, ground surveillance and airborne early warning and command posts. This chapter reports the progress made by DOD in space and aeronautics during 1974 to enhance its defense capabilities.

Significant actions were taken this past year to expand and improve the Defense Satellite Communications System better to serve the needs of the National Command Authorities and the World Wide Military Command and Control System. Existing earth terminals were upgraded to operate with the new generation communications satellites and new large terminals were placed in procurement action for use in the DSCS around the world. Two new Phase II satellites were readied for launch in early 1975 and action was taken to procure six additional satellites to replenish the system on a periodic basis. New electronic components were ordered which will add to the efficiency and versatility of the system. Also, the Navy initiated operation of its shipboard terminals in the DSCS.

The NAVSTAR global positioning satellite program advanced significantly during 1974. The joint program office was formed and manned by representatives of all military Services and the Defense Mapping Agency. Contracts were let for the Phase I satellites and for user equipment development. The first technology satellite for flight demonstration of the atomic clocks was successfully launched in July. In August a decision was made to expand the constellation to six satellites to provide precise tracking capabilities for test of important Department of Defense weapon platforms. If the objectives of cost and performance are met during the first phase of the NAVSTAR program then a decision may be made to expand the program to a world-wide two-

dimensional capability. Such a capability is not presently planned prior to 1981, although acceleration to 1979 is being kept as an option if it can be shown to provide cost benefits. The accuracy of the world-wide two-dimensional system will be approximately 50 meters. Expansion from two-dimension to three-dimension with accuracies of 10 meters in any direction is planned by 1984.

Weather data from anywhere on the globe can be stored aboard the Defense Meteorological Satellite Program and transmitted to Air Force Global Weather Central in Nebraska. Real-time local area imagery can also be transmitted to mobile readout stations for on-the-spot use by U.S. forces in the area, and during the past two years has been made routinely available to the civil/scientific community through the National Oceanic and Atmospheric Administration.

The Advanced Research Projects Agency and the Air Force are currently engaged in advancing the technology which would permit better surveillance of passive ("quiet") satellites. Groundbased and space sensors will both be used to provide the best mix of capabilities.

The Department of Defense is committed to support the NASA Space Shuttle program, providing an interim upper stage for use in 1980 until the NASA space tug is developed in the mid-1980's. Certain military payloads would be flown from the Kennedy Space Center starting in 1980.

Increased operational air mobility is being provided by the C-5A heavy logistics transport aircraft and SAC C-135 tanker. Approximately 50,000 hours of flying time have been logged during the past year.

The B-1 strategic bomber prototype had a successful first flight on 23 December 1974. The flight, lasting over an hour, permitted an assessment of the aircraft's low-speed flying qualities and of such subsystem operations as throttle transients and afterburner lights.

The remotely piloted vehicles (RPV) concept has been advanced significantly during the past year through the use of very reliable and miniature electronic devices and more efficient configuration design.

The concept permits extended flight duration missions, releasing personnel not only from tedious flights but from highly dangerous missions.

### **Space Activities**

Military space programs have had a significant impact on strategic and tactical forces with the evolution of communications, meteorological, navigation, and surveillance satellite systems. With the maturing of space technology and the success of space systems operations on a routine basis, we have proceeded with confidence toward the implementation of those programs which would greatly enhance our land, naval, and air forces.

#### *Defense Satellite Communications System (DSCS)*

The objective of the DSCS is to provide rapid, reliable and secure communications to satisfy the requirements of the National Command Authorities and the World Wide Military Command and Control System. During 1974, the Phase I communications satellites, which were launched in the period 1966 through 1968, continued in use. However, by the end of the year the number of Phase I satellites still in operation was reduced to the extent that continuous service in the Phase I system was no longer possible. This concluded a highly successful program, albeit, one of limited capability.

With the successful launch of the third and fourth Phase II communications satellites on 13 December 1973, the DSCS was in position to renew operations in the Phase II system which had been interrupted by the failure of the first two Phase II satellites. After extensive testing these two new satellites were placed in operation in February 1974, one over the Atlantic Ocean and one over the Pacific Ocean. Dual launch of the fifth and sixth satellites by mid-1975 will extend the coverage of the DSCS and will provide an on-orbit spare.

The Air Force, as an agent for the DSCS, has contracted for procurement of six additional Phase II satellites which will be launched in pairs as needed to replenish the DSCS space segment.

Also, during 1974, the modification of Phase I DSCS earth terminals to increase their capability and reliability was completed for Phase II satellite use. The Army contracted for the procurement of new Phase II large earth terminals used in the DSCS and the Navy's Fleet Satellite Communications System after extensive testing of the engineering model terminal in an operational environment at Palo Alto, California. The Air Force has contracted for the production of Time Division Multiplex equipment which will provide more efficient utilization of communications channels in the DSCS. In late 1974, the Army placed initial production con-

tracts for digital modulation equipment for use in DSCS ground terminals which will make the system capable of accepting directly the inputs of digital computers and communications systems which operate in the digital mode. During 1974, also, the Navy activated its interim shipboard terminals for operation with the DSCS II satellites.

#### *Fleet Satellite Communications System*

The Fleet Satellite Communications System (FLTSATCOM) objective is to develop and deploy a satellite communications system to satisfy the most urgent, worldwide near-term tactical communications requirements of the Navy and Air Force. Initial contracts were awarded in late 1972. Production has commenced for both shipboard terminal installations and the large Fleet Broadcast shore transmitters permitting installations to commence in 1975. Resolution of difficult technical problems in early 1974 permitted final satellite design accomplishment in December. Production is expected to commence in mid-1975. The shipboard terminal equipment will be operated on a leased "Gapfiller" capability in the MARISAT spacecraft until the FLTSATCOM system is operational in 1977.

#### *Air Force Satellite Communications System*

The Air Force Satellite Communications (AFSATCOM) System will provide communications capability via satellite to satisfy high priority Air Force requirements for command and control of strategic forces. The AFSATCOM space segment is comprised of Air Force ultra high frequency (UHF) communications capability on the Navy Fleet Satellite Communications (FLTSATCOM) System and the Air Force Satellite Data Systems (SDS), and global backup capability on other Department of Defense satellites. The AFSATCOM terminal segment will consist of airborne, mobile and fixed terminals. The terminal development was continued and initial operational testing is scheduled to begin in early 1975.

#### *Army Satellite Communications Activities*

The Army Satellite Communications Ground Environment includes the development of strategic and tactical satellite communications around terminals for use by all Services. Two major projects in this program element are the Defense Satellite Communications System (DSCS) Phase II and the Tactical Satellite Communications (TACSATCOM) system. A third and smaller project in this program is devoted to the exploratory development required to support the two major projects.

The U.S. Army has essentially completed modifying all existing DSCS ground terminals to upgrade their reliability and communications capacity.

New heavy transportable terminals have been installed at Palo Alto, California in support of the Air Force Satellite Control Facility and at Fort Detrick, Maryland in support of DSCS requirements. Additional heavy terminals have been contracted for to satisfy other area needs of the DSCS. A light transportable terminal is currently in engineering development for a mid-FY 75 delivery.

The small terminal contract for test models of highly transportable satellite ground terminals was awarded in December 1972 and seven models are to be delivered by mid-FY 75 for extensive field testing. These terminals will provide mobile multichannel communications for the Army in the field utilizing the DSCS Phase II satellites. Engineering Development has begun on a UHF manpack terminal and a contract award is expected in mid-FY 1975 for engineering development of the UHF vehicular terminal.

The interim operational capability continues to support various contingencies and field exercises. Operational testing through the year has assisted in further development of concepts for the utilization of this significant transmission medium in support of combat readiness operations.

#### ***Defense Meteorological Satellite Program (DMSP)***

This space program, formerly called the Defense Systems Application Program, provides timely, high-quality visual and infrared weather data to our military forces. Two satellites are in orbit at all times, one providing data in the early morning and early evening, and the other near local noon and midnight. The orbit is circular, near-polar, at an altitude of 450 nautical miles, and each satellite circles the earth every 102 minutes. Weather data from anywhere in the world can be stored aboard the satellites and transmitted to Air Force Global Weather Central in Nebraska. Real-time local area imagery can also be transmitted to mobile readout stations for on-the-spot use by U.S. forces in the area. Since December 1972, the data from this program have been made routinely available to the civil/scientific community through the National Oceanic and Atmospheric Administration (NOAA). The Department of Defense is also cooperating with NASA and NOAA in the development of an operationally improved civil weather satellite, the TIROS-N.

#### ***Space Surveillance***

The Defense Advanced Research Projects Agency (ARPA) will develop and demonstrate new optical techniques for Space Surveillance which will allow significant reductions in the costs of systems which will search for and automatically detect satellites. The program includes gathering data on satellites using the ARPA (Maui) Hawaiian Island

Optical Station to form a target signatures catalog for detailed systems design. A new generation of sensors with very large formats employing advanced readout and data processing schemes is under development. The final phase of this multi-year program will be a series of verification experiments which demonstrate the capabilities of these advanced sensors for autonomous surveillance of space. Ground tests of these devices will be conducted at the Maui Optical Station.

For the near-term capability, the MIT Lincoln Laboratory, under Air Force sponsorship, is developing a simplified version of an operational system to be operating in the White Sands Missile Range area in the spring of 1975.

The Air Force is advancing technology critical to space-based systems that would be capable of providing long range real-time surveillance of satellites.

Long-term requirements are expected to place heavy demands on surveillance systems and will require more sophisticated approaches. These satellites would have the advantages of eliminating the requirements for overseas ground stations. These systems are expected to be operating in the early 1980s.

#### ***Space Object Identification***

Since 1972 ARPA has been involved in a broad research program to advance the technologies of space object identification. Both optical and radar techniques are being defined, developed, and demonstrated to measure the physical characteristics of space objects. Wideband microwave techniques have been developed and have demonstrated great utility for providing precise spatial information on space objects. Transfer of this technology to the Services is underway. Millimeter wave imaging techniques are approaching the point where a demonstration of their potential is possible. A development program which could lead to a wideband laser imaging radar is also underway. In the optical area, sensors are being developed to measure the effects of atmospheric turbulence on pictures of space objects taken by large ground-based telescopes. Removal of the atmospherically imposed distortions will greatly improve the present image quality. A verification test of an atmospheric correction imaging system is planned for the ARPA Maui Optical Station. Radar and optical techniques developed under ARPA sponsorship will not only be used to obtain diagnostic information on our own satellites, but also will serve as a prime source of technology for improvement of the Space Surveillance and Detection Tracking System (SPADATS) ability to obtain diagnostic data on space objects.

#### ***Navigation Satellite Activity***

The Navy Navigation Satellite System, referred to as TRANSIT, will have achieved a decade of opera-

tion in 1975. The system has served the Department of Defense and the nation well in that time. The purpose of developing TRANSIT was to provide the Navy with a worldwide, two dimensional system for position fixing to an accuracy of better than one tenth of a mile—primarily in support of submarines. TRANSIT usage has been expanding both militarily and commercially. It has been adapted for use in such diverse activities as offshore oil exploration and for measurement of the drift of ice over the poles. The six satellites operating provide an opportunity at least every two hours, depending upon the latitude, for a user to take a position fix.

Since the early 1970's, a TRANSIT improvement program has been underway. The improved satellites will provide stationkeeping in their orbital plans, improved anti-jamming characteristics and radiation hardening. The first improved satellite was tested in 1972. It is no longer operational; two more, now under development, will be launched within the next year or so. Eventually at least three of the improved satellites will be a part of the operational constellation.

### *NAVSTAR Global Positioning System*

The objective of the NAVSTAR Global Positioning System is to increase weapon system effectiveness, reduce positioning and navigation system proliferation, and promote cost avoidance.

Approval was given in December 1973 for the validation of the NAVSTAR satellite navigation concept. In June 1974, the contract was awarded for satellite development. In August 1974, a decision was made to expand the initial set of orbiting satellites from four to six in order to support range tracking tests of priority Department of Defense systems. In October 1974, the contract for the satellite control segment and the user equipment was awarded. The first technology support satellite for the program was launched this summer. Its purpose is to confirm the design and operation of the rubidium atomic clocks and provide signal propagation information to confirm theoretical predictions for the system.

In 1976, the user equipment sets are scheduled to begin tests at a pseudo satellite test range in Arizona. During 1976 and 1977, the six satellites are scheduled to be launched for use in concept validation. In early 1978, a decision is scheduled on system deployment. This decision on deployment depends on demonstration of system accuracy and upon achieving low life cycle costs for user equipment. An initial operational capability is planned for 1981 with a full operational capability by 1984. The system should provide three dimensional position data to an accuracy of less than ten meters; three dimensional velocity information to an accuracy of

two or three centimeters per second, and time information to an accuracy of a few nanoseconds. This information will be continuously available worldwide.

If the NAVSTAR system is deployed the DoD envisions discontinuing its use of most other externally referenced radio aids to navigation and position fixing, including such systems as OMEGA, LORAN and TRANSIT. Investigations have indicated a significant savings may be possible through cost avoidance. Proliferation and maintenance of a number of navigation and position fixing equipment will be halted by focusing on one basic system, NAVSTAR, for use by all.

### *Space Boosters*

The Atlas and Titan III standard launch vehicles and the surplus IRBM SM-75 Thor and surplus ICBM Atlas E/F vehicles comprise the DoD family of space boosters. During 1974 there were a total of eight Titan III space launches including two launches of NASA payloads on Titan III E, and one launch of a NASA payload on Titan III C. The Titan III E carries a NASA Centaur upper stage. There were two SM-75 Thor launches this year, both successful, and one successful Atlas F space launch.

### *Space Shuttle*

The DoD and NASA continued to work closely this past year in their respective roles, with NASA as the Shuttle developer and the DoD as an important future user of the Space Shuttle. The DoD strongly supports the development of this space vehicle. The DoD program goals are (1) to insure that NASA knows and understands DoD needs so that the Space Shuttle will be of maximum utility for military payloads; (2) to provide data to support decisions leading to future use of the Shuttle; and (3) to explore ways DoD can benefit most from the Shuttle's unique capabilities. The DoD has agreed to develop a low cost Interim Upper Stage (IUS) for use with the Shuttle during the period starting in 1980 and continuing until the NASA upper stage (Space Tug) is developed in the mid-1980's; to fly certain military payloads on the Shuttle beginning in 1980 at the Kennedy Space Center; and to plan a Shuttle launch and landing capability at Vandenberg AFB (VAFB). Initial Operational Capability at VAFB is expected to be not earlier than December 1982. It is expected that transition from the current expendable space boosters such as Atlas and Titan to the Space Shuttle will be completed by the mid-1980's.

### **Aeronautics**

In air superiority, the challenge is to provide aircraft that can compete with a technically sophis-

ticated opponent; to provide less costly and sophisticated tactical aircraft for use in quantity; and to provide the most efficient means of air mobility required in support of our forces. Air mobility is an essential element of both tactical and strategic movement of combat forces and supplies.

#### ***C-5A Heavy Logistics Transport Aircraft***

The C-5 Force continued to perform a variety of logistics missions, logging approximately 50,000 hours of flying time during the year. These missions included support of Operation NIMBUS STAR which was conducted to reopen the Suez Canal. In May, Military Airlift Command (MAC) began qualification of C-5 aircrews in aerial refueling operations and in August, a MAC C-5 flew nonstop from Dover AFB, Delaware, to Clark AFB, Philippines, a distance of over 10,000 miles, utilizing the fuel from two separate aerial refuelings. The flight demonstrated the increased operational flexibility and global mobility provided to the airlift force by the team of C-5 and SAC KC-135 tanker.

#### ***Advanced Medium STOL Transport Prototypes***

The Advanced Medium Short Takeoff and Landing Transport (AMST) prototype program involves two contractors building two advanced technology prototypes each for test and evaluation as development options for tactical airlift modernization. An FY 74 Congressional funding reduction limited contractor efforts during the first half of the year. However, with Congressional approval of the full FY 75 request, the program is now proceeding at a more rapid pace. Both contractors have almost completed the engineering effort and are proceeding with major assembly.

Flight test of one prototype is scheduled to begin in April 1976, and the other contractor will follow in August 1976. The Army, Marines, and NASA are participating with the Air Force and the two contractors in developing the flight test plan.

#### ***A-10 Close Air Support Aircraft***

The development of the A-10 aircraft proceeded without major difficulty. The two prototype aircraft have had over 1000 hours of flight test, including a comparative flight evaluation with the A-7 in a combat scenario. In the evaluation which included an evaluation team and four combat-experienced tactical air command pilots who flew the missions, the A-10 was judged the more effective aircraft in the close air-support (CAS) role.

The results from the flight tests and the comparative evaluation are being used to eliminate many of the problems associated with the start-up of manufacturing, and thus insure a smooth transition from development to production.

The first of six preproduction aircraft, required for the extensive test and evaluation effort necessary to support a full production decision, is in final assembly and checkout for delivery in early 1975. Production of the initial increment of 22 aircraft was approved in December 1974, and the first of these aircraft is scheduled for delivery in November 1975. The full-production decision will be made in late 1975.

#### ***B-1 Bomber Program***

To maintain a viable manned bomber element of the strategic TRIAD in the 1980's, the Air Force is developing the B-1 bomber. The B-1 has been under development since 1970. Roll-out occurred in October 1974 and first flight on 23 December 1974. The first phase of flight testing, utilizing the first of three Research, Development, Test and Evaluation (RDT&E) aircraft, began in December. A production decision is scheduled for November 1976. During 1974, major aircraft sections completed static testing and a second aircraft underwent proof load testing and a successful flight was concluded on 23 December 1974.

The B-1 engine completed its Preliminary Flight Readiness Tests (PFRT) in April 1974 and compatibility of the engine with the inlet was verified with full-scale inlet/engine wind tunnel testing.

Because of cost and technical considerations, a decision was reached in October 1974 to eliminate the crew escape capsule from the fourth and subsequent aircraft in the B-1 program. Primary crew escape from these aircraft will be by ejection seat with a bailout capability for additional personnel.

#### ***A-6E All-Weather Attack Aircraft***

The newest member of the Intruder series is the A-6E All-Weather Attack Aircraft—the only true all-weather attack aircraft in the U.S. Navy and U.S. Marine Corps force structures. The A-6E has a new attack system and is capable of close air support, interdiction, and deep strike missions under adverse weather conditions, day or night. The A-6E's in use today are significantly superior to the A-6A's used in S.E. ASIA, and are achieving increased performance with decreased maintenance and improved reliability. The A-6E has been deployed to the U.S. SIXTH FLEET, is currently in the Fleet Marine Force Atlantic, and it is ready for deployment to the U.S. SEVENTH FLEET.

#### ***F-14 Carrier-Based Tactical Fighter***

In flight tests, as well as in the fleet training environment, the F-14A continues to demonstrate its multitrack, multishot Phoenix air-to-air missile capability, compiling an unprecedented (88 percent)

hit ratio. By October 1974, 100 F-14 aircraft had accumulated over 18,000 flight hours. The first two squadrons were deployed on USS ENTERPRISE in September 1974 and two additional squadrons are operating at the Naval Air Station Oceana on the East Coast.

#### ***Navy Air Combat Fighter (NACF)***

The NACF is visualized as a fighter/attack airplane which will be superior to the bulk of threat fighters in air fighting capability and will contribute effectively to the air-to-ground missions through the use of precision guided munitions. A primary goal is to produce a combat aircraft that will have an associated life cycle cost of less than half that of the F-14 in an effort to provide an alternative that will permit us to arrest the decline of Navy and Marine Corps force structure. It is visualized that the NACF will replace the F-4 and A-7 in the Navy and Marine Corps. The final configuration and weapon suite of the airplane will be determined through trade-offs of capability versus cost. The Navy, by congressional direction is investigating the feasibility of using a variant of the USAF Air Combat Fighter (ACF) to satisfy NACF requirements. Fleet deliveries of the NACF are planned in the early 1980's.

#### ***F-15 Advanced Tactical Fighter***

The F-15 Advanced Tactical Fighter program is proceeding on schedule. The first operational aircraft was delivered to Tactical Air Command in November 1974. At the end of 1974 the twenty aircraft in the Air Force flight test program had accumulated over 3000 flight hours while conducting F-15 systems tests and evaluating aircraft performance.

#### ***F-4 Wild Weasel (WW) Anti-Radiation Avionics***

The objective of the Air Force's Wild Weasel (WW) Research and Development program is to design, fabricate, and flight test a system which will provide designated strike aircraft the capability to search out and destroy hostile radar systems. This development program will greatly improve the combat effectiveness of our tactical forces in the area of Defense Suppression. In 1974 a pilot Class V modification program was implemented by the Air Force. The WWII is being designed to be capable of controlling the Navy's next generation anti-radiation mission—HARM. Plans are under way to modify a significant number of the newer F-4's with the advanced Wild Weasel avionics system.

#### ***Lightweight Fighter and Air Combat Fighter Program***

The Lightweight Fighter (LWF) program has explored the advantages of new aerodynamic and

propulsion technologies. Two contractors each have two prototype aircraft participating in a joint USAF-contractor flight test. Because of the performance gains to be realized by these designs, coupled with the potentially lower cost, the Department of Defense and the USAF will initiate full scale development of a mission version of the most promising candidate, to be known as the Air Combat Fighter. This development is scheduled to commence after source selection is made in January 1975.

The objective of the ACF program is to develop an affordable, high performance air superiority fighter aircraft. This program uses the lightweight Fighter Prototype program as a base to evolve desired combinations of new technologies into a fighter version of one of the two LWF prototypes. The resulting ACF will be an airplane designed for "dogfighting" to the degree that it should have a significant air combat maneuvering advantage over the 1980-1990 threat fighters. Further, it will provide a lower cost fighter choice to complement the F-15. The aircraft to be selected will also compete as a replacement for the F-104 aircraft now being used by European allies and for other sales to friendly countries.

#### ***Utility Tactical Transport Aircraft System (UTTAS)***

The Utility Tactical Transport Aircraft System (UTTAS) will be the Army's first assault helicopter capable of carrying a combat-equipped infantry squad. It is designed to lift 11 infantrymen in a tactical troop assault and other related missions now performed by the UH-1 series helicopter. Sizing and other design parameters were chosen with a view towards reducing life cycle costs. The UTTAS will have an increased payload, thus reducing the number of troop-carrying helicopters required. The UTTAS will exhibit substantially improved maintainability, reliability, survivability and performance. The Army awarded contracts in August 1972 for the production of prototypes by two manufacturers. Prototypes will participate in a competitive fly-off during 1975-76. The UTTAS development is essentially on schedule. Both aircraft are currently undergoing flight test.

#### ***Heavy Lift Helicopter (HLH)***

The original Heavy Lift Helicopter (HLH) program goal was to field a tandem rotor, three engine, crane-type helicopter designed to carry externally bulk cargo, to off-load containerships, and to move heavy tactical equipment. Development of advanced technology components for the HLH, such as the flight control system, rotor drive system, and cargo handling system, has been under way since 1971. The newly developed fly-by-wire flight control system has been successfully demonstrated in flight,

and tests of the individual components will be completed in March 1975. A single austere prototype aircraft will be built to validate these advancements in the state-of-the-art and to verify the HLH technology. First flight of this prototype is planned for April 1976.

### ***CH-53E Helicopter***

This improved version of the H-53 series helicopter (currently in use by Navy, Marine Corps and Air Force) will be utilized by the Navy and Marines in a variety of missions ranging from amphibious assault to Vertical On-Board Delivery (VOD) of high priority fleet freight to both aircraft carriers and ships not accompanied by a carrier. The 53E features a third engine, seven main rotor blades with an increased rotor diameter, and a newly designed tail section. Payload performance will be more than double that of the CH-53D, increasing from 7.2 to over 16.1 tons, in either the internal or external mode of lift. This helo will retain full shipboard compatibility for basing and maintainability while requiring only a 10% increase in flight deck spot factor. Extensive commonality (over 60%) with the current CH/RH-53s in Navy service reduces development, training and logistic support costs. One of these aircraft was lost in a catastrophic failure of the rotor hub assembly. A new hub is being designed.

### ***COBRA/TOW***

The Army COBRA/TOW program, a retrofit of a portion of existing AH-1G COBRA helicopters and a purchase of new aircraft with the highly effective Tube Launched Optical Tracked Wire Guided (TOW) Missile, continued in 1974. Developmental and operational testing was conducted in 1973 and 1974 with prototype aircraft. Delivery of the COBRA/TOW begins in June of 1975. Testing to upgrade the engine, transmission and dynamic components to improve aircraft agility and maneuverability is continuing. A program has also been initiated to purchase additional quantities of the AH-1J twin-engine SEACOBRA attack helicopter for the Marine Corps, with modifications to improve performance and ordnance load capability and to provide for installation of the TOW missile system.

### ***Advanced Attack Helicopter (AAH)***

The AAH is a two-phase development program. The first phase is being conducted competitively with Bell and Hughes as the prime contractors. This phase is aimed at obtaining the best airframe and culminates in a fly-off between the two designs. The development and integration of the full mission equipment (weapons, sensors and navigation) will be accomplished in the second phase with the winning contractor only.

Design-to-cost is being stringently applied to the AAH program. The design-to-cost goal is \$1.7M (flyaway unit cost in FY 72 dollars). Contractors have been given unusual flexibility in trading off performance, within certain limits, in order to hold production costs down.

The program is proceeding well technically. First flight is scheduled for the Spring of 1975. R&D costs for phase 1 have risen above earlier estimates due to both inflation and real cost increases including an unexpectedly heavy effort on cost-performance design tradeoffs. As a result of the increased phase 1 costs, completion of this phase is expected to slip five to six months.

### ***E-2C Carrier-Based Airborne Warning and Control System***

The Hawkeye has completed its development stage and is in production. Initial deployment of this new Airborne Early Warning/Command and Control (AEW/C&C) system began in September 1974. The E-2C will eventually replace the earlier version E-2B on all CV's and CVA's. Initial indications are that the E-2C has significant performance benefits as well as greatly increased reliability over the E-2B. In conjunction with the F-14 and the S-3A, the E-2C will significantly upgrade fleet defense capabilities.

### ***E-3A Airborne Warning and Control System (AWACS)***

AWACS, officially designated E-3A, is a mobile, fast moving, survivable command, control and surveillance system mounted in a modified Boeing 707-320B. Its distinguishing technical feature is the ability to detect and track targets at all altitudes over land and water.

The System Integration Demonstration (SID) for evaluating a representative set of mission avionics (identification friend or foe, computer, displays, radar, navigation, communication) was conducted from March through October 1974. The results of this demonstration, which included development and operational testing, were used to support a December 1974 decision on whether to produce the first six AWACS. NATO established a Special Task Group (STG) to study AWACS as a possible NATO funded airborne early warning and backup control system. A deployment of the SID prototype aircraft to Europe will occur during April-May 1975 to demonstrate the AWACS' capabilities to NATO officials. The STG is scheduled to submit a recommendation in April 1975. Fabrication continued on three development test and evaluation systems, two of which will be flown in 1975.

### ***E-4A/B Advanced Airborne Command Post (AABNCP)***

The AABNCP will provide the National Command Authorities (NCA) and Strategic Air Command (SAC) with a significantly improved and highly survivable airborne command, control and communication (C<sup>3</sup>) center that will operate during all phases of a general war. At the end of 1974, three 747 aircraft had been accepted by the Air Force for modification as E-4A interim National Emergency Airborne Command Posts (NEACP) through transfer of C<sup>3</sup> equipment from present EC-135 command post aircraft. The contract for development of the advanced C<sup>3</sup> equipment was awarded in January 1974 and Preliminary Design Review was completed in August 1974. The advanced C<sup>3</sup> equipment will be installed in the fourth 747 aircraft (E-4B), now being fabricated for use as a test bed aircraft.

### ***Air Traffic Management***

The objective of this project is to perform engineering development of an Air Traffic Management Automated Center and its associated Ground-Air-Ground Digital Data Link (DDL). These subsystems of the Air Traffic Management System (ATMS) are designed to facilitate the safe and orderly flow of large numbers of Army aircraft under tactical conditions, and to provide an over-the-horizon digital radio communications link between cooperating aircraft and the Air Traffic Management Automated Center (ATMAC). The program will include a concept formulation and redefinition of the flight operations center for the Air Traffic Management System. A recent review of the ATMS by the Army indicates a need for reducing the requirement for automation in the orderly and expeditious movement of cooperative aircraft in the tactical area of operations. The concept formulation phase will provide this redirection. Testing of the engineering development model of the Position Location Reporting System will commence in January 1975. This is a joint USA/USMC operational evaluation program and tests will be completed in June 1975. If it is determined to proceed into Phase II of the program, a contract for service test models of the Position Location Reporting System will be awarded jointly with the USMC.

### ***Aircraft Research and Technology***

There are various facets of the research and development programs that support the aeronautics programs. These include outstanding advancements in engine development, aircraft structures, avionics, and rotor systems engineering for helicopters. In addition, there has been considerable effort in de-

veloping the use of recoverable remotely piloted vehicles as substitutes for manned systems in performing various missions.

### ***Aeronautical Propulsion Research and Technology***

A major success of the Army's aeronautical propulsion research and exploratory development program has been the development of efficient analytical methods for the design of small high-temperature combustors. A combustor recently designed and fabricated on the basis of these new analytical techniques immediately achieved almost all its design performance parameters. The significant improvements in combustion efficiency and demonstrated compliance with 1975 proposed EPA regulations for this class of aircraft propulsion engines indicate tremendous potential for weight reduction and lower emissions. Comparable to the technological advance in combustor design, was the achievement of single-stage pressure-ratio of 10:1 for the 3-5 lbs/sec class of compressors.

### ***Turbine Engine Development***

Engineering development of the 1500 shaft horsepower (SHP) UTTAS engine began in March 1972 as a derivative of the Army demonstrator gas turbine engine program. The engine development is proceeding on schedule. The preliminary flight rating test was completed in August 1974 and met the design power requirements. Emphasis upon the human factors aspect of maintainability will significantly reduce the maintenance man-hour costs over the life of this advanced technology engine. The modular aspect of this new engine is proving extremely helpful in test cell assembly and tear down.

The small turbine advanced gas generator (STAGG) program was contracted for in November 1971 with four contractors competing in a 36-month core-engine development. The configuration design phase was completed in October 1972 and initial gas generator tests commenced in September 1973. This advanced development will integrate the essential gas generator components for engine environment tests. The initial test results indicate that the increased power and reduced fuel consumption objectives of 35% and 20%, respectively, over current engines have been achieved. STAGG technology will support future Army aircraft and auxiliary power plants in the 200-1000 SHP range.

### ***Composite Aircraft Structures***

The successful design, fabrication and test of a group of graphite-epoxy composite components suitable for flight on existing Navy aircraft have confirmed weight savings and increased in projected production cost savings associated with composites use. Among the components which have been devel-

oped are an S-3 spoiler, F-14 overwing fairing, F-14 main landing gear door and a wing for the BQM-34E supersonic target vehicle. The recent test flight of the graphite-epoxy wing on the BQM-34E supersonic target marked the first flight of a composite aircraft wing. Advantages of the composite wing relative to the existing metal wing include a weight saving of 54% and estimated 40% lower production costs. Fabrication of additional numbers of these components followed by their carefully monitored placement on operational aircraft will provide long term Navy service experience with graphite composites. Critical technical and confidence factors governing an extensive production commitment to composite structures include: (a) development of confidence in the long term service durability of composites structures in an operational ship based environment; (b) extension of composite design and fabrication technology to large primary structures; (c) establishment of greater confidence in acquisition and life cycle cost projections for composite structures.

### *Aircraft Structures and Material Technology*

The Army's structures and materials program continues to demonstrate significant progress in the feasibility of composite applications in primary and secondary aircraft structures. Progress has permitted the design of a monocoque/sandwich aft fuselage for future tactical and utility helicopters. Design and fabrication of a composite rotor and tail boom for the AH-1 COBRA was initiated and testing is scheduled to commence in 1975. Indications are that composite rotor blades and airframe structures can provide significant system cost advantages in the 1980's. Specifically, a 7% increase in productivity and a 5% reduction in life-cycle cost are projected based on progress to date. It has also been demonstrated that the use of composites in rotor blades can be used to absorb acquisition radar signals thereby offering the potential of greatly reducing the radar cross section of helicopters. Progress has also been made in the development of composite materials for aircraft windshields. Included are the development of hard-surface coated polycarbonates, glass/polycarbonates and transparent crystallized glass. These advances will permit windshields that are more abrasion and impact resistant and that have improved ballistic properties.

### *US Army Avionics*

The Proximity Warning System (PWS) will soon become a reality at four major installations where the Army has its greatest concentration of aircraft. Fort Rucker, Fort Hood, Fort Campbell, and Fort Bragg have undertaken a major aircraft retrofit program designed to reduce significantly aircraft

collision hazard within the Army. The PWS warns a pilot by visual and aural means whenever one or more aircraft are within a selectable range of 1,000, 3,000, or 5,000 feet and within an altitude of  $\pm 300$  feet of his aircraft. The system issues a visual warning to the pilot and informs him that an "intruder" is above, below or at the same altitude as his "protected" aircraft. An audio warning is also generated and injected into the intercommunications system of the aircraft whenever an intruder penetrates the protected volume of airspace.

The Receiver-Transponder is designed to operate a second, remotely located light for application in tandem seat aircraft configurations. In addition to the "Confidence Test Switch" to verify operational readiness, each system has the provision of testing by means of a ground transponder test station. When the "Transponder Ground Test" switch is actuated, an unattended ground station is interrogated and responds with signals simulating an aircraft during changing altitudes. One ground station will serve the entire airfield.

The Proximity Warning System is the first step toward eliminating the mid-air collision threat. Follow-on technology will be closely monitored to insure every available means is explored to provide the best possible solution to this long recognized problem.

### *Helicopter Noise Reduction*

Acoustic detectability is a major factor in helicopter survivability. An investigation to explore potential methods of noise reduction for a tilt-rotor aircraft indicates the need to determine aircraft performance, weight, and far-field rotor acoustic signature as a function of selected design characteristics. The Army will be able to establish the cost in performance and dollars of further reducing the noise of the proposed tilt-rotor aircraft. A test facility is nearing completion, and once acoustic modifications are made, a unique facility will be available for research on basic mechanisms of rotary wing aerodynamic sound generation.

### *Tilt Rotor Research Aircraft*

The Army and the National Aeronautics and Space Administration (NASA) entered formal agreement on 1 November 1971 jointly to develop and test a tilt rotor research aircraft. The research aircraft will be used to advance the state-of-the-art of the tilt rotor concept and to verify the technology base heretofore established by DoD/NASA and industry. Bell Helicopter Company was awarded the contract in July 1973 for fabrication and flight test of two research aircraft. The detail design was completed in December 1974 with aircraft rollout

scheduled for October 1975. First flight of the tilt rotor is scheduled for July 1976.

### *Helicopter Rotor Dynamics*

Improvements in the responsiveness, efficiency, and utility of Army helicopters are achieved through progress in the structural dynamics of rotor blades. A sophisticated dynamics research model of a helicopter rotor system has been completed and is now available for research testing. By selecting different combinations of springs, rotor characteristics can be varied from those representative of stiff, hingeless rotors to those of fully articulated systems. Data obtained from use of this research model will allow, for the first time, comparison between theory and test data over a broad range of structural characteristics.

### *Advancing Blade Concept (ABC) Demonstrator Vehicle*

The ABC development program was initiated by the Army in December 1971. The program included fabrication and flight test of two aircraft equipped with the ABC rotor to verify and demonstrate the concept. The ABC incorporates two coaxial contra-rotating rigid rotors, thereby allowing utilization of the full lift capability of the advancing blade. Flight tests were initiated in July 1973 but were temporarily halted in August when the first of the two aircraft was damaged during a test flight. Additional wind tunnel testing and redesign were completed in 1974. Flight tests are expected to resume in 1975 to investigate the low speed flight characteristics of the ABC rotor. The auxiliary thrust engines for high speed flight tests will be installed and tested after successful completion of the low speed tests.

### *Rotor Systems Research Aircraft (RSRA)*

This is a joint Army/NASA program initiated in 1971 to design, fabricate and test two rotor systems research aircraft (RSRA). The RSRA will provide the government with the capability to conduct flight research of new rotor concepts, rotorcraft components and subsystems, and to accurately verify performance of existing rotor systems on a common, fully instrumented test bed. Sikorsky Aircraft was awarded the contract in November 1973 and was nearing the final design review at the end of 1974. First flight and delivery are scheduled for 1976.

### *Fluidic Stabilization System for Helicopters*

Flight tests of a three axis advanced hydrofluidic stabilization system were initiated in August 1973. The system is being tested on a UH-1M and OH-58 aircraft. Hydrofluidic controls offer the potential of improved reliability, lower cost, reduced maintenance requirements, and decreased system vulnerability

compared to electromechanical stabilization systems currently in use. Plans are to install ten systems on OH-58 training aircraft at Fort Rucker, Alabama, to verify improved reliability and reduced maintenance requirements.

### *Remotely Piloted Vehicles (RPVs)*

An RPV is an unmanned aircraft which is flown by a pilot from a remote location. The pilot may control the aircraft continuously or at intervals of his choosing.

The Department of Defense's current interest in RPVs is based essentially on two facts: First, modern air defenses could make many manned aircraft missions either impossible to accomplish or too expensive in trained manpower and resources; second, technological advances now permit the RPV concept to be developed through the use of very reliable and very small electronic devices as well as more efficient airframes and engines.

The size of these unmanned aircraft now being developed, or under active consideration for development, range from relatively large to very small "model" airplane size. However, since a pilot's size, weight, and life support systems do not have to be considered, the RPV is designed to be just large enough to carry the necessary mission-required devices and fuel. This fact allows the designer to drastically reduce or eliminate system characteristics that would aid an enemy to detect or attack the aircraft, and therefore increase the probability of accomplishing the mission while penetrating enemy defended airspace. In other instances, the RPV may be employed behind our own lines for safety and use long range sensors to watch enemy activity. This type of RPV could stay aloft for more than a day at a time and would release personnel from this type of tedious flying to other important combat operations.

Missions being considered for RPVs include:

- Long range stand-off surveillance
- Deep penetration reconnaissance
- Shallow penetrations for target acquisition
- Laser designation for smart weapons
- Platforms for air-ground weapons
- Flying a warhead into a target
- Aerial communications relay

### **Space Research and Technology**

Space research and technology must invariably consider the environment within which and against which satellites must function for years. Hence, not only must the space environment be better monitored and understood, but also the earth's atmosphere and its impact on equipment basic to many of our space programs.

### ***Solar Radiation (SOLRAD) Monitoring Satellite Program***

The objective of this program is to monitor the space environment from a satellite system and thus provide basis for identifying changes in solar activity and the subsequent effect of such events will have on communications systems and terrestrial environmental phenomena. Eventually, the system will provide the capability to anticipate changes in solar activity and predict subsequent impact in the near-earth space environment. The system consists of two sun-oriented satellites which are deployed in 70,000 mile circular earth-orbits with attendant ground facilities for data acquisition processing and dissemination. Spacecraft construction is nearly complete with the total program on schedule for a launch date in November 1975. Both satellites will measure solar activity in the form of X-ray, ultra-violet and particle emissions. SOLRAD will be launched on a TITAN III missile along with several other multi-service experiments as part of the USAF-managed Space Test Program.

### ***Gamma Ray Spectrometer Experiments***

A high resolution gamma ray spectrometer and charged particle sensors were launched into orbit in October 1972 to survey the radiation background in the upper atmosphere and near space environment from a 400-nautical mile polar orbit. Preparations are in progress for the launch of a follow-on spectrometer to provide a long term monitoring capability for radiation sources in this regime. The space background measurements accomplished in the earlier program will permit improved precision in the location of radiation sources and the calculation and measurement of nuclear explosion effects on the environment, and is expected to form the basis for the design of sensors for operational space systems. Data from these experiments will permit the location of debris from nuclear tests at high altitudes, and will assist in the estimation of potential environmental damage from wide-scale nuclear explosions.

### ***Environmental Remote Sensing***

Environmental data from the remote ocean areas are essential to measuring accurately an initial state of the total environment as a function of time and space. Modern methods for predicting changes to that initial condition utilize computerized models of the earth's atmosphere and interactive ocean surface which are critically limited by the initial measurement or observation. The Navy operates in the remote ocean areas of the world and thus has a continuing need for precise environmental information on a global basis. The Naval Weather Service provides a complete array of computer generated

products which are used for direct fleet support such as: aircraft carrier operations, storm evasion, and submarine warfare and amphibious landings. The advent of satellite-borne sensors and supporting ground systems which automatically provide measurements over broad ocean areas is a major technological milestone for the environmental community. The Navy is establishing a Satellite Processing Center (SPC) which will be part of the existing Fleet Numerical Weather Central located at Monterey, California. The SPC objective is to obtain all available satellite data, and process it automatically into refined numerical global models. The unique Navy problem of measuring and forecasting sea surface temperature, sea state and wave spectrum will play a major role in the operation. Hardware and system specifications have been completed. An Initial Operating Capability is planned in FY 77. The SPC is designed to exploit data contributed from all present and planned environmental satellite systems (DoD, NOAA, NASA, experiments on NIMBUS series and GOES).

### ***Upper Atmospheric Research***

Army ballistic missile defense systems, long range Army communications systems, electronic warfare techniques and Army long range missile design and testing require an accurate knowledge of the physical and dynamic properties of the upper atmosphere. The objective of the Army upper atmosphere research and development program is to develop techniques, software, and equipment to increase the effectiveness of weapon systems which must traverse the upper atmosphere or whose success depends upon a knowledge of upper atmospheric effects on energy propagation.

An extensive measurement program will continue in the 10 to 100 Km region whereby solar ultra-violet flux, composition, thermal and wind measurements will be made with balloon-borne, rocket-borne and ground based programs.

### ***Space Ground Support***

Department of Defense 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 and by the Army's White Sands Missile Range and Kwajalein Missile Range. These facilities are available to other Government, industry and international agencies that may require their support.

### ***Eastern Test Range (ETR)***

In 1974 the ETR continued to support DoD space and missile operations, NASA space programs, and commercial and international satellites launched

from the Cape Canaveral, Fla. area. This support included launch, range safety, and data acquisition functions. Support for commercial communications satellite launches under the overall sponsorship of NASA continued. Planning for FY 75/76 activities was initiated to support new DoD test programs and the NASA Appollo-Soyuz test program to be conducted in cooperation with the USSR. Instrumented aircraft and ships assigned to the ETR were heavily used in support of DoD requirements on both the Eastern and Western Test Ranges. Improvement and modernization of range instrumentation and associated supporting systems continued on schedule with emphasis being placed upon improvements in the radar tracking, range safety and real time data distribution systems. The second Advanced Range Instrumentation Ship (ARIS) completed a major modification program. Two ARIS (USNS Vandenberg and USNS Arnold) are now available for worldwide support of missile and space programs.

#### ***Space and Missile Test Center (SAMTEC)***

SAMTEC continued to operate the Western Test Range (WTR) in support of space and ballistic missile launches from Vandenberg Air Force Base, California. The last SAMTEC Range Instrumentation Ship (USNS Huntsville) was deactivated; future SAMTEC ship support will be provided by the ETR Advanced Range Instrumentation Ships (ARIS). SAMTEC has continued to improve range instrumentation to meet user requirements. An Unattended Scoring System (USS) was placed in operation, providing a scoring capability in broad ocean areas previously performed by an instrumentation ship. A new Telemetry Integrated Processing System is planned which will replace present systems and provide improved and more efficient support of new requirements. SAMTEC also became increasingly active in the advanced planning for Space Shuttle.

#### ***Satellite Control Facility (SCF)***

During 1974 the SCF workload remained relatively stable, consisting of support to R&D and operational satellites. This support included real-time telemetry, tracking and command/control, post pass and post flight data analysis, and payload recovery. Interim wideband communications links from the Guam and Hawaii Tracking Stations to the Satellite Test Center in California became operational. Actions continued to increase communications capability from the other remote stations.

#### ***Arnold Engineering Development Center (AEDC)***

AEDC provided environmental simulation testing for major aeronautical, missile, and space programs under development as well as existing operational systems. AEDC supported a wide variety of testing

ranging from basic R&D investigations to scale model testing to full scale flight hardware testing covering the general areas of Propulsion, Aerodynamics, Space Environment and ballistics. Programs supported include F-15, Advanced Ballistic Reentry Systems (ABRES), Minuteman, Trident, Light Weight Fighter, Conventional Munitions, Rocket Propulsion and Airspace Flight Dynamics. AEDC also supported NASA Propulsion, Aerodynamics and Shuttle testing.

#### ***White Sands Missile Range (WSMR)***

The Army WSMR continued to provide support to DoD and NASA aeronautics and space programs. A full spectrum of launch, flight and recovery services was provided including ground and flight safety, surveillance, command and control, and data acquisition and analysis. NASA program support included the Skylab calibration rocket program, R&D and operational balloon and balloon payload programs, an upper atmospheric rocket sounding program using the Aerobee rocket vehicle, numerous smaller rocket systems, and a variety of astronomical test programs.

#### ***Kwajalein Missile Range (KMR)***

The Army's KMR continued to provide, maintain and operate a national range to support strategic offensive and defensive system test programs and to operate reentry radars to support all DoD reentry programs. On 27 March 1974, the U.S. agreed with Japan on the location at Kwajalein of a temporary down range tracking station to support two launches in the Japanese space program.

### **International Cooperation**

The United States continued giving close support to the United Kingdom in their implementation of the military SKYNET II SATCOM Program. The communications subsystems of the SKYNET II satellites were manufactured in the United States. On 18 January 1974 the National Aeronautics and Space Administration launched the SKYNET IIA communications satellite from Cape Canaveral, Florida; however, the second stage of the rocket misfired and, as a result, the satellite could not achieve its proper orbit. Through use of its Satellite Control Facilities, the USAF was to have placed the satellite in stationary orbit over the Indian Ocean at which time the operational and communications control of the satellite would have been turned over to the U.K. The follow-on SKYNET IIB communications satellite was launched on 30 November 1974.

In March 1973 NATO contracted with the United States to develop, procure, and launch two communications satellites in support of the NATO Phase III SATCOM Program. Production efforts on

these satellites continued in the United States during 1974. The schedule is such that the first of the two communications satellites should be ready for launch in late 1975. Some manufacture of the NATO space vehicle has been subcontracted by the United States to the United Kingdom. In March 1974 NATO also made the decision to space-qualify the engineering model, thus making a third satellite available for the NATO Phase III SATCOM system. NASA will launch the NATO III satellite and the USAF will provide orbital services. The USAF has provided technical support to the NATO SATCOM Program since its inception. During 1974 several U.S., U.K. and NATO meetings were held to improve plans for more effective use of SATCOM systems in the event of contingencies involving failures of communications satellites and to improve the interoperability capabilities of the systems. The United States furnished technical expert assistance to NATO for development of specifications for the procurement of NATO Phase III satellite ground terminals (SGTs) and the improvement of Phase II STSs. Assistance was also provided for developing standards and specifications for interfacing the NATO SATCOM and terrestrial communications systems.

An agreement was reached between the U.S.A. and the U.S.S.R. on 30 September 1971 to modify the 20 June 1963 Memorandum of Understanding (MOU) signed in Geneva, Switzerland, which called for the establishment of a Direct Communications Link (DCL) between the U.S.A. and the U.S.S.R. The September 1971 agreement to improve the DCL specified the use of two parallel satellite communications circuits (via INTELSAT and Molniya 2) to increase reliability and preclude third country

intervention. Progress on the development of the improved DCL has been substantial during 1974. The U.S. has completed installation and testing at both earth stations, Ft. Detrick, Maryland and Etam, West Virginia, and at associated terrestrial facilities. Upon completion of work at the Soviet DCL facilities, U.S.A.-U.S.S.R. testing will begin, followed shortly by DCL system activation.

### **Aeronautics and Astronautics Coordinating Board (AACB)**

The AACB is the principal formal coordinating body between the Department of Defense and NASA in the aeronautics and space areas. The Board met three times over the past year. A National Aeronautical Facilities Program, consisting of large aeronautical facilities essential to future U.S. civil and military aeronautical preeminence, has been developed; and, at the Board's direction an advocacy briefing has been provided to interested Committees of Congress, various agencies in the Executive Branch, and to appropriate industry organization. The Board has also identified a number of high priority aeronautical R&D programs for inclusion in the budgets of the DoD and NASA. In the space area, the AACB concentrated largely on reviewing the Space Shuttle development, the DoD plans to provide the low cost interim upper stage for use with the Shuttle at Kennedy Space Center, and the minimum Shuttle launch facilities at Vandenberg Air Force Base necessary to support high inclination space launches and full Shuttle utilization in the 1980's.



## Introduction

The Department of Transportation (DOT) has the general responsibility within the government to foster fast, safe, convenient and efficient transportation for all citizens. It accomplishes that mission through a series of modal administrations, one for each of several types of transportation. About half of the Department's employees belong to the Federal Aviation Administration (FAA) which is responsible for assuring the safe and efficient use of the nation's airspace by both military and civil aviation, for fostering civil aeronautics and air commerce in the United States and abroad, and for supporting the requirements of national defense. While FAA therefore is the major element of the DOT to be concerned with aeronautics and space, other elements, particularly the Office of the Secretary, also have a share in the work of fostering and regulating the activities of civilian aviation. This chapter begins with a series of discussions of programs that are supported by the Office of the Secretary and continues with discussions of programs sponsored by FAA. Applications of the technology generated by space research may be sponsored by any element of the Department; many of the Department's research and development efforts are conducted by the Transportation Systems Center in Cambridge, Massachusetts.

### Office of the Secretary Programs

Typical of the programs initiated or sponsored by the Office of the Secretary are the Climatic Impact Assessment Program (CIAP), the jet noise program, the efforts in air transportation system evaluation, the advanced air traffic management system, the search and rescue electronics research program and others. Following are brief descriptions of the projects:

#### *The Climatic Impact Assessment Program*

CIAP was established in the Office of the Secretary in 1971. It is a congressionally sponsored program that represents the first comprehensive effort to gather all the significant factors for a study of the effects of propulsion effluents which would derive

from a world aircraft fleet operating in the stratosphere. The objective of the program is to determine a basis for regulatory constraints to assure that no adverse environmental effects would impact the world population.

#### *Accomplishments in 1974*

- Achieved international collaboration and scientific data exchange with some ten countries in the area of stratospheric research. Included were United Kingdom, France, and USSR, which are now operating supersonic transports.
- Evaluated and integrated the scientific data from flight measurements and laboratory research effort into six scientific documents.
- The CIAP Report of Findings contains the analysis of the collected data and identifies some areas in which future actions will be required. The report was completed by the end of 1974 as originally committed to the Congress.
- Initiated arrangements for publication of CIAP documents for public distribution.
- Initiated follow-on activity to monitor the atmospheric composition over an extended period to add further to the capability to regulate operations and protect the environment.

#### *Jet Noise Suppression Program*

Noise is judged to be the most critical constraint to the future growth of civil aviation. Substantial progress has been made in noise abatement techniques for approach and landing. Progress will continue, but, at the present time, aircraft noise during takeoff is dominated by jet exhaust.

DOT initiated a program to study the fundamental mechanisms of jet noise generation and abatement. The objective is to investigate suppression concepts for the various jet engine cycles that will result in the greatest noise attenuation with the least degradation of performance.

The investigation of the phenomena is directed toward the following program goals:

1. Understanding of the aero-acoustic mechanisms of various jet noise suppressors, including scaling effects.

2. Development of analytical and experimental techniques to evaluate acoustic source distribution in suppressors.
3. Understanding of the aero-acoustic performance of these suppressors in flight.

Significant progress has been accomplished. Most significant is the further development of a laser velocimeter to measure the mean and turbulence velocity in high speed-high temperature flow. This development can also be used to study the flow around other aerodynamic machinery for purposes of improving the efficiency and energy consumption through these techniques. A large scale eddy structure of the jet was shown to exist. Results of this type give promise of new noise suppression devices.

### *Air Transportation System Evaluation*

The past year produced several changes in the Department's approach to long-range R&D planning for air transportation systems. The completion of the Civil Aviation Research and Development (CARD) Implementation Plan in 1973 had signaled a need to stimulate a number of joint DOT/NASA managed and funded system evaluation studies. Although the Quiet Short Haul Air Transportation Project Office of the FAA was dissolved at the beginning of the year, continued follow-up was effected through cooperative R&D activities for short haul studies as well as the evaluation of air cargo systems, lighter-than-air technology, and a comprehensive approach to technology assessment of comparative intercity transportation systems. A thorough evaluation of the air system development trends was incorporated in the program evaluation of the Upgraded Third Generation Air Traffic Control System. In these studies, the importance of augmenting the system performance by improved utilization of existing facilities was highlighted.

### *Advanced Air Traffic Management System*

The completion of the Advanced Air Traffic Management System (AATMS) Study described in last year's report provided a conceptual basis for identifying research needs and defining development plans for potential air traffic management applications in the long-term future. The study was conducted in multi-year phases and built upon the work of the DOT Air Traffic Control Advisory Committee in 1969 which highlighted the need for FAA work to upgrade the air traffic control system. The AATMS study defined potential means for further extending the planned Upgraded Third Generation Air Traffic Control System to meet long-range projections of aviation demands for service, safety and flexibility with cost consciousness. The results of the study indicate that high levels of automation and the application of satellite

technology appear to be promising areas of development work for future air traffic control system applications.

### *Search and Rescue Electronics*

A study sponsored by the Office of Safety Affairs of the Assistant Secretary for Environment, Safety and Consumer Affairs and conducted by the Transportation Systems Center reviewed current search and rescue electronic equipment and the existing and proposed locator systems in order to develop a program plan for improving search and rescue techniques for distressed air and sea casualties. The study analyzed various satellite monitoring systems and proposed development plans which would make better use of space technology for future systems and avoid duplication among interested agencies of the government.

### **Aviation Safety Research and Development**

During 1974, as in previous years, FAA conducted numerous research and development programs designed to make aviation safer. Broadly speaking, these efforts sought ways to reduce or eliminate hazards incident to takeoff and landing operations and those incident to en route operations. They also sought to deal with the problem of aircraft security.

### *Airport and Vicinity*

*Low Visibility Landing.*—FAA continued research and development efforts designed to provide increased safety in terminal areas during low visibility conditions. Among these efforts was the initiation of Category III weather flights using an Air Force C-141 aircraft. (Category III refers to weather conditions allowing no forward visibility.) These flights, conducted under actual weather conditions, will eventually provide engineering data that will enable FAA to evaluate operation concepts and functional characteristics of a totally integrated air-ground all-weather landing system.

The agency also initiated flight testing of a high-resolution-radar independent landing monitor (ILM). These tests will make it possible for FAA to determine the capability and role of the ILM in enhancing safety during low visibility landing conditions.

*Microwave Landing System (MLS).*—A key element of the upgraded Third Generation Air Traffic Control (ATC) system, which is expected to come into use during the 1980's, the microwave landing system will replace the current instrument landing system, which falls short of meeting urgent tactical needs and does not provide highly accurate signals under all siting conditions because of the inherent limitations of the VHF and UHF radio frequencies at which it operates. The microwave system, however, will be designed to meet the needs of all aircraft, both civil

and military, and will have the modularity and flexibility to serve sites that cannot be accommodated by the present ILS over the full range of weather conditions and traffic densities.

The MLS development program, scheduled to end in 1977, is being conducted in three phases. Phase I, technique analysis and contract definition, was completed in 1973. Phase II, feasibility demonstration, calling for the testing of four feasibility models at the National Aviation Facilities Experimental Center (NAFEC), in Atlantic City, N.J., and Wallops Island, Va., was completed in December 1974. Phase III, prototype development and evaluation, is scheduled to begin in March 1975.

*Wake Vortex Avoidance.*—These vortices form in the wake of all aircraft, but most severely in the wake of widebodied jets, and present a serious potential hazard—particularly on approach, landing, and take-off—to close-trailing smaller aircraft. In consequence, they have forced FAA to provide increased longitudinal separation between aircraft. This practice has had the effect of restricting both airspace and airport capacity.

Accordingly, FAA is attacking the problem on two fronts: (1) at the source, by studying airplane configurations and attempting to correct the problem by changes to the airframe; (2) by developing a wake vortex avoidance system (WVAS) that would detect and track vortices, based upon wind data measured near the touchdown area, and inform ATC controllers when separations imposed by the vortex phenomenon may be reduced. The first approach, which is being investigated by NASA, is for the long term. As to the WVAS development program—the short-term solution—FAA has detected and tracked more than 20,000 vortices using new acoustic sensors at the John F. Kennedy International Airport in New York and Stapleton Airport in Denver. This is the first step in characterizing vortex behavior and permitting the development of a vortex avoidance system. A functional design of a wake vortex avoidance system will be tested in the near future.

*Aircraft Security.*—In its continuing efforts to deter aircraft hijacking, sabotage, and other overt acts against aircraft, FAA engaged in the following activities, among others, during the calendar year:

- Completed an explosives taggant feasibility study that provided information on taggants and became the basis of the government-wide inter-agency explosive taggant program. (Taggants are substances which, when added to explosives or explosive detonating devices, facilitate the detection of explosives or detonating devices by dogs or other means.)

- Published a report on the performance and cost effectiveness of weapon detectors used by airport security personnel.
- Continued work on an automatic weapon and explosives detection system using each of two X-ray spectrums.

*Other Terminal Area Safety Developments.*—In addition to the foregoing, FAA pursued a variety of other programs designed to improve performance and enhance safety in and around airports.

These efforts included—

- Concluding an interagency agreement with the U.S. Navy to evaluate the shape and configuration of grooves on airport runways as a means of minimizing hydroplaning on wet surfaces.
- Issuing a technical report providing design and construction criteria for (1) fibrous reinforced pavement concrete, (2) free drainage runway surface courses, (3) prestressed concrete pavement, and (4) stabilized bases under airport pavements.
- Awarding a contract to study and develop techniques for the use of heated runways as a method of controlling snow and ice on airport pavements.
- Developing a low-impact absorbing support structure for approach lights that would collapse and do minimum damage to aircraft in the event of accidental impact.
- Designing a lighted wind cone for installation at the end of runways in an effort to provide better wind-cone visibility.
- Completing a survey of the electrostatic charging tendency of fuel delivered at 10 major airports. This survey was part of an FAA-industry program to prevent explosions from electrostatic discharges during aircraft fueling.
- Testing high-capacity, long-range firefighting foam-dispensing systems to determine the effectiveness of the larger types of firefighting equipment and amass data useful in the development of Advisory Circulars and International Civil Aviation Organization recommended practices.
- Continuing the investigation of stall deterrent devices and flight characteristics criteria for avoidance of inadvertent stalls in terminal area maneuvers.
- Completing tests and data analysis documenting the feasibility of the proposed Concorde SST landing distance rule.
- Testing chemical glycerine as a warm fog-dispersal agent in a series of fog seedings that employed a small commercial helicopter as a fog-seeding platform. The test revealed that while some favorable increases in surface visibility

could be attributed to the combined effects of fog seeding and helicopter downwash, the overall results were not sufficient to warrant continued development of the technique.

- Continuing an in-house engineering study on the conceptual design of a thermal ground-based fog-dispersal system for use at a major U.S. airport that experiences a high frequency of fog.

### ***En Route and Post-Crash Safety***

FAA's calendar year 1974 research and development efforts to improve safety during flight and increase the chances of survival in the event of an accident included—

- Continuing the investigation and development of means to reduce midair collisions. Flight tests are planned for completion by summer of 1975 for three airborne Collision Avoidance System (CAS) devices. In the area of separation assurance, FAA is committed to the development of a well-reasoned and technically based recommendation on measures that provide the largest benefit for the cost, both to the aviation community and the Government. The activity specifically addresses the comparative performance, costs, and benefits of CAS devices and alternative means of achieving comparable separation capabilities. These include extensions of the manual ground-based ATC system as well as augmentation of the ground system by Intermittent Positive Control (IPC).
- Completing a series of feasibility studies on the on-board generation of nitrogen for use in fuel tank inerting. These studies looked to a more viable technology for meeting improved fuel-system fire protection rules.
- Initiating toxic gas-emission tests of jet transport cabin materials in order to develop a data bank to support proposed rulemaking.
- Completing full-scale cabin studies of the effect on visual acuity of smoke emissions from burning material.
- Conducting tests to establish safe oxygen levels in fuel tanks for protection against explosions in ground fires. The tests sought to verify the requirements for improved fuel-system fire protection rules and obtain data for evaluating the Concorde fuel system.
- Continuing tests on the flash-fire propensities of cabin-interior materials. These tests are being conducted in cooperation with the National Bureau of Standards.
- Initiating a program to improve the fire safety characteristics of cabin flight attendant uniforms.
- Completing a program to determine the characteristics of flames from failed combustors in tur-

bine engines. The data gathered by this program will be used to establish criteria for engine fire protection and detection.

- Undertaking with NASA analysis and test of the cashworthiness of light general aviation aircraft and human tolerance to crashes. This effort seeks to develop structural design criteria that will lead to light aircraft with a significantly improved capability to withstand crashes.
- Developing data that establish the characteristics, capabilities, and effectiveness of ground trainers used in training pilots in specific maneuvers.
- Developing techniques of structural dynamic analysis for use in the certification of small general aviation aircraft subjected to survival crash impacts. This effort was concerned with securing data for updating the airworthiness standards of normal, utility, and acrobatic general aviation aircraft.
- Publishing a statistical summary of 8 years of general aviation accident data to be used in the identification of design features that may have been causal factors in fatal accidents.
- Continuing the study of psychosocial or "lifestyle" reconstructions as an aid in understanding the cause of aircraft accidents, especially accidents attributed to pilot error or poor judgment.
- Completing the testing of a propeller vibration measuring technique for general aviation aircraft to provide data for propeller certification standards.
- Completing the evaluation of a U.S. Air Force method for detecting incipient turbine engine failure.
- Pursuing a program to confirm the values of Doppler radar techniques as a means of locating dangerous thunderstorms.
- Completing specifications for the procurement of a video system to monitor the visibility in remote mountain passes used by general aviation aircraft.

### ***Air Traffic Control and Navigation***

In addition to its responsibilities in maintaining safety in the air, FAA is also charged with insuring the efficient and equitable utilization of the nation's airspace and maintaining a common ATC system for both civil and military aircraft. Performing these additional functions requires the application of the most promising developments of a rapidly evolving technology.

#### ***National Airspace System Modernization***

The primary focus of FAA's efforts to modernize the National Airspace System (NAS) has been con-

centrated on the introduction of two semi-automated air traffic control systems—namely, NAS En Route Stage A at the 20 air route traffic control centers (ARTCC's) in the contiguous 48 States and Automated Radar Terminal System (ARTS) III at 61 of the Nation's busiest terminal areas.

The enroute program is being implemented in two phases. Phase I provides automatic flight data processing and interfacility data transfer; phase II, digital radar display and radar data processing.

At the beginning of the calendar year, all 20 ARTCCs possessed an operational capability in automatic flight data processing and interfacility data transfer. They were also using computer updating equipment, which facilitates communications between the controller and the automated system. At this writing, fourteen of the twenty ARTCCs are fully commissioned NAS En Route Stage A facilities, possessing digital radar display and radar data processing. Six others were in various stages of testing radar data processing. The second implementation phase is expected to be completed at the twentieth center by mid-1975.

The terminal automation system reached a significant landmark during the reporting period when, in September 1974, the sixtieth ARTS II system became operational at San Francisco/Oakland. The Dallas/Ft. Worth system will be commissioned in February 1975. With this development, all 61 ARTS III systems will have reached operational status.

FAA plans to provide 30 of these 61 high density terminal facilities with primary tracking and continuous data recording. The research and development effort for these additions to the ARTS III system was completed in August 1973. Procurement specifications were prepared, and a contract award is expected to be made August 1975.

FAA also plans to introduce a less complex automation system—ARTS II—at 70 lower-density terminal radar control facilities. Delivery of this system will begin in mid-1975.

In addition, a variation of the ARTS III system was purchased for installation at the Anchorage, Alaska, ARTCC. This system which will use long-range radar inputs and en route plan view displays, will provide the area now served by the Fairbanks, Alaska, ARTCC, which is scheduled to close, with remote radar service. Delivery of the new system was made in late 1974.

#### *Upgraded Third Generation ATC System*

In addition to improving the performance and reliability of the present ATC system, FAA is working toward an upgraded third generation ATC system capable of handling the ATC requirements of the 1980's and beyond. Significant calendar year developments in this effort follow.

*Aeronautical Satellite (AEROSAT) Program.*—On May 9, 1974, the United States signed a memorandum of understanding—signed later by Canada and the European Space Research Organization (ESRO), representing nine European nations—establishing a joint Aeronautical Satellite (AEROSAT) program. The joint program will provide two satellites in geostationary orbit over the Atlantic Ocean to be used for experimentation and evaluation of improved oceanic air traffic control and communication systems characterized by high quality voice and data transmission as well as dependent and independent surveillance. The successful demonstration of a cost-effective oceanic air traffic control system based on satellites could eventually lead to the international implementation of such a system to replace the current high frequency radio circuits which suffer from serious propagation and operating deficiencies. In September 1974, the Communications Satellite Corp. (COMSAT) was selected to build and operate the satellite segment of the AEROSAT system.

*Discrete Address Beacon (DABS).*—This improved ATC beacon system is intended to allow ground equipment to uniquely interrogate specific aircraft of interest. At the same time, it could significantly reduce electronic interference in the beacon environment and provide an integral data link that can be used with a ground-based anti-collision systems called IPC. During the year, the technical feasibility of DABS was demonstrated and verified using an experimental facility at Hanscom Field, Massachusetts. With these results in hand, FAA expects to contract for three engineering-model ground sensors and approximately 30 airborne transponders in June 1975.

*Intermittent Positive Control (IPC).*—This technique, initially developed by the DOT Air Traffic Control Advisory Committee, would provide an intermittent form of ground-based air traffic control advisory and separation service to aircraft flying under visual flight rules (VFR). IPC, which would operate in conjunction with the Discrete Address Beacon System (DABS), would intervene whenever a VFR aircraft was on a collision course with another VFR or IFR aircraft. In 1974, FAA generated a plan for experimenting with the development of IPC service. The plan, which sets forth an effort in two phases, calls for the use of the DABS Experimental Facility for the initial testing phase and for the final testing phase in a multisite ATC environment. Phase I is scheduled for completion by April 1976; Phase II, by November 1977.

*Other Developments.*—In addition to the foregoing, FAA—

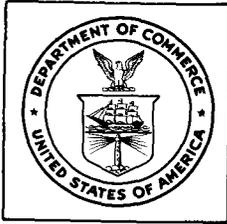
- Began testing the anti-mid-air collision capability of Synchro-DABS. This equipment used

in conjunction with the DABS/IPC system, could provide aircraft with an on-board capability for collision detection and warning at a minimum added cost. Aircraft equipped with Synchro-DABS would be able to detect and avoid all aircraft carrying a DABS transponder, even if DABS ground-system coverage was unavailable. Synchro-DABS experimental equipment was built by the Transportation System Center. Testing began at the Naval Weapons Center, China Lake, California, in late 1974.

- Designed and made available for installation on air traffic control radar beacon systems (ATCRBS) a field retrofit package of a National Facilities Experimental Center (NAFEC) Dipole Feed antenna. The retrofit package allows beacon interrogation to be transmitted and transponder replies received via the primary radar antenna. The significantly improved radiation pattern permits better target detection in cluttered environments, and reduces target fading due to vertical lobing. ATCRBS's at 56 en route sites had been provided with this modification by the end of the reporting period.
- Developed a field modification kit to improve the reliability and performance of the agency's Airport Surface Detection Equipment (ASDE II) radars. All the ASDE's were to be modified with the aid of the kit to improve their performance.
- Developed and installed at the John F. Kennedy International Airport a new BRITE display for use with ASDE's. The display made possible better viewing of targets, even under the brightest lighting.
- Incorporated the Service C teletypewriter weather system, the only remaining unautomated weather network, into the Weather Message Switching Center (WMSC). This action completed the automation of the FAA's three major weather network—Services A, C, and O.
- Reduced the channel spacing of its VHF/UHF nav aids by half, thereby doubling the number of channels available. FAA will continue assign-

ing new facilities on 100 kHz spacing unless frequency congestion necessitates use of a 50 kHz assignment. No existing facility channel assignments will be changed before January 1976, which will minimize inconvenience to users with radio equipment incapable of receiving the split channel frequencies.

- Contracted for the installation of an inertial navigation system in its C-135 jet. The object, as announced in February 1974, was to demonstrate and test a satellite-supported oceanic ATC communications and surveillance system. The satellite to be used in the experiment was the NASA Applications Technology Satellite 6, an experimental unmanned spacecraft designed for the conduct of meteorological, communication, scientific, and technological experiments.
- Completed plans for conducting at the Kansas City ARTCC an operational evaluation of automated conflict alert for the en route system. The conflict alert software would operate initially for air traffic at high altitudes (24,000 feet and above). The computer would detect potential conflicts about two minutes in advance and signal the controller by flashing the alphanumeric data blocks of the aircraft involved directly on to the controller's radarscope. An additional display, identifying the aircraft, would also appear on one side of the scope, thereby further facilitating controller analysis of the situation.
- Conducted cockpit display tests at NAFEC for Data Link, a communication system designed to reduce the need for live voice messages by substituting in their place message displays that would be read by the pilot in the cockpit. The tests were conducted in NAFEC's cockpit simulator, and the messages—ATC and weather advisories—were displayed in the form of paper printouts and alphanumeric readout devices.
- Began work to define a system for integrating weather data into the National Airspace System. The objective was the automatic transmission and display of weather data at appropriate ATC facilities.

**V**

# Department of Commerce

## Introduction

Department of Commerce agencies that actively utilize or contribute to aeronautics and space activities in carrying out their missions are 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 require programs to assure that the environment and its resources are wisely used; to develop and operate systems to monitor and predict environmental conditions; to explore the feasibility of beneficial environmental modification; to more rationally use and conserve our coastal zone areas; to strengthen and advance the Nation's science and technology and to facilitate its 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 have been or are being accomplished by establishing and maintaining an operational satellite system; by continuing to implement effective marine resources monitoring, assessment, and prediction programs; by continuing to monitor our marine environment through improved and continued use of sensors installed on ships, aircraft, and satellites; by improving our weather observations and forecasts through the establishment of automated observation stations, installation of improved radar systems, and continued atmospheric research programs such as the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE); by conducting research in such areas as lightning suppression, hurricane and precipitation control, and instrumentation development; by improving data collection, processing, and dissemination techniques; by providing basic measurement and calibration methods for operating technical systems and engineering data needed in the design and construction of sophisti-

cated space and aeronautics equipment; by installing, testing, and evaluating shipboard satellite equipment; by conducting electromagnetic wave propagation studies for the improvement of space communications and collision avoidance systems; and applying satellite imagery to demographic studies.

## Use of Satellites in Environmental Monitoring and Prediction

### *Environmental Satellite Operations*

At the beginning of 1974, the National Environmental Satellite Service (NESS) of the National Oceanic and Atmospheric Administration (NOAA) was operating three polar-orbiting satellites: ESSA 8 of the older TIROS Operational Satellite (TOS) series and NOAA 2 and NOAA 3 of the Improved TOS (ITOS) series. NOAA 3 was used as the primary global data-gathering satellite during most of 1974. However, from mid-July through mid-October NOAA 2 was returned to primary duty. Favorable spacecraft temperatures made it possible to use the NOAA 2 Vertical Temperature Profile Radiometer (VTPR) for that period and thus to reserve the NOAA 3 instrument for future use. ITOS G was successfully launched on November 15, 1974, and named NOAA 4. Following the NASA post-launch systems checkout, NOAA 4 became the primary operational satellite on December 4, and NOAA 3 will serve as its "in-orbit" backup. NOAA 4 has an instrument complement identical to that of NOAA 3, except that the VTPR on NOAA 4 has been modified by the addition of baffles to prevent an off field-of-view light leak that was causing some contamination in data acquired by the NOAA 2 and NOAA 3 instruments.

On May 17, 1974, NASA launched the Synchronous Meteorological Satellite, SMS 1, the prototype spacecraft for the Geostationary Operational Environmental Satellite (GOES) system. This satellite is equipped with a Visible and Infrared Spin-Scan Radiometer (VISSR) for earth viewing, a Space Environment Monitor (SEM) for monitoring ener-

getic particles and geomagnetism, a Data Collection System (DCS) for gathering environmental data from a variety of remote earth platforms, and a Weather Facsimile (WEFAX) broadcast system to relay processed satellite and conventional weather data to a variety of national and international users equipped with Automatic Picture Transmission (APT) receivers. SMS 1 was placed in geostationary orbit at 45° West longitude, 35,903 kilometers above the equator. Its primary mission from June 25 through September 23 was to support the GATE. Between September 23 and November 15, the spacecraft was moved to its permanent operating station near 75° West longitude. At its permanent location, the SMS/GOES VISSR provides near-continuous viewing of a circular area extending from 70°N to 70°S and from 5°W to 145°W. Full disc pictures are available at 30-minute intervals from the two VISSR sensors. The visible sensor provides daytime viewing with a resolution of one kilometer, and the infrared sensor provides both day and night viewing with a resolution of eight kilometers. The SEM monitors solar X-ray flux, solar proton flux, and variations in the Earth's magnetic field. The DCS permits the collection of environmental data from automatic sensors in remote areas. Among the platforms to be monitored by the DCS are river stage gauges, rainfall gauges, seismic and tsunami meters, automatic weather stations, buoys, and ships at sea. The spacecraft can accommodate data from 10,000 or more individual observing platforms every six hours.

Evolving requirements and improved technology have led to the start of planning and development of a new operational polar-orbiting satellite series. TIROS N, the NASA prototype and subsequent operational spacecraft, will carry advanced versions of instruments now on the ITOS spacecraft and have a remote platform location and data collection capability. This satellite system will improve environmental predictions by providing atmospheric observations of increased accuracy and coverage. TIROS N is scheduled for launch sometime in 1978.

#### *Vertical Temperature and Wind Profiles*

VTPR soundings are used routinely in the numerical weather prediction program of the National Meteorological Center (NMC). Approximately 1,000 vertical profiles of atmospheric temperature are derived daily from VTPR radiance data by NESS and used by NMC in their upper-air analyses over the World's oceans.

A data processing system that combines Nimbus 5 experimental environmental satellite observations from the Infrared Temperature Profile Radiometer, the Temperature Humidity Infrared Radiometer, the Selective Chopper Radiometer, and the Nimbus E

Microwave Spectrometer has been successfully developed. This system obtains the best possible set of sounding radiances which are then converted into temperature profiles from the surface to 50 kilometers and moisture profiles to 15 kilometers. An analysis of temperatures obtained with this system shows that these profiles are superior to those obtained from any of the individual sounders.

SMS 1 images are being used to derive wind vectors from cloud motions. It now is possible to obtain winds both day and night because of the availability of infrared images. The infrared data also are used to determine cloud top temperatures. A new system, called the Man-Machine Interactive Processing System (MMIPS), has been developed for this purpose. MMIPS is a computer system used to display satellite imagery in static and animated forms. Using a relatively simple program, which incorporates existing theories of infrared radiation, the system computes the temperature of the observed cloud. From these temperatures it is possible to determine the cloud heights and thus assign wind vectors to their proper level in the atmosphere. This new procedure became operational August 19, 1974. NMC also uses these data as direct input to their numerical weather forecasts and these data are transmitted, together with VTPR data, to other nations via the Global Telecommunications System. These wind vector data also are an important part of the data base for research studies of atmospheric circulation.

#### *Environmental Warning Services*

SMS 1 became the primary warning service platform upon reaching its permanent position near 75° West longitude. However, since SMS 1 WEFAX operates on S-band frequencies, both ATS 1 and ATS 3 satellites will continue to provide WEFAX service on VHF frequencies for users who have not converted to S-band receivers. Photographic images from the VISSR, either full disc or sectors of the disc, are distributed to the Satellite Field Services Stations (SFSS). Sectors of the full disc picture then are sent to 16 Weather Service Forecast Offices (WSFO), the first increment of a planned network of about 50 WSFO/GOES facilities. The WSFO's receiving these data use them routinely to improve short-term forecast and advisory service to the public, aviation and shipping.

Very High Resolution Radiometer (VHRR) Sectorizer Display Systems, which provide visible and infrared images with one kilometer resolution, have been installed at the Gilmore Creek, Alaska, and Wallops, Virginia, Command and Data Acquisition Stations and at the San Francisco SFSS. WSFO's in Alaska are equipped to receive and display the VHRR sectors from Gilmore Creek, and selected WSFO's in

the Western United States can receive the VHRR sectors from San Francisco. These observations help provide better environmental forecast and warning services to public and commercial users. The Wallops data are relayed to Suitland for processing.

During July and August 1974, the National Weather Service (NWS) and NESS conducted a short-range forecasting experiment on northern Chesapeake Bay to determine if satellite data could be used to provide detailed and timely weather warning and forecast services to the boating public. SMS 1 high resolution images were correlated with special reports of wind conditions from many private boaters and marinas in the Upper Bay to better understand how the local wind fields were inferred from the cloud images. In addition, radar reports were obtained to correlate precipitation with cloud images. Experiments were conducted with various ways of wording the weather summaries and forecasts and displaying the data. The information was carried by the NWS VHF continuous weather broadcast from Baltimore.

#### *Determining Ocean Conditions*

NOAA 2 and 3 satellite images continued in use for developing improved methods of mapping oceanographic parameters. An experimental Gulf Stream area thermal boundaries chart developed by NESS and based on interpretation of VHRR infrared (IR) images is slated to become operational about the beginning of 1975. NWS will use this product to initiate a Gulf Stream information service to the public. A cloud-free sequence of VHRR IR images revealed a large cold eddy along the edge of the Sargasso Sea and Gulf Stream in March 1974. Use of satellite data enabled a research vessel to proceed directly to the eddy and implant a special buoy to carry out research work. Satellite tracking of the buoy indicated a slow counterclockwise circulation in the eddy. Information on the Gulf Stream is of special interest to the shipping and fishing industries. Ships using East Coast routes try to stay in the Gulf Stream northbound and avoid it southbound to minimize transit times and save fuel. Commercial fishermen use water mass boundary data to increase the efficiency of their operations. The nutrients on which fish feed accumulate on boundaries between shelf, slope, and Gulf Stream waters, and large concentrations of fish are usually found in such areas.

NESS continues to prepare experimental ice charts of Alaskan waters based on NOAA's high resolution satellite images and disseminates them over NWS facsimile circuits. To plan sea transport in these areas, marine interests need to know of the existence and location of ice along sea routes, and whether the ice is forming or breaking up. Infrared sensing systems on the NOAA satellites permit the observation of

major ice features throughout the year. Significant ice boundaries, openings, and thin areas can be detected in the visible images, and improved estimates can be made of thickness and the physical state of the ice from surface temperature information contained in the infrared images. Satellite observations permit more efficient ice surveillance, which results in economic savings and increased safety to shipping operations.

#### *Determining Lake Conditions*

The NOAA Great Lakes Environmental Research Laboratory (GLERL) is using both NOAA 2 and ERTS 1 images in its studies. Snow extent maps, prepared from NOAA 2 VHRR images for the southern Ontario basin, have been compared with aircraft-observed gamma ray data as a part of the International Field Year of the Great Lakes (IFYGL) analysis program. This information is useful in determining how much snow will melt and affect lake levels.

Determinations of surface water temperatures of the Great Lakes have been made using NOAA 2 data. These measurements show close agreement with similar data obtained from aircraft and ships. Upwelling of water along the shorelines of the Lakes also has been observed in both NOAA 2 and ERTS 1 satellite data. The ability to detect upwelling is important because it can cause rapid changes in surface water temperatures and mixing conditions. This action promotes algae growth which may clog municipal water intakes.

Both VHRR and ERTS data have been used to determine ice formation, growth, movement, and breakup in the Lakes as a part of the study to improve the ice forecasts for shipping and for the program to extend the navigation season on the Great Lakes. This is part of a GLERL program to study the geographical extent and physical properties of Lake ice.

Experimental charts of Great Lakes ice conditions, based on interpretation of VHRR images, were developed by NESS and disseminated twice weekly via the NWS facsimile network. This information, together with other efforts, has resulted in a favorable economic impact on the shipping industry permitting extension of the Great Lakes shipping season by at least 30 days annually.

#### *Determining Hydrological Conditions*

Quantitative estimates of snow cover derived from VHRR data were extended to include the Willamette River basin in the Pacific Northwest, increasing to four the number of river basins covered during the past year. The others are the Genesee River, the Red River of the North, and the American River. These estimates were sent to River Forecast Centers for use in river and flood potential forecasting. River and

rainfall gauges, equipped with radio transceivers to permit interrogation and data collection via the GOES DCS, are being installed at 44 remote locations in flood prone, Western river basins. Rainfall and river stage information from these remote observing sites will provide data to River Forecast Centers for early assessment of storm rainfall, an important factor in improving river forecasting and flood warning services, and in estimating potential water supplies.

It has been established that VHRR IR data can be used to identify areas of flooding from large rivers. In the case of Mississippi River floods, a comparison of the flood extent using both NOAA 2 and ERTS 1 data showed the NOAA 2 measurements differed from ERTS measurements by only 13 percent. This is surprisingly good considering that the resolution of the VHRR images is 1,000 meters compared to 80 meters for ERTS.

### ***Pollution Monitoring***

Further analysis results based on the combined satellite, aircraft, and surface data collected in the New York Bight in April 1973 are now available. The ERTS 1 Multispectral Scanner data, together with aircraft remote sensing and shipboard measurements, have provided information which can be used to identify and to map major water masses and acid dumping sites within the New York Bight. The optical properties of the water masses in the visible spectrum result in spectral signatures sufficiently characteristic to form a basis for classification and mapping. Evidence also has been found that under sunglint conditions large oil slicks in the ocean can be detected by means of the multispectral imagery from the ERTS.

### ***Environmental Monitoring Using Data Buoys***

The NOAA Data Buoy Office (NDBO) is developing and testing environmental data buoy systems and components to measure oceanic and atmospheric parameters. Buoy data are telemetered via earth satellites and shore stations. The basic objective is the development of several types of instrumented, unattended buoys, either moored or drifting, on the high seas or in the coastal zone, to collect and relay marine environmental data for operational and research use.

The NDBO developed and tested six prototype Buoy Transmit Terminals (BTT) and subsequently contracted for 75 production BTT units. These terminals are intended for use with the Nimbus F satellite data collection and location system. Five Data Collection Platform Radio Sets (DCPRS), for use with the GOES satellite system, were acquired for test and evaluation. Tests linking up several units with the GOES satellite system were successful.

### ***Fisheries***

The Inter-American Tropical Tuna Commission used NOAA 2 and 3 remotely sensed infrared data to reveal the relationships of ocean thermal fronts to biological features, particularly to tuna fishing locations.

Final results of the Skylab Gamefish Experiment, conducted by the National Marine Fisheries Service (NMFS) in the Northeastern Gulf of Mexico, demonstrated that satellite remote sensing may have potential for increasing the probability of gamefishing success. Using data acquired by private and professional sportsfishermen and NASA and NMFS elements, it was possible to identify white marlin fishing areas from significant oceanographic parameters. By correlating fish catch with oceanographic data, predictive models were developed to identify areas of high productive capacity thus offering potential for significantly reducing the fisherman's search time. The four environmental parameters used in the models were chlorophyll-a, sea-surface temperature, water turbidity, and salinity which were determined from data obtained by aircraft remote sensors and shipboard oceanographic instrumentation. To date, excessive cloud cover has prevented meaningful use of Skylab data acquired during the study.

Other continuing NMFS efforts include the application of aircraft remote sensing techniques to make population estimates of Atlantic bluefin tuna resources and to assess the populations of walrus, bowhead whales, grey whales, and northern fur seals in the Beaufort Sea, the Bering Sea, and the Bering Strait.

### ***Meteorological Data***

The NOAA National Severe Storms Laboratory (NSSL) is participating in a joint program with NASA and some universities on the establishment of ground truth for satellites in the Atmospheric Variability Experiment. This experiment is designed to test procedures for assessing the accuracy of satellite-derived meteorological data.

### **Other Satellite and Space Applications**

#### ***Weather Modifications***

The NOAA Atmospheric Physics and Chemistry Laboratory continued its experimental work in lightning suppression. For the first time, thunderstorms were seeded with aluminum coated chaff from two aircraft flying at two different levels. The effect of the seeding was an immediate release on the chaff of a corona discharge which was measured outside the storm by a special antenna on one of the aircraft. This work has special application in the reduction of lightning induced forest fires and the suppression of

lightning at the Kennedy Space Center during spacecraft launches.

The NOAA National Hurricane Research Laboratory (NHRL) made extensive use of visual and infrared satellite information in evaluating results of hurricane modification experiments and in studying the climatology of Pacific typhoons. In addition, the NHRL is conducting, on behalf of the NWS, NESS and the USAF Air Weather Service (AWS), a study to determine the accuracy of locations and intensities of tropical cyclones derived from satellite pictures. This study is to aid in decisions about the extent to which satellites can replace aircraft reconnaissance of tropical cyclones.

### *International Cooperation*

GATE, the largest and most complex international weather experiment in history, was conducted from June 15 to September 23, 1974. Dakar, Senegal, was the field headquarters for this experiment. The experimental area was located off the West African coast between 20° North and 10° South latitude and 0° and 50° West longitude. Some 4,000 people from 72 nations participated, and 40 ships, 13 instrumented aircraft, 6 satellite systems, and other scientific equipment were used during this 100-day research program. Environmental satellites used were the United States' NOAA 2 and 3, ATS 3, SMS 1, Nimbus 5, and the Defense Meteorological Satellite and the USSR's Meteor 18. GATE was sponsored by the World Meteorological Organization (WMO) and the International Council of Scientific Unions. The United States effort was coordinated by NOAA. The vast amount of data assembled will be used to improve weather forecasts and to expand man's understanding of the mechanisms which produce climate changes such as the drought now affecting Africa's Sahelian belt.

October 1, 1974, marked the 10th anniversary of environmental satellite data exchange on the direct circuit connecting Moscow and Washington. These data included visible and infrared photographs from NOAA 2 and 3 and the USSR Meteor 13 through 18. Meteor 16, 17, and 18 were launched between March and July 1974. Soviet satellites now are providing experimental APT service over eastern Europe and Soviet territories.

Under the WMO Voluntary Assistance Program, the NWS installed APT ground stations in 19 countries and ordered stations for installation in 6 others.

### *Demographic Studies*

The Bureau of the Census, using Agency for International Development funds, is studying the applicability of ERTS 1 images to demographic studies and other census operations in three developing coun-

tries. The countries involved, Afghanistan, Kenya and Bolivia, were deliberately selected for their variety of physical and cultural environments, and their disparate histories of census taking and statistical development. The willingness and ability of their governments to participate in such a project also was a determining factor.

ERTS images are being used to develop new mapping processes, to plan the allocation of enumeration resources, to evaluate census results, to monitor the extent of urban development, and to form a basis for land use classification. Benefits to be derived from this effort are the production of better data on population numbers, trends, and locations and on urban growth in the three countries.

The Bureau of the Census also is investigating the applicability of satellite images to domestic census programs. The major objective is to find a means of detecting and measuring the peripheral growth of the larger cities in the United States. The Bureau is responsible for designating urbanized areas for measurement after each decennial census. These measurements are for use in various Federal funding formulas and grant applications such as those used in the Revenue Sharing legislation. The Bureau has completed imagery-derived urbanized area definitions for the first group of a representative selection of cities. The results have been examined in detail and comparisons have been made with urbanized area measurements developed by conventional decennial census procedures and by Earth image procedures to determine their relationship in terms of population, the administrative status of component parts, land area, and geographic configuration; time and resources required for both methods of delineation also have been compared.

### *Navigation/Communications Satellite*

The Maritime Administration is continuing its program to apply satellite technology to ship navigation and radio-communication problems. Tests were conducted with merchant ships using NASA's ATS 5 and ATS 6 satellite communications to evaluate equipment, techniques, and various frequency bands. The objective is to extend to shipping the communication services now provided between locations ashore and to make available continuous, accurate ship location information to both ships and shore stations. Such capabilities will permit the use of improved management techniques such as automation, more efficient operations, and better control of ship movements.

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

The National Ocean Survey (NOS) plans to determine geoid and gravity conditions over the Earth's

ocean regions, utilizing radar altimeter measurements from the GEOS C satellite. Pre-launch tests are underway using a simulated set of altimetry measurements and a mathematical model to determine station positions and the Earth's gravitational field. This model is based on Doppler data, surface gravity anomalies, and geometrically obtained directions and distances.

NOS surveyors are remeasuring the United States with almost pinpoint accuracy. Using a system known as Doppler geodesy, the National Geodetic Survey is making measurements at about 130 points in all 50 states at points approximately 150 miles apart. So far, NOS has determined the exact position of 35 stations in the continental United States and 6 stations in Alaska. These determinations, based on Doppler measurements using geodetic receivers (Geoceiver) that receive signals from the Navy Transit Satellites, measure the Doppler shift and precise time of satellite signals with signals generated by the Geoceiver. The survey will result in the more accurate location of survey markers, providing an extremely accurate base for topographic mapping and navigational charting and for improving techniques for earthquake prediction.

#### *Satellite Communications*

The Office of Telecommunications (OT) has developed a model to predict the interference and noise that will be detected by the ATS 6 satellite during an experiment to monitor interference from terrestrial communication systems operating near 6 GHz. This model was used by NASA to design the experiment and to select areas on the Earth's surface to be monitored from the satellite. OT developed requirements for multiple, narrow beam satellite transmit and receive antenna patterns for the U. S. Postal Service proposed Electronic Mail System. In developing these requirements, it was necessary to consider geographical coverage and electronic isolation of various antenna patterns in terms of different geostationary orbital positions and receive/transmit frequencies.

#### *Lunar Ranging*

The National Bureau of Standards (NBS) developed the major components of a low-cost telescope of special design and high light gathering power for use in lunar ranging. The system has been assembled and preliminary tests performed. Recent calculations have led to an improved knowledge of the lunar mass distribution and location of reflectors with respect to the lunar center of mass

### **Space Support Activities**

#### *Skylab and ERTS Support*

NOAA support to the Skylab and ERTS programs included NWS forecasts of cloud cover for use in

scheduling Earth-sensing experiments from Skylab, supporting aircraft, and ERTS 1. Forecasts also were made for the landing and recovery of the final Skylab flight.

The Space Environment Laboratory (SEL) continued its support to the Skylab Apollo Telescope Mount (ATM) experiment. The Space Environment Services Center provided solar activity forecasts to the ATM principal investigators and to the mission flight controller during the manned and unmanned phases of Skylab.

#### *Space Environment Services*

A significant improvement was made in the quality of the space environment services provided by SEL following the launch of the SMS 1 satellite in May. The SEL receives solar X-ray, solar proton, and magnetic data at Boulder, Colorado, directly from the SMS 1 satellite. These data are used by the Space Environment Services Center forecasters and also are relayed to the USAF AWS for use in their operations. The SMS 1 satellite provided data that were critical for prompt and accurate evaluation of a series of major solar flares in July. A large geomagnetic storm, following the larger flares in this series, produced disturbances in long-line telephone circuits, electric power distribution systems, and the usual disruptions in ionospheric radio communications.

#### *Cryogenic Technology*

NBS is providing NASA with basic data and engineering information on very low temperature (cryogenic) fluids and systems for use in spacecraft application. Measurements of the compressibility of parahydrogen have been extended to higher pressures and temperatures. Work on cryogenic insulation and heat transfer in liquid oxygen systems also is being performed. An experimental radio frequency mass measuring facility has been completed for use in measuring fuel levels in the zero gravity of space. This effort is in direct support of the cryogenic life support and propellant systems of the Space Shuttle.

#### *Analysis of Apollo Lunar Samples*

NBS is determining the chemical and isotopic composition of lunar samples collected on the various Apollo missions. Recent work indicated that lunar soils show an isotopic abundance of potassium distinct from that of lunar rocks. Studies now in progress are analyzing additional lunar samples to determine if this condition is common to all parts of the lunar surface and to determine what additional data may be required to further understand this phenomenon.

#### *Space Shuttle Experiments*

NBS is assisting NASA in plans to utilize the Space Shuttle as an orbital workshop for materials

science and manufacturing in a zero gravity, vacuum environment. Projects involve research and development in crystal growth, purification of materials, physical processes in fluids, and composite materials preparation; these projects are expected to yield new and innovative materials processing methods of wide commercial importance.

#### ***Measurements and Calibrations***

NBS studies of Cassiopeia A, an astronomical electromagnetic source, now are providing a convenient means of routinely calibrating satellite communications systems antennas. NBS continues to provide new and improved radiometric standards and techniques for use in astrophysical observations of the sun and stars. Program accomplishments include use of the NASA Orbiting Astronomical Observatory (OAO 3) satellite for discovery of the first stellar corona and for spectroscopic observation of solar winds.

#### ***Time Services***

Precision space navigation demands accurate and dependable time-signal information. NBS provides very accurate time and frequency signals by radio broadcast. NBS stations broadcasted ATM observation program information and NOAA/NASA experiment plans for the Skylab Mission. Experiments using the NASA ATS 3 satellite for disseminating time signals have verified the advantages of a satellite system to provide better than ten microsecond accuracy using simple low-cost techniques. This past year, NBS began broadcasting time-of-day information through NASA's recently launched SMS 1 satellite. The 468 MHz signal was receivable on relatively inexpensive equipment throughout most of North and South America and parts of Europe and Africa. The signal accuracy and wide availability will find many applications for communications and for monitoring seismic events at widely separated remote sites.

### **Atmospheric and Space Physics**

#### ***Astrophysics***

The Joint Institute for Laboratory Astrophysics, a cooperative effort of the NBS and the University of Colorado for the study of highly ionized gases, has developed several models to explain chromospheric networks, supergranule cells, and spots in the solar chromosphere. Experiments aboard OAO 3 are producing the first far ultraviolet data of cool stars with sufficient resolution to accurately model cool stellar atmospheres.

#### ***Interplanetary Physics***

SEL has developed a new theoretical three-dimensional description of the solar wind, including

non-radial flow from the sun, which produced surprising results in comparison with standard two-dimensional solar wind models. Not only do the results explain the Pioneer 10 and 11 solar wind data at the planetary orbit distance of Jupiter better than older models, but they also modify predictions of astrophysical models of stellar winds which are based on solar wind modeling.

#### ***Magnetospheric Physics***

The distribution of electrons and protons in the Earth's radiation belts, and their variation with time, are controlled by interactions between the particles and low frequency electromagnetic (radio) and electrostatic waves. Recent theoretical work on these interaction mechanisms by SEL has been able to account for the steady state character of the Earth's radiation zones and has provided the first good explanation of the slot region between the inner and outer Van Allen radiation belts.

#### ***Ionospheric Physics***

A major mystery of the northern lights has been the excessive number of low energy electrons which appear to enter the atmosphere, at times in numbers too large to be explained as coming from any source in outer space. A recent theory by SEL postulates that these apparently excess electrons have been back-scattered from the Earth's atmosphere below and then reflected downwards again by electric fields above the measuring instruments, to appear for the second time as if originating from outer space.

The NOAA Aeronomy Laboratory is currently examining radar echoes from E-region irregularities in the auroral ionosphere that are closely related to the auroral electrojet current system. By obtaining data on the location, intensity, and drift direction of the irregularities it will be possible to monitor the location, intensity, and direction of the electrojet. Since data from a single radar cover a much greater range (approximately 1000 km) than a ground-based magnetometer, the information can eventually be used to supplement, or in some cases replace the magnetometer data.

#### ***Atmospheric Photochemistry***

NBS is providing data essential to determining the photochemical process behavior of pollutants in the Earth's atmosphere. A new technique involving modulated laser excitation of molecular vibrational levels is being applied to detection and measurement of various atmospheric pollutants. Studies have yielded valuable data on the reactions of ozone with nitric oxide, sulfur monoxide and molecular oxygen for use by the Department of Transportation (DOT) to assess the effect of supersonic aircraft effluents on the stratospheric ozone layer.

The NOAA Air Resources Laboratories are continuing efforts to measure nitric oxide from balloon and aircraft platforms in the atmosphere and to develop instruments to measure nitrogen dioxide.

NBS measurements of kinetic and photochemical processes including dissociation rates, ionization potentials, and collisional excitation rates of atmospheric species are important to the understanding of planetary atmospheres. Photochemistry studies of the reactivity of methane and ammonia have provided a better understanding of the atmospheres of Jupiter and Saturn. Measurements of the radiation extinction coefficients of nitrogen dioxide in the ultraviolet region as a function of temperature are being used in assessing the impact of high altitude aircraft on the Earth's atmosphere and to determine atmospheric transmissivity of solar energy.

The Aeronomy Laboratory, using night airglow emission measurements, finds that major fluctuations in atmospheric temperature in the 80 to 100 kilometer region are evidence of large scale compressional "gravity" waves propagated either from the troposphere or from auroral latitudes.

## **Aeronautical Programs**

### *Safety Services for Aeronautics*

The NOAA Wave Propagation Laboratory installed and operated an acoustic Doppler wind measuring system at Stapleton International Airport in Denver, Colorado. The system array covered the entire height range from 30 to 500 meters using a bistatic or angular scattering approach. Comparisons of acoustic wind profiles with those obtained by radiosondes showed good agreement. The experiment demonstrated that acoustic sounders can operate successfully in an airport noise environment, and that it should be possible to measure wind profiles by this remote sensor system to a height of 700 meters, with accuracies that meet airport operational requirements.

NSSL continued its experimental work with thunderstorms and tornadoes in an effort to more accurately predict the development, intensity, and location of these hazards to aircraft operations. An experiment was conducted from April to June 1974 utilizing dual Doppler and conventional weather radars, and experimental electronic tornado detectors, radiosondes, instrumented aircraft, and ground cameras. Researchers have been able to identify characteristic Doppler radar signatures of tornado producing thunderstorms. In the two tornadic storms observed, the parent circulation above the tornadoes extend to at least nine kilometers, which indicates that tornadoes are not just low level, surface phenomena. The ex-

periment also included the sowing of metallized chaff in clear air to determine a three-dimensional wind field by Doppler radar measurements. This work may contribute much toward improving warning to aviation interests of mechanical and clear air turbulence.

Doppler radar has played a vital role in identifying various species of birds in flight. The size, shape, wing span, frequency of wingbeat, and body motion combine to form Doppler fingerprints of specific birds. So far Aeronomy Laboratory scientists, using this technique, can distinguish between ducks and geese. These echoes can be plotted graphically or broadcast through a loudspeaker. The results of this work may help air traffic controllers prevent dangerous collisions between birds and aircraft.

The OT continued work on a model to predict interference among collision avoidance, radar altimeter, navigation and aeronautical/maritime satellite systems. The model includes the effects of rain attenuation and ducting on transmissions in the frequency spectrum from 100 MHz to 20 GHz. It is designed to meet requirements for maximum frequency utilization in air-to-air, air-to-satellite and satellite-to-earth systems.

### *Aeronautical Charts*

NOS published a flight case size planning chart in response to a Federal Aviation Administration (FAA) requirement. This chart is designed for preflight and enroute planning for flights under Visual Flight Rules (VFR). It contains basically the same information as the VFR/IFR Wall Size Planning Chart with the addition of lists of selected Flight Service Stations and Weather Service Offices located at airport sites, a tabulation of Special Use Airspace, a mileage table listing distances, and a city/aerodrome location index.

The first edition of the Alaska Terminal Publication (ATP), a joint civil/military aviation publication, was issued. The publication, to be produced every 56 days, includes Instrument Approach Procedures (IAP), Standard Instrument Departures (SID), Standard Terminal Arrival Routes (STAR), Taxi Charts, and other supplemental data. The Alaska SID and the Alaska IAP Charts were discontinued as separate publications. In May 1974, the Alaska Enroute Charts and the Alaska Chart Supplement revision cycle was changed from 28 days to 56 days.

A study of the application of ERTS images showed that hydrographic features could be extracted efficiently and effectively for use as update source data in the maintenance of aeronautical charts. This study is continuing with investigations of other applications to the aeronautical chart product and production process.

## **Environmental Data Programs**

### ***Satellite Data Service***

The Environmental Data Service (EDS) and NESS have established a Satellite Data Services Branch at NESS Headquarters in Suitland, Md., to manage distribution of most environmental satellite data after operational utilization is completed. This new unit also provides Earth Resources Technology Satellite data to marine and meteorological users.

### ***Ground-Based and Skylab Solar Data***

The World Data Center A for Solar-Terrestrial Physics collected reports on the times and the nature of observations of the sun made by ground-based worldwide solar observatories that coincide with the Skylab solar observations of May 28, 1973 through February 8, 1974. This information has been combined into a *Catalog of Observation Times of Ground-Based Skylab Coordinated Solar Observing Programs*; the catalog will permit investigators and others to identify the collateral observations available at the times interesting phenomena were noted by Skylab.

### ***Solar and Earth Space Data***

SEM data from the SMS 1 satellite include changes in the Earth's magnetic field and the flux of protons, electrons, alpha particles, and solar X-rays on standard monitoring time scales. These data, available through the National Geophysical and Solar Terrestrial Data Center (NGSDC), serve as an important space environment monitoring data base for space

science studies and for solar-terrestrial research and applications.

NGSDC now has derived the auroral electrojet magnetic activity quantitative indices for 1966 through 1972 and is making the data available on magnetic tapes. Summaries have been published by World Data Center A. The indices, which chart the onset time and development of magnetic substorms, are used to study communication satellite failures, telecommunications problems during magnetic disturbances, and power failures. Their use for modeling the complex interactions between the solar wind and the Earth's magnetosphere is being compared with the use of interplanetary field data for the same purpose.

### ***International Sea-Surface Temperature Data***

The National Oceanographic Data Center and NESS have undertaken a joint, two-phase pilot study on the international exchange of sea-surface temperatures derived from satellite data. The purpose of the study is to better identify specific user needs for the satellite data and for data exchange and archiving. During Phase 1, sea-surface temperature data, derived from the NOAA 2 and 3 VHRR instruments, were made available to interested participants of the 1974 field season of the Cooperative Investigation of the Northern Part of the Eastern Central Atlantic (CINECA) in the form of unenhanced and enhanced IR images and in digital form. The data were used by the CINECA investigators in conjunction with oceanographic and fisheries data collected from research vessels and aircraft. The field test portion of the pilot study has been completed and the evaluation phase is now underway.



## Introduction

The Department of the Interior seeks to use the most cost effective operational systems available to inventory, develop, manage, and conserve these resources to the public benefit. The diversity of resources accounts for the breadth of interests of the department for information with which to make meaningful decisions. The needs of man for energy and power, food, water, mineral resources, recreational sites and activities, and a congenial environment must all be balanced. However, nature is dynamic and its changes, be they subtle, catastrophic, manmade, or natural must be monitored to provide continuing accurate, up-to-date information needed by the manager to make decisions and to see the effects of his decisions. The uses made of aircraft and spacecraft, and the data acquired from these platforms then contribute to these information needs.

## Space

### Operations

*Earth Resources Observation Systems.*—A primary objective of the Interior Department's Earth Resources Observation Systems (EROS) program is to develop remote-sensing techniques and products and encourage their incorporation into operational aspects of departmental activities. Major strides have been made in this effort during 1974.

The EROS Data Center, Sioux Falls, South Dakota, is in its third year of operation as the primary public sales outlet for spacecraft- and aircraft-acquired remote-sensing data. These data include NASA aircraft remote-sensing data, aerial mapping photography obtained by the U.S. Geological Survey (USGS), and satellite data from ERTS-1 and Skylab. Data sales to Federal agencies, State and local governments, universities, private industry, and the general public totaled \$885,000 in FY 1974 and are projected at \$1,750,000 for FY 1975.

The EROS Data Center also conducts formal

training courses and provides professional assistance, particularly in techniques for extraction of information from remote-sensing data, to users. Approximately 200 individual scientists visited the Data Center during the year to receive such assistance. EROS Applications Assistance Facilities are operated by the Data Center in Bay St. Louis, Mississippi, Denver, Colorado, Phoenix, Arizona, Menlo Park, California, and Reston, Virginia, to meet the local needs for remote-sensing technology transfer. At the Mississippi facility, for example, more than 830 requests for satellite and aircraft data were filled, more than 200 people attended 16 different remote-sensing training classes, and the staff completed uncontrolled ERTS mosaics of Mississippi and Louisiana.

The Alaska Power Administration is now using satellite imagery in their planning studies.

A Bureau of Indian Affairs project to assist Alaska Natives in their land selection program, used ERTS imagery as an interpretative base at a scale of 1:250,000 to depict vegetation, landforms, hydrology, and indications of mineralization. A township and range grid was added to the imagery to aid in the land selection.

*Natural Resources Information System.*—The Bureau of Indian Affairs is implementing the Natural Resources Information System (NRIS) that was developed for the resource-oriented bureaus in the Department of the Interior. The NRIS manipulates digitized graphics derived from satellite, aircraft, and ground data, with most of the interesting operations centered around "area" maps, i.e., maps that can be specified as a set of closed regions with a single attribute per region. Functions performed include scaling, translation, rectification to common base, extraction by area or attribute criteria, extraction by geographic limits (windowing), inquiry of a point's attribute, area calculations, and compositing (logical union) of two or more maps. The program is running on the Washington State University and Arizona State Highways computers for the benefit of tribes in those states.

*Use of Remote-Sensing Techniques for Planetary Exploration.*—USGS provided NASA with guidance on application of remote-sensing techniques to planetary exploration, support on mission planning including the Viking Lander, and post-mission analysis. Geologic analyses and mapping of lunar data from Apollo 15, 16, and 17 were completed. Analysis of the Mariner data and production of Mars maps continued. Mosaicking of images and mapping data from the Venus-Mercury fly-by is proceeding.

*Satellite Navigation Aids.*—Satellite navigation aids are being used in marine geology investigations and cooperative activities including the International Phase of Drilling cruise in the North Atlantic Ocean the the Institut Français du Pétrole research program on the Blake Plateau, Gulf of Alaska, and Beaufort Sea. It will become increasingly important as coastal and oceanographic studies are accelerated, especially in the assessment and the development of energy resources of the Outer Continental Shelf.

#### *Research on Application of Remote Sensing from Space*

*Geological Studies.*—The USGS utilizes data from manned and unmanned spacecraft to improve remote-sensing techniques as a supplement to conventional and airborne research methods. Objectives include: determination of variations of physical properties which can be used to discriminate materials or conditions, such as spectral reflectance or thermal inertia; evaluation of the broad view supplied by satellite imagery to analysis of geomorphic and tectonic relationships of regional or larger scope; identification and repetitive observation of features whose physical condition or detectibility vary with time, season, or circumstance by use of satellite imagery or by ground monitoring through relay by satellite telemetry.

Some significant results of investigations include: near-infrared reflectance anomalies associated with some young volcanic rocks of southwestern U.S., which are at least as mafic as andesites, have been observed in the multispectral data from Skylab. Thermal-inertia maps obtained from Nimbus satellite data have been used in conjunction with ERTS images to resolve ambiguous rock-type identification in the Arabian Peninsula. A theoretical model of the effects of volume scatterers on microwave emission has been used to explain the discrimination of older from new snow on Nimbus 5 (1.55 cm) images. Visual and photographic observations from Skylab 4 show that the primary eruption cloud of the Sakurazima volcano, Japan, did not penetrate the tropopause. Quality of the data from the Skylab multispectral photographic camera and especially the Earth Terrain Camera was adequate to map at 1:250,000-scale geologic terrain, geomorphology, and surface

geology and to use the results to make environmental geologic and engineering interpretations. Details less than 3 m in size of arroyos and gullies in Arizona were identifiable on S190B photographs. The ERTS Data Collection System (DCS) has demonstrated that a global volcano surveillance system is now technologically and economically possible and that DCS has excellent potential for near real time water management purposes.

Analysis of POGO satellite data has resulted in a global magnetic anomaly map. Verification of several distinct anomalies was obtained by examining individual satellite profiles of Project Magnet data. The utility of satellite magnetometry for geologic and geophysical mapping has been demonstrated. Computer processing of digital tapes (CCT's) of ERTS data has resulted in considerably improved imagery which can be enhanced or ratioed for specific geologic studies.

*Discovering Resources.*—Preliminary examination of space images in the Umiat and Yukon-Tanana Upland areas of Alaska reveals short and intermediate linear patterns which have a direct correlation with subsurface geology and/or geophysics and suggest concealed structures of possible potential for oil or gas accumulation. Northeast- and northwest-trending giant linears may have guided the localization of mineralized belts in Alaska; this hypothesis has been substantiated by the independent location of porphyry copper-molybdenum deposits at the intersection of northwest- and northeast-trending faults in an area predictable by the hypothesis, but not by the conventional localization of mineralization concept.

*Discovery of Active Faults.*—Field examination of faults on the Coastal Plain of eastern Maryland and Delaware, originally observed on ERTS-1 images, has revealed that some of these faults are active. This faulting is thought to be due in part to compaction of the Coastal Plain sediments, and as such probably would not cause anything more than minor earthquakes. However, the potential seismic activity is important in planning sites for nuclear powerplants which must be designed to withstand any anticipated ground movements.

*Control of Water Resources.*—Using a combination of satellite images and ground sensed data relayed by satellite, an ecological predictive model has been developed and used in Florida to enhance wood stork rookery formation in the Everglades National Park by properly regulating water levels. The wood stork is an endangered wildlife species.

SMS/GOES satellite, launched in May 1974, has the potential to provide more continuous radio relay of messages from data collection sites than ERTS, and testing has begun using six hydrologic platforms.

Data from ERTS, Skylab, and aircraft were used as testimony in a court case to identify and summarize important hydrologic features. Portrayal of the salient features on the imagery, acquired over the Green Swamp, Florida, resulted in an out-of-court settlement between the consortium of developers and the State of Florida.

In collaboration with NASA, NOAA, and U.S. Army Corps of Engineers, a series of related flood-applications analyses employing ERTS, NOAA 2 and aircraft data were compiled and published as a compendium by the American Water Resources Association.

*Mapping.*—The USGS has continued to examine cartographic applications of both ERTS-1 and Skylab images. A color mosaic of Florida and a monochromatic mosaic of Arizona were prepared for lithographic printing. The publication of satellite image maps has stimulated the development of new procedures combining expertise in computational photogrammetry, image geometric control, photo-mechanical mosaicking, and color lithography.

Following a technique developed by William Evans of Stanford Research Institute, the USGS is conducting experiments with reflectors to explore the capability of the ERTS system to locate ground control points smaller than a resolution element of an ERTS image. The control extension capability of ERTS is also being investigated by testing the accuracy of ground positions derived from a strip of ERTS images. Enhancement of ERTS imagery by correlation of successive images of the same scene using digital processing is being investigated.

Parameters for printing ERTS images have been redefined in cooperation with NASA, and ERTS-B images will be printed out on the Space Oblique Mercator projection as defined by the Geological Survey. The USGS has contracted for a study and demonstration of a promising automated register system for ERTS and other remote sensor images, which will provide the technology to convert ERTS to an automated mapping system.

*Land Use Studies.*—Demonstrations by the USGS of the use of remote sensing to various land use evaluation problems continues; in the Central Atlantic Regional Ecological Test Site where cost factors are presented along with land use products produced from different remote sensor source materials, so that potential users may determine appropriateness of mapping level and scale versus cost and benefits; in the Census Cities project where correlations of census data and aerial and satellite data are being made to construct an urban spatial growth model; and in the project directed toward direct computer recognition of land use patterns from ERTS digital data, where maps utilizing level II and III classifica-

tion detail at a scale of 1:24,000 are being produced for direct comparison with existing line maps. Because the land use data are already digitized, the land areas are counted and measured almost immediately and reported by jurisdictional areas.

*Pollution Studies.*—ERTS imagery of selected areas of Pennsylvania, West Virginia, and Ohio was examined by the Bureau of Mines to evaluate its potential for detecting air pollution effects in the environment resulting from smoke plumes emanating from coal-fired electric powerplants and coke ovens. Detection of specific point sources of pollution is possible if the plume emitted is of sufficient size, and more importantly, if the plume of condensed water vapor or solid material can be contrasted with its background. Detection of specific vegetation damage from air pollutants was not accomplished. Though the area of primary interest did show variances in spectral reflectance, these areas did not form a unique pattern over the different dates investigated.

*Evaluating Wildlife Habitats.*—Evaluation of ERTS-1 imagery by the Fish and Wildlife Service for determining numbers, distribution and quality of wetlands in North Dakota indicated that ponds and lakes larger than 1.6 hectares can be accurately mapped from a single near-infrared band of data. The perimeter and the shape of water bodies also could be determined, thus providing valuable information regarding the quality of nesting habitat for waterfowl. The synoptic and temporal aspects of ERTS data and supporting aerial photography also show promise in providing quantitative habitat data for determining the effects of water development projects on estuarine, riparian, and upland habitats. Digital processing of ERTS-1 data in combination with analysis of high-altitude aerial photography are being evaluated for use in a standardized habitat evaluation system of the Fish and Wildlife Service.

*Management Data for Indian Reservations.*—The Bureau of Indian Affairs has coordinated an evaluation by the State of Washington and the Northwest Indian Tribes of the use of high-altitude aircraft photography and ERTS-1 imagery as monitoring tools in the high-quality forest of the Pacific Northwest. The repetitive coverage of ERTS imagery makes it potentially the tool needed by the manager; however, the study showed that better interpretative information is needed either by automated interpretation of the original digital data or better imagery resolution.

Review of a comparative analysis of ERTS interpretations of land use with conventional aerial photo interpretations of the Crow-Northern Cheyenne Reservations, Montana, led the Colville Tribe to use ERTS imagery and the same land use classification scheme for overall reservation resources delineations.

*Weather Modification.*—The Bureau of Reclamation is continuing to use experimental ERTS-1 data in Project Skywater's Colorado River Basin Pilot Project (CRBPP), the largest winter orographic cloud-seeding experiment in the United States. The use of precipitation data transmitted via ERTS-1 DCS has improved the quality of information available for control of the CRBPP by helping to identify periods of heavy snowfall during which project operations must be curtailed to avoid contributing to the avalanche hazard. The use of satellite data is being initiated for the Project Skywater High Plains Cooperative Program involving weather modification experimentation to better meet long-range water problems in the semi-arid High Plains of the United States. Preliminary testing of the system which will include 64 precipitation gages was conducted during the 1974 summer season.

*Regional Planning.*—ERTS-1 data are also being used on the Rio Grande Regional Environmental Project, New Mexico-Texas, to provide information for regional planning decisions. Under a Bureau contract, ERTS-1 digital data are being processed by computer to determine the time-varying spectral signatures of area crop species, thus providing spectral norms against which individual crop signatures may be compared to identify automatically species, type, distribution, and plant vigor conditions. In addition, these techniques help to depict urban, suburban, and agricultural land use; mineral and water resources; and cultural features required to make more effective water-use projections for the area. A similar activity involves computer processing of ERTS-1 digital data to produce land use maps to monitor changes along portions of the Colorado River.

A major lineation identified on an ERTS mosaic of the Lower Colorado River may be significant to the Bureau of Reclamation in relation to salinity control problems and the geothermal resources development potential in the area.

The Bureau of Reclamation's Upper Missouri Region is using ERTS-1 data in its planning programs, and to estimate various land uses for preparation of the Garrison Diversion Unit Environmental Impact Statement.

ERTS imagery of the Western Dakotas is also being used to study several alternative pipeline routes for delivering industrial water to coal fields. ERTS imagery is also being used to investigate major geological features in and around construction sites (dams, canals, etc.). The resolution limitation, however, restricts its use primarily to preliminary observation with large-scale aerial photographs required for more detailed engineering geological investigations.

### *Aircraft Operations*

The Office of Aircraft Services (OAS) completed its first full year of operation this past June 30. The Boise Headquarters is now fully staffed with a Division of Management Services and a Division of Technical Services. The regional office in Anchorage, Alaska, consolidated departmental aircraft operations personnel and equipment into one entity in January, and has coordinated aircraft use in Alaska among all Bureaus and Offices since that time. Plans for the role of OAS in the conterminous 48 States are being formulated based on the evaluation report of the pilot operation in Alaska. Some positive results have been obtained in all three purposes of OAS: raising safety standards, increasing efficiency, and promoting economical operation of departmental aircraft activities.

The Southwestern, Bonneville, and Alaska Power Administrations, and the Bureau of Reclamation use contract aircraft for various purposes, including transport of personnel to remote project sites, transmission line and water resource project maintenance and inspection, and snow surveys. The Bureau of Land Management primarily uses aircraft to meet the logistical requirements of wildland fire control, and to obtain color, color infrared, and black and white aerial photography, and infrared scanner and radar imagery to locate and map fires. Bonneville Power Administration also performs for the U.S. Fish and Wildlife Service aerotriangulation and photogrammetric mapping for the determination of tidal boundaries, property ownerships, and contour maps for construction site grading.

The Bureau of Indian Affairs' agreements with NASA and the USGS to obtain high-altitude photography over all reservations continued in effect. Resulting orthophoto base maps and natural resource overlays are used to develop and implement comprehensive reservation planning. The maps project will be completed for all reservations in FY 1976. As part of the continuing operational comprehensive planning and environmental monitoring remote-sensing project on the Salt River Indian Reservation, an amplification of the Anderson Land Use Classification was developed for Indian lands in Arizona.

This year, the USGS contracted for a record high volume of over 391,000 square miles of aerial photography for its national topographic mapping program, of which almost 60% was high-altitude quad-centered photography used in support of an accelerated orthophotoquad program.

The USGS also utilized contract and other Federal aircraft to acquire photographic, other remote sensor and geophysical data for the support of geological

and geophysical investigations. These include reconnaissance and detailed geologic mapping, exploration for and evaluation of mineral and energy sources, monitoring volcanic activities, appraisal of resources in wildlife area, and environmental, engineering, and land-use studies. Airborne sensors were used to acquire data for the compilation of aeromagnetic, gravity, radioactivity, gamma-ray, INPUT, VLF (Very Low Frequency), and geochemical maps. A high sensitivity aeromagnetic survey of a 300,000 square mile area of the continental shelf off the east coast of the United States is underway, with a completion date of fall 1975. The objectives are to assess the economic, especially fuel, potential of the continental margin and also to obtain new knowledge of its geologic structure and tectonic relationships.

High-altitude aerial photography covering the State of Arizona has been obtained by NASA aircraft in support of the Arizona Land Use Experiment (ALUE) being conducted jointly by NASA/USDI/State of Arizona. The ALUE photography and the USGS-prepared orthophotoquads have been used extensively in regional planning projects and environmental studies for proposed electric generating plant and transmission line facilities throughout Arizona, to update county maps, for geologic, soils, and vegetation mapping, and in water resources and wildlife studies. Other energy related applications by private and commercial users include photogeologic studies in connection with uranium and petroleum exploration in northern Arizona.

The Bureau of Reclamation used aerial photography and scanner imagery for a woody vegetation identification and control study on reservoirs in Kansas, and for planning, development and management of multipurpose water resource projects.

The Fish and Wildlife Service continued to conduct aerial surveys over large portions of the 50 States, Canada and Mexico to collect data for research and management purposes. Assessment of the status of waterfowl habitat and the detection of illegal dredge and fill operations along the Atlantic and Gulf Coasts were dependent on remote sensing aircraft data.

Overflights of flood refuse dumps, begun in 1973 by the Bureau of Mines, were completed in 1974. Early detection and determination of the aerial extent of two fires allowed prompt extinguishment at a much lower cost than would have been the case had the fires spread undetected into the nearby coal deposits. Based on the success of this project and earlier aerial infrared monitoring research, the Bureau contracted to have the entire Anthracite Region of Pennsylvania mapped with aerial infrared radiometry and aerial photography. Aerial data were gathered in 1974, and the contractor is analyzing the

data, preparing a thermatic atlas of the Anthracite Region, preparing a report on potential areas for future strip mining in the region, and investigating and mapping entry/exit areas of ground water into mines in the Southern Field. This information will be used in the Bureau's environmental programs in the region.

#### *Research Using Aerial Data*

*Mineral and Geothermal Source Prospecting.*—The USGS continued to apply the interdisciplinary approach of physics and geology to the development and improvement of remote-sensing techniques by identifying the parameters by which rocks, soil, and moisture can be remotely discriminated and developing models and methods to analyze and display remote-sensor data. A thermal and reflectance image of the Raft River, Idaho, area, acquired at a time selected using a theoretical model, shows the presence of warm geothermal anomalies which were confirmed by ground probe measurements. High-altitude thermal infrared images over the Colorado Front Range display a previously unobserved circular feature that encompasses most of the area of gold mineralization at the Central City-Idaho Springs, Colorado, mineral district. An aerial infrared survey of the Mount Baker volcano, Washington, shows that the present activity is consolidated within and peripheral to the crater south of the main summit. An engineering model Fraunhofer Line Discriminator (FLD) performed successfully from a helicopter and measured luminescence differences of pine trees growing on copper-rich and normal soils. Prospecting for mineral deposits through the determination of geochemical stress in plants is also continuing using spectral reflectance data and analysis of multiband photography. Feasibility studies using the VLF system for bedrock mapping in hard rock areas and for detecting geothermal anomalies are proceeding.

*Water Resources.*—The Office of Water Research and Technology is supporting research on the optimum aerial remote sensor for mapping fracture traces in the Piedmont region of South Carolina to identify areas of high ground-water potential. At Lake Minnetonka, Minnesota, four Hasselblad cameras for multispectral photography and specific spectral analysis are being used in lake overflights to assess water quality trends. Aerial photographic studies are continuing in Colorado on the determination of snow depth and water-equivalent volume in the San Juan Mountains. Other supported research are the application of multispectral photography in the planning and management of North Carolina's water resources, and the use of low-altitude remote sensing for detection of water distribution and movement in subsoils of Missouri.

Aerial data are being used in rangeland research

studies and in applications for property boundary surveys by the Bureau of Land Management.

*Mining.*—An analysis of the geologic structure of the Buchanan County, Virginia, coal mining area was made by the Bureau of Mines to evaluate airborne side-looking radar (SLAR) imagery for delineating structural features that may cause mining problems. The fault and joint systems, identified through lineament analysis of the imagery and confirmed by surface and in-mine observations, are known to affect gas migration and accumulation and to weaken roof rock in mining workings. The investigation demonstrated that SLAR surveys can be useful in locating the best sites for drill holes to drain off gas in advance of mining or for commercial gas production.

The Bureau of Mines acquired 12 bands of aerial multispectral scanner imagery and four types of aerial photography at two altitudes of an experimental underground coal gasification site in Princetown, West Virginia. The imagery and photography will be used along with ERTS-1 imagery to map potential vent zones for gas and to determine the usefulness of overflights in preparing environmental impact statements for such projects.

*Hydrology and Other.*—The Bureau of Reclamation used black and white, color, and color infrared aerial photography in a variety of research projects, including monitoring flood conditions on the Trinity River, California, and the Yellowstone River, Montana, where a 100-year flood occurred; to map flood plain vegetation on the James River in North and South Dakota; to assess fish and wildlife habitat; in a cooperative program with the Bureau of Land Management, to study reclamation and rehabilitation of strip mining sites; and to identify lands being irrigated in violation of water rights on the Truckee-Carson Irrigation District, Nevada. Multispectral photography and optical-mechanical scanner imagery are being used in demonstrating a relationship between crop reflectance or emission and the depth to near-surface ground water in irrigated agriculture.

The Fish and Wildlife Service applied color infrared aerial photography to solving problems of waterfowl census techniques. Preliminary findings indicate that digital processing and computer analysis of photography may be a useful tool in the census and inventory of specific waterfowl populations. In Minnesota, multispectral photography was utilized to identify wetlands as small as 6 m in diameter and to map them according to the type of emergent vegetation appearing in 1:16,000-scale photography.

Bonneville Power Administration has contracted for low-altitude infrared photography of some reservoirs in the Pacific Northwest as an aid to the deter-

mination of locations and magnitudes of hydraulic bank storage. This is in addition to the continuing investigation of the suitability of infrared photography for providing resources and land use data utilized in facility location and environmental impact evaluations.

### International Cooperation

The USGS effort in international remote sensing included courses conducted in several countries and at the EROS Data Center in Sioux Falls, South Dakota; international seminars and workshops; special projects and pilot studies in various countries; and feasible programs for warning, assessment, and monitoring natural disasters.

#### *Training in the Use of Remote Sensing Data*

Fifty-eight scientists and resource managers from 35 foreign countries completed training courses at the EROS Data Center in 1974. The basic theme for the two international workshop-seminars held in June and September was to apply ERTS data for monitoring and inventorying resources of each participant's country. Disciplines covered included geology, agriculture, forestry and rangeland, hydrology, geography, land use, and cartography.

An East African seminar and workshop was held in Nairobi, Kenya, during March-April. The seminar's goals were to provide a background of fundamental concepts in the application of remote-sensing technology to resource development and environmental protection using ERTS data; to familiarize participants with optical data processing techniques that could be performed in their own locales; and to provide a basis for planning use of ERTS and accessory remote-sensing systems for national resources and environmental agency functions. The workshop sessions involved 33 participants from 10 African countries.

A short course in remote sensing for scientists from Indonesia was conducted on the island of Bali in January-February. The course served to train 22 Indonesian students, and to develop and commence the study of multispectral aerial photography for selected sites in Bali. The project in research of applications of remote sensing that began with the training course is continuing.

In the first year of the Thailand Remote Sensing Training Project 72 participants, 60 from Thailand and 12 from Economic Commission for Asia and the Far East and Mekong Secretariat countries, received 6 weeks of intensive classroom instruction in fundamentals of remote sensing and applications of ERTS data to problems in agriculture, forestry, land development, hydrology, geology, and oceanography. Consequent to the training program, at least six Thailand

Government departments have established programs in which ERTS and aerial remote-sensor data are being applied experimentally in research and management subject areas.

### ***Resource Development and Mapping***

Feasibility studies relating to use of ERTS imagery in mapping and evaluating selected environmental features of Mali, Upper Volta, and Niger were performed by USGS hydrologists. ERTS imagery was found to be a valuable source of information for mapping certain geohydrologic features, for the study of problems of water resources, range utilization, tsetse fly infestation, and the occurrence of river blindness.

Under a binational, multidisciplinary research project between the USGS and several Icelandic scientific organizations, a number of significant findings were made in the study of the varied dynamic, environmental phenomena of Iceland using imagery from ERTS-1. Some areas of high-temperature geothermal activity have been delineated on the basis of altered ground or snowmelt patterns. New lava flows and depositional patterns of volcanic ash are mappable. ERTS imagery has recorded short-term glaciological changes, such as surging glaciers, and permitted planimetric revision of glaciological features on maps, and mapping of subglacial volcanic and structural features. Of particular value to Iceland has been the small-scale mapping of regional vegetative cover, including areas where active soil reclamation is being carried out.

USGS completed a 1-month advisory and guidance mission to Companhia de Pesquisas de Recursos Minerais, which is initiating research demonstration projects in remote sensing in Bahia and southern Brazil, and is working with the geological and resources agencies of South Vietnam and Bangladesh to develop remote-sensing programs applicable to resource development and mapping.

A USGS project to demonstrate the application of ERTS-1 data to geologic analysis in Afghanistan in collaboration with Afghanistan Government scien-

tists was conducted in 1974. The project investigated relationships between structural and other geologic features as presently mapped and described, and features and conditions as depicted by ERTS-1 data. The ERTS data provided new information that is immediately valuable for the review and editing of geologic maps being compiled by the Government of Afghanistan.

The USGS is cooperating with the Government of Yemen in a study of their mineral and water resources problems. ERTS imagery will be applied where possible in the study.

### ***Evaluating Natural Disasters***

A project conducted through the Office of Foreign Disaster Relief Coordination, called for a USGS study of potential applications of ERTS and other satellite data to determine the nature and extent of natural disasters, to planning of relief measures, and to the development of warning procedures. The evaluation concluded that floods and fires can readily be monitored and analyzed and that suitable data analysis techniques are available at present. The ERTS DCS is also highly usable for flood warning and for warning of volcanic eruptions if ground sensors are properly emplaced and DCS reception stations are available. The techniques for assessment of earthquake damage, drought, crop disasters, glacier movement, and water quality are in varied states of development.

Flooding along approximately 300 river miles of the Indus and Jhelum Rivers in Pakistan were delineated in a matter of hours using techniques developed by the Mississippi River flood experiment, prompting the U.N. Food and Agricultural Organization to request technical assistance in evaluating flood-related disasters. The USGS analysis of ERTS imagery, in addition to delineating the extent of flooding, also revealed leakage under a dam, water loss from irrigation canals, areas of ponded waters following the flood, locations of ground-water discharge, and correlative hydrologic information.



### Introduction

Growth of international space cooperation efforts in support of foreign policy objectives and the goals included in the National Aeronautics and Space Act were a matter of high priority to the Department of State during 1974. Attention continued to be focused both on cooperation with individual countries and on space endeavors with multilateral and international organizations.

Particular progress was obtained in the support of efforts toward a European community by the cooperation of NASA with nine countries in their developing a large space laboratory for use with the U.S. Space Shuttle system. Support of bilateral relations with the USSR continued through the Joint Apollo/Soyuz Test Project 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*

Meeting in New York from July 1 to 12, the Committee on the Peaceful Uses of Outer Space adopted and decided to submit to the General Assembly the draft convention on the registration of manmade objects in outer space forwarded to it by the Legal Subcommittee. The draft registration convention fully met U.S. objectives.

For the future work of the Legal Subcommittee, the Committee agreed that priority should be accorded to a draft treaty relating to the moon, the elaboration of principles governing the use of satellites for direct television broadcasting, and the legal

implications of remote sensing of the earth from space.

Reviewing the work of the Scientific and Technical Subcommittee, the Committee endorsed four studies it had recommended on organizational and financial aspects of alternative systems for dissemination of remote sensing data. The Committee's approval of these studies was in line with the U.S. position that organizational and financial aspects should be examined together with legal questions.

The Committee noted and endorsed the other recommendations of its sub-groups, but was unable to reach agreement on the question of possibly reconvening the Working Group on Direct Broadcast Satellites. Consideration of a proposal to hold all meetings of the Legal Subcommittee in Geneva rather than alternating between New York and Geneva was deferred until a comparative cost analysis could be prepared.

#### *General Assembly*

The agenda of the 29th General Assembly had two items on outer space: a draft convention on the registration of objects launched into outer space, and the report of the Outer Space Committee. The United States joined in cosponsoring a resolution commending the text of the Convention on Registration of Objects Launched into Outer Space and requesting the UN Secretary-General to open the Convention for signature and ratification at the earliest possible date. This was passed unanimously by the First Committee in October and by the General Assembly in November. The Outer Space Committee report was approved by an omnibus resolution, also adopted unanimously by the First Committee and the General Assembly, which recommended *inter alia* that the Legal Subcommittee consider with equal high priority at its next session (a) a draft treaty relating to the Moon, (b) elaboration of principles governing the use by States of artificial Earth satellites for direct television broadcasting, and (c) the legal implications of remote sensing of the Earth from space.

### *Legal Subcommittee*

Meeting in Geneva from May 6 to 31, the Legal Subcommittee completed work on a draft convention on the registration of objects launched into outer space for the exploration or use of outer space. The convention converts the existing system of voluntary registration submissions by launching states to the U.N. Secretary-General into a mandatory regime. The United States played an active role in the drafting and negotiation of the convention. The final negotiations resolved the question of requiring launching states to mark all space objects with an international designator or registration number. The U.S. maintained that such a requirement was unfeasible on both technical and economic grounds. A compromise formulation provides that if a space object is so marked, this fact shall be reported in the registration submission; however, the marking is not compulsory.

The Subcommittee again considered the subject of a draft treaty relating to the moon but was unable to resolve the main outstanding issues: the scope of the treaty (whether, as advocated by the United States, it should cover all bodies of the solar system), furnishing of information on missions (whether certain information should be provided before launch), and provisions concerning exploitation of natural resources of the celestial bodies to be covered by the treaty. Discussion of these issues will therefore be continued at the Subcommittee's next session in 1975.

The Legal Subcommittee considered the report of the Working Group on Direct Broadcast Satellites, including proposed principles on direct broadcasting submitted by the United States and other countries. A working group of the Subcommittee began drafting a composite group of principles based on areas of agreement reflected in the Working Group's report, but was unable to reach consensus on any draft text. Broad areas of disagreement persisted regarding possible approaches to controls over international satellite direct broadcasting. The Subcommittee agreed that in view of the amount of work yet to be done the subject should be a priority item at its next session.

The Subcommittee also considered the report of the Working Group on Remote Sensing, which had requested it to take up the legal implications of such activities. Certain countries had submitted draft agreements or principles. However, the Legal Subcommittee did not have the time to take the matter up in any depth, and therefore decided to continue work on this problem at its next session. In general discussion of the subject, a number of countries advocated some form of control by a sensed state over dissemination of data concerning its territory. The United States has maintained a policy of open

availability of data obtained by remote sensing satellites in its experimental program. The United States has also consistently upheld the right of unrestricted overflight by satellites for peaceful use of outer space in conformity with the Outer Space Treaty.

### *Working Group on Remote Sensing*

The deliberations of the Working Group demonstrated growing awareness of the possible uses and benefits of remote sensing from satellites of natural resources and the environment. Meeting in New York in February and March, the Working Group noted that in three years the number of countries with coordinating bodies for activities in the remote sensing field had increased from six to 20, and that imagery for maps of natural features was now available for all major parts of the world's land areas. It noted that the United States, Brazil and France had offered various training programs in this field. A number of Working Group members accepted the U.S. invitation to visit the Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota.

The Working Group devoted a great deal of attention to possible future organizational schemes for the reception, storage and dissemination of remote sensing data, examining the possibilities of national, regional and international systems. For practical and other reasons, regional and national centers seemed to hold more promise than a universal system with all states participating in a single organization.

The Working Group noted that the most experience from remote sensing had been obtained in the meteorological field, and welcomed the launching in 1974 of the NOAA Geostationary Operational Environmental Satellite (GOES), which will be coordinated with satellites from countries as part of the Global Atmospheric Research Program (GARP) to be initiated in 1977. The Working Group expected that there would be growing emphasis on the use of remote sensing to study pollution, and noted that in this area, as well as that of sensing earth resources, only experimental projects have been conducted to date. Those projects have included the U.S. Earth Resources Technology Satellite (ERTS) and the Skylab Earth Resources Experimental Package (EREP), and will include a second ERTS satellite in 1975.

A number of countries have submitted draft agreements or principles on the legal aspects of remote sensing. The Working Group recognized that, in view of the different approaches to the legal questions that have been suggested, there is a need for further consideration of legal aspects and recommended that the Legal Subcommittee give high priority to this question.

### ***Working Group on Direct Broadcast Satellites (DBS)***

The DBS Working Group held its fifth session from March 11 to 22 at Geneva, continuing its consideration of political-legal as well as technical and economic aspects of this developing experimental technology. The Working Group's attention again centered on the question of drafting principles to govern the use of direct broadcast satellites. The United States has maintained that adoption of binding principles would be unwise and premature. However, taking into account the strong desire of many other countries to move in this direction, the United States submitted a set of draft voluntary guidelines or principles which reflect common interests and the most widely shared areas of understanding and agreement on this subject. The United States' draft was well received, and considerable attention has been paid by the Working Group and by the Outer Space Legal Subcommittee to the U.S. proposals. Other proposals have been put before the Working Group by the Soviet Union, by Canada and Sweden jointly, and by Argentina.

While tabling its own draft, the United States argued that the controversial question lies at the heart of restrictive proposals—whether or not each state should have the right to prohibit, through withholding its prior consent, direct television broadcasts to its territory—should be carefully examined in all its implications before any action is taken.

The United States also reviewed the progress of DBS experimentation, including in particular the launch of the Applications Technology Satellite (ATS-6) for a period of experimental broadcasting to community receivers in remote areas of the United States, to be followed by a year-long experiment of the same kind over India beginning in 1975.

### ***Scientific and Technical Subcommittee***

The Subcommittee gave priority in its proceedings to the report of the Working Group on Remote Sensing of the Earth by Satellites and to the U.N. space applications program. The United States has played a major role in both of these fields and was able to cite many examples of cooperation with other countries in various fields of space research and application.

During the Subcommittee meetings, consideration was given to possible modes of international dissemination of data obtained by satellite remote sensing. The United States suggested possible advantages in a system of regional centers for distributing such data. The Subcommittee recommended that its parent Committee request a series of studies under the auspices of the U.N. Secretary-General on the subject, including a summary of cost-effectiveness studies;

analyses of organizational and financial requirements for the establishment of an international center, or of regional centers, for the storage and dissemination of remote sensing data; and the possible establishment of educational and training facilities.

## **International Cooperation**

### ***Cooperation with Europe***

Continued efforts on the European Space Research Organization project to develop the Space Laboratory for use with NASA's Space Shuttle have been fruitful in improving our abilities in international cooperation on major space projects. This project, which will cost between \$300 and \$400 million makes it one of the most important cooperative programs in which the U.S. has become involved.

In June agreements were signed with West Germany and France for the reimbursable launch by NASA of the Symphonie satellite. This is a communications experiment to be conducted by the two countries. Under the agreement NASA will furnish launches and launch services for the satellite on a fully reimbursable basis.

### ***Cooperation with Japan***

Space cooperation between the United States and Japan during 1974 was dominated by a continued flow of space hardware and technology to Japan, as authorized under terms of the 1969 United States/Japanese Space Cooperation Agreement. These exports are being transferred under United States/Japan industry arrangements subject to the approval of the Department of State's Office of Munitions Control and are to be used in Japanese efforts to develop a space launch vehicle and a number of scientific and practical applications satellites for launching starting in 1975.

Negotiations were completed on an agreement for NASA to furnish reimbursable launches to synchronous orbit of three Japanese satellites. The first is a meteorological satellite to participate in the international GARP (Global Atmospheric Research Program) to study weather. The second is an experimental communications satellite and the third is an experimental broadcast satellite.

### ***Cooperation with the Soviet Union***

Joint NASA/Soviet Academy of Sciences Working Groups continued to implement the May 24, 1972 US/USSR. Agreement Concerning Cooperation in the Exploration and Use of Outer Space. This agreement provides for the Apollo-Soyuz Test Project, a joint experimental flight in 1975 to test compatible rendezvous and docking systems, and for cooperation in space sciences and applications.

*Apollo-Soyuz Test Project (ASTP)*—ASTP is the joint US/USSR manned space flight provided for by the US/USSR Agreement Concerning Cooperation in Space which President Nixon and Chairman Kosygin signed at the Moscow Summit in May 1972.

This experimental flight, on schedule for July 1975, is to test compatible rendezvous and docking systems being developed for future US and USSR manned spacecraft. A successful mission will contribute to a rescue capability for future manned space flights and broaden opportunities for US and USSR space cooperation in the years ahead.

The ASTP mission plan calls for the Soyuz to be launched first from the Soviet launch site at Baikonur. The first Apollo launch opportunity will occur about 7½ hours after Soyuz liftoff. Once in orbit, the Apollo will perform the necessary rendezvous maneuvers and then dock with the Soyuz. For about two days, the astronauts and the cosmonauts will exchange visits between vehicles and carry out joint activities, including experiments in space science and applications. There will be additional tests of the compatible docking mechanisms, and after final separation, the Apollo spacecraft will conduct further independent activities before re-entry.

The docking mechanisms to be used in the mission are separately developed by the two nations but are based on a single set of agreed design specifications for components which must be compatible. Thus, while there is no transfer of manufacturing know-how, US and Soviet engineers are closely engaged in the solution of common problems.

With design and development essentially complete, major progress in 1974 included joint compatibility tests of communications and docking systems and the start of intensive joint flight crew and flight controller training. During the year, the Soviet side conducted two unmanned flights of the Soyuz spacecraft to test new systems and equipment to be used in the joint mission and announced plans for an additional test flight of a manned Soyuz modified to an ASTP configuration. Meanwhile, NASA and the Soviet Academy of Sciences approved flight information plans for both the pre-mission and flight phases of the project. Plans have been made for the conduct of pre-launch tests at the US and USSR launch sites, and a joint flight readiness review has been scheduled for May 1975.

*Space Science and Applications.*—In the space science area, a joint NASA/Soviet Academy Conference on the Cosmochemistry of the Moon and the Planets was held in Moscow in June. During the Conference, a detailed Soviet briefing on the results of their recent missions to Mars was provided for a team of US specialists associated with the NASA Viking Project. US and Soviet specialists who are

preparing the joint experiment involving the correlation of geomagnetic data through ATS-6 met in the US in October for testing of breadboard equipment and technical coordination. The Space Biology and Medicine Working Group met in the USSR last October to exchange biomedical results of the Soyuz 13 and 14 and Skylab space flights.

In the space applications area, the joint Working Group on the Natural Environment agreed to (1) continued analysis and exchange of ERTS/Cosmos microwave methods to determine moisture. In addition, the Working Group agreed on actions looking to the definition of coordinated studies in (1) geology and geomorphology, (2) vegetation, soil, and land use, and (3) hydrology. In connection with the proposed coordinated studies of vegetation, soil and land use, US scientists visited the Kursk test site in the Soviet Union. Also, US and USSR experimental scientists met in Leningrad in May to present the results of the final analyses of the data obtained during the joint Bering Sea Microwave sensing experiment. This was the first time two independent research groups have made microwave radiometry measurements of sea ice and the ocean surface under the same conditions of varying surface roughness and intervening atmospheric conditions with generally the same results.

#### *Technology Transfer*

In 1974 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 the European area. The Department continued to emphasize the export of hardware rather than the technology necessary to produce the hardware.

### **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 88 as of December 31, 1974 with the completion of membership requirements during 1974 by Cyprus, Lebanon, Haiti and Bolivia. The definitive agreements consist of an Inter-governmental Agreement and an Operating Agreement. The U.S. Government is a party to the former, and designated the Communications Satellite Corporation (ComSat), a U.S. company, to be its Signatory to the latter. INTELSAT has a structure consisting 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. The first meeting of the Assembly of Parties took place February 4-8, 1974, and dealt generally with matters primarily of interest to the Parties as sovereign states, including consideration of the establishment by the U.S. of space segment facilities separate from the INTELSAT space segment, the selection of a Panel of Experts from which Presidents of Arbitral Tribunals will be selected, and consideration of the establishment of formal relations with several international organizations. ComSat participated in the second meeting of the Meeting of Signatories in April 1974 and represented the United States at the bi-monthly meetings of the Board of Governors. The Secretary-General made progress in organizing the Executive Organ which will provide financial, legal and administrative support. ComSat will provide certain technical and operational management services to INTELSAT under contract until 1979.

As of December 31, 1974 there were 81 INTELSAT earth stations operating in 59 countries. In November 1974 the sixth satellite in the INTELSAT IV series was launched and the seventh satellite in the series will be launched in early 1975 thus adding substantial capacity to the global communications coverage. These satellites enable INTELSAT to provide circuits for voice, data, teletype and facsimile as well as television channels. Communications capability will be further augmented by the launch during 1975 of the first of two INTELSAT IV-A satellites. Whereas the INTELSAT IV satellites each have a design capacity of 4,000 circuits, the IV-A's will each have a design capacity of 7,500 circuits. During 1974 design work was advanced on the next generation of satellites, the INTELSAT V series.

#### *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 Administra-

tion (FAA), the European Space Research Organization (ESRO) 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. ESRO has selected the Communications Satellite Corporation (ComSat), a United States corporation, 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 1970's. 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-1980's.

#### *Maritime Satellites*

For a number of years the world's maritime nations have 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 1974 in the efforts of the Intergovernmental Maritime Consultative Organization (IMCO) to examine how a maritime communications satellite capability might be developed and implemented. Under IMCO sponsorship an international conference will be convened in 1975 to examine the establishment of an international maritime satellite system.

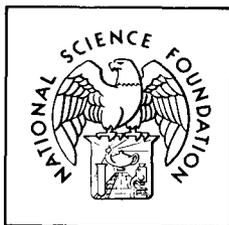
### **Support to Federal Agencies**

#### *NASA Spaceflight Support*

The Department and its posts overseas continued in 1974 to support NASA manned space flight missions, by arranging for the basing of recovery, tracking and other mobile support forces at foreign installations.

#### *Cooperation with the Department of Defense*

During 1974 the Department of State continued to work closely with the Department of Defense on various military space issues having international implications.



### Introduction

The National Science Foundation, established to promote the progress of science, supports research and educational activities in many fields of science. Research activities carried out with NSF support are directed to improving our understanding of natural phenomena from which stem new opportunities for further accomplishments in basic and applied science. Programs in the Foundation related to aeronautics and space science are found in areas of astronomy, atmospheric sciences, engineering, materials, chemistry, polar studies, and applied research. Many NSF investigators use facilities at the National Research Centers, administered under contract with the Foundation. Educational support includes grant funds for institutional programs and individuals.

### Astronomy

#### *General*

The comet Kohoutek, the most thoroughly observed comet in history, was detected late last year in the radio range, and molecules of methyl cyanide, hydrogen cyanide, and other compounds were found. Detection of the water molecule, long suspected to be present in comets, confirmed the icy model of comets. In September, what is believed to be a thirteenth satellite of the planet Jupiter was discovered. Further observations are being made to confirm the orbit. From its retrograde motion, it is theorized that it could have been an asteroid that passed near the giant planet and was captured.

Among the several new pulsar discoveries supported by the Foundation, one pulsar was found to be also a member of a double star system. In this double system, the two stars revolve about each other in 7.75 hours. From the period of pulsation and its constancy, the age of the neutron star is estimated to be several thousand years.

With X-ray detectors mounted on a balloon, MIT astronomers used the Moon as a shutter as it made one of its rare passes last August in front of the Crab Nebula, source of visible light and X-rays. In spite

of technical difficulties, blind pointing and on-board data recording showed the entire disappearance and reappearance of the nebula. The size and shape were observed to be somewhat different than expected. From X-rays of energy between 20 and 150 kilovolts, the size of the nebula was three times larger as it reappeared at a different angle from behind the moving Moon than when it disappeared. The size is smaller than that measured during the last occultation in 1964, and its extension in shape is at a right angle to the visual extension direction. Observations at this and other occultations will allow construction of a map of the sources which will help in understanding the physical makeup of this supernova remnant, still in a very energetic state after 920 years.

During the year there was increased ground-based support of NASA space missions through coordinated observations by scientists using optical, infrared, and radio telescopes at university and National Center observatories. Of special interest was the support to Skylab by solar astronomers, and to the Pioneer 10 and 11 missions to Jupiter and the Mariner Venus-Mercury flight by planetary scientists. The ground-based observations help ensure the maximum return in the effort to better understand the physics of the solar system.

#### *Kitt Peak National Observatory*

The primary mission of the Kitt Peak National Observatory (KPNO) is to provide facilities for research in solar, planetary, stellar, and galactic astronomy. Major ground-based telescopes, auxiliary instrumentation, and related support facilities are available to observatory staff and visiting astronomers from research and educational institutions throughout the United States and abroad.

The principal observing facilities of KPNO are located on Kitt Peak, 40 miles southwest of Tucson, Ariz. These facilities include nine stellar telescopes. The most recent addition is the 4-meter Mayall Telescope, which was brought into full operation in August 1974. This powerful instrument with its fast prime focus opens new fields of galactic and extra-

galactic astronomy. The new Solar Vacuum Telescope and Magnetograph provides full-disk, high resolution maps of the magnetic fields and gas motions on the Sun. It provided solar magnetograms as part of the ground-based support for the NASA-Skylab Apollo Telescope Mount solar experiments.

In 1974, astronomers using the 1.5-meter McMath Solar Telescope reported the discovery of two new organic molecules in the atmosphere of Jupiter: ethane and acetylene. While the discovery of simple organic molecules is not indicative of life on Jupiter, evidence of their presence is important to understanding steps in the chemical evolution of that planet.

Excellent data have been obtained in far larger amounts than originally expected from the ultraviolet spectrometer designed and built by KPNO and placed on board the NASA Mariner 10 spacecraft. Data from the Venus flyby indicate the presence of significant concentrations of hydrogen, helium, carbon, and oxygen atoms in the upper atmosphere and indicate an exospheric temperature of 400° K. (260° F.) Data from the Mercury encounter indicate the presence of an atmosphere consisting largely of the gases argon and neon, with some evidence of hydrogen and helium.

#### ***National Radio Astronomy Observatory (NRAO)***

The National Radio Astronomy Observatory (NRAO), with headquarters in Charlottesville, Va., provides advanced facilities for research in radio astronomy. The major observatory instruments, located at Green Bank, W. Va., include a 300-foot meridian transit telescope, a 140-foot fully steerable telescope, a three-element interferometer consisting of 85-foot telescopes that can operate in conjunction with a remote portable 45-foot antenna, and a 36-foot millimeter wave telescope. Observations at decimeter and meter wavelengths are made with the 300-foot and 140-foot telescopes, and studies of the angular structure of radio sources are made with the interferometer. Extremely short wavelength observations required for interstellar molecular spectroscopy are made with a 36-foot radio telescope located on Kitt Peak, near Tucson, Ariz.

An important new observing facility, the Very Large Array (VLA), is under construction on the Plains of San Augustin near Socorro, New Mexico. When completed in 1981, the VLA will have both radio image formation and spectral line analysis capabilities. Partial operation is scheduled to begin in November 1976.

Scientific programs in progress using the NRAO major telescope systems include galactic studies, investigations of discrete radio sources, and tests of general relativity. Observations of interstellar gas and dust clouds are providing details of the large-scale

structure of our own Milky Way galaxy as well as delineating processes involved in star formation. Two new interstellar molecules have been discovered—dimethyl ether, the largest molecule yet detected in space, and silicon monosulphide, the first interstellar molecule composed only of elements with atomic weight greater than 20. Very long baseline (VLB) observations, in cooperation with other radio astronomy observatories, have been providing details of the size and shape of the emitting regions of compact radio sources, including quasars and pulsars. Radio measurements of the relativistic bending of electromagnetic radiation in the presence of strong gravitational fields are providing important new checks of general relativity theory.

#### ***National Astronomy and Ionosphere Center (NAIC)***

In 1974, the major upgrading of the 1,000-foot-diameter radio/radar telescope was completed at the NAIC observing site near Arecibo, P.R. This upgrading will provide the world's most advanced research instrumentation for radio and radar astronomy and ionospheric research. When final surveys and alignments are complete in early 1975, the new aluminum panels of the telescope will form a precision spherical surface accurate to within 1/8 inch. This new surface broadens the frequency range available for scientific observations by a factor of 12. A 450-kilowatt 5-band planetary radar transmitter, sponsored by the National Aeronautics and Space Administration and completed in October 1974, increases the planetary ranging and surface mapping capabilities of the Arecibo telescope by a thousandfold.

One of many fruitful scientific programs at NAIC involves a search for new pulsars in the galactic plane. With a newly installed ultrasensitive receiver system, 21 new pulsars were soon discovered. Examination of the radiation coming from these pulsars enables radio astronomers to make more accurate estimates of pulsar distances and to better understand the structure, origin, and evolution of our galaxy.

#### ***Cerro Tololo Inter-American Observatory (CTIO)***

The Cerro Tololo Inter-American Observatory, providing ground-based telescopes, auxiliary instrumentation, and support facilities for studies of astronomical objects in the Southern Hemisphere, offers what has been judged to be the best atmospheric "seeing" conditions for astronomical research available anywhere in the world. The observing facilities on Cerro Tololo include eight major telescopes. A major new 4-meter telescope, installed in late 1974, is scheduled to become fully operational in 1975. Operation of the two similar 4-meter telescopes at CTIO and KPNO is an unprecedented step for optical astronomy, providing the first opportunity for a

coordinated attack on "limit" problems in astronomy using advanced instruments that are located in both the Northern and Southern Hemispheres. Astronomers at CTIO have accomplished outstanding results. In studies of the clouds of hot ionized interstellar hydrogen gas in the Magellanic Clouds, measurements of Doppler shifts in the spectral line profiles confirmed that the Large Magellanic Cloud is a thin rotating disk viewed face on, and that the clouds surrounding some of the hot luminous stars exhibit violent internal motions.

Astronomers at CTIO have also pursued extensive studies of infrared sources associated with very young stars in dark clouds within our own galaxy. Astronomers have been conducting searches for the youngest known astronomical objects, using an image intensifier sensitive to infrared wavelengths that makes it possible to look through the shrouds of gas and dust surrounding the youngest stars. A number of objects were found that appear very bright in the sky at infrared wavelengths of 1 micron but are invisible in the optical range. It is likely that many of these are young stars still deriving their energy from the collapse of the clouds of dust and gas out of which they were formed.

A new computer-based data system, successfully tested in 1974, forms an integral unit that makes it possible for astronomers to secure a quick look at large quantities of processed data on nearly a real-time basis. Expansion of the CTIO data system has made possible heavy use of new pieces of equipment that are greatly increasing the operational efficiency and sensitivity of existing telescopes.

## **Atmospheric Sciences**

### ***Solar-Terrestrial Research***

The space physics of the Earth's environment and the interaction of this environment with the Earth's atmosphere are concerns of NSF's Solar-Terrestrial program. The Sun continuously forces out from its surface a flow of charged particles—the solar wind. Intermittently and by mechanisms not yet understood, much smaller numbers of particles in disturbed solar regions are accelerated to high energies and are hurled into space. A large part of NSF's program is devoted to a study of these particles and their interactions. Optical and radio studies of the dynamics of the atmosphere are supported, as well as investigations using cosmic rays as a probing tool to study the solar wind. Studies on the outer reaches of the solar atmosphere, the interplanetary plasma, and the Earth's magnetosphere are included; also observational and theoretical research on the interaction of the solar wind with the Earth's magnetosphere and

the atmosphere of other planets. Major attention is devoted to the Earth's magnetosphere and particles and fields in it. Trapping and release of particles, wave-particle interactions, and currents and magnetic fields are all associated with spectacular aurora, magnetic storms, interferences with radio, long-line telephonic communication, and with surges on large power networks. During the year progress continued to be made in several research areas. For instance, analysis has been continuing on the fact that the North American electric power grid is depositing small amounts of the electromagnetic energy in the near-Earth magnetosphere—a phenomenon that was unexpectedly discovered in a study of radio waves transmitted from the Antarctic through the magnetosphere and received in Canada.

### ***Aeronomy***

The atmosphere of the Earth at high altitudes is generally taken as the domain of aeronomy. The Foundation supports theoretical and field studies of phenomena that occur in this region and laboratory investigations to provide insight into the atomic and molecular processes taking place there. Phenomena investigated include light of the night sky, aurora, ionospheric instabilities, and the dynamics of the normal ionosphere at all latitudes. The most intensive investigations, important to the International Magnetospheric Study, involve the auroral zone in Alaska. Some aeronomy research is being devoted to studies of the chemistry of the atmosphere in the hope that the constitution of the "normal" stratosphere and mesosphere (which extends beyond the stratosphere) can be determined. This work is particularly important in order to have a reference against which to measure possible future alterations due to human activity.

### ***Meteorology***

NSF supports a broad range of investigations into the dynamical and physical behavior of the atmosphere, including field observations, laboratory experiments, and theoretical and numerical analysis of the data together with the development of techniques for remote sensing. Techniques are being developed for remote sensing of atmospheric motions, and of particulate and gaseous species. A variety of studies on radar is supported, along with other investigations attempting to monitor the build-up of carbon dioxide in the global atmosphere and changes in concentrations of atmospheric particulates. Over the past several years there has been an expanded program of stratospheric research, supported in part by transfers of funds from the Department of Transportation. Balloon and aircraft measurements of trace constituents such as water vapor and nitric acid and numerical modeling of stratospheric dynamics are included.

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

The National Center for Atmospheric Research has two major objectives: to plan and conduct or participate in selected atmospheric programs, and to develop and operate major research facilities and services most needed by atmospheric scientists.

During the summer of 1974, NCAR scientists, ground measurement teams, and aircraft assisted with the Global Atmospheric Research Program-Atlantic Tropical Experiment (GATE). This experiment produced the most extensive data ever gathered on tropical meteorological processes and their interaction with global atmospheric circulations. These data gathered are of critical importance in developing and testing models of intermediate-scale tropical weather and climate systems, as well as of worldwide systems.

In NCAR's continuing research on hailstorms, detailed analyses of the airflow and moisture budget of a typical hailstorm are conducted. This work has advanced the understanding required to improve the predictions of hailstorm severity, and to determine the best approach for suppressing hail.

Scientists at NCAR's High Altitude Observatory obtained about 35,000 photographs of the solar corona over a 7-month period with equipment aboard the NASA manned spacecraft SKYAB. These reveal both persistent and many transient phenomena in the corona during seven rotations of the Sun. Such photos were previously available only during the rare and brief total eclipses of the Sun.

### **U.S. Antarctic Research Program**

Most of the upper atmosphere physics studies of the multidisciplinary U.S. Antarctic Research Program are done at Siple Station near the base of the Antarctic Peninsula. Instrumentation includes a unique 21.4-kilometer-long Very Low Frequency (VLF) dipole antenna, which serves as both a receiver and a transmitter, and will be of importance in the International Magnetospheric Study, planned for 1976-1979. Instrumented balloons are sent aloft every other year to detect particles precipitated from trapped radiation through interaction with electromagnetic waves; *in situ* VLF activity is measured on some flights. Measurements from these instruments contribute to investigation of how solar energy crosses the boundaries separating the various magnetic regimes and affects the terrestrial environment. Especially useful is the ability to compare particle measurements with wave measurements, allowing investigation of wave-particle interactions as a function of frequency. Many measurements are made simultaneously in Quebec, at the Northern Hemisphere conjugate of Siple Station. Other upper at-

mosphere research in Antarctica takes place at McMurdo Station (cosmic ray observatory) and at the geographic south pole (aurora studies).

### **Engineering**

Many NSF-funded research activities dealing with fluid dynamic problems are directly applicable to space and aeronautical problems. Some current areas of support include unsteady viscous flows, near wake studies, large-scale organized structure in turbulent-free shear flows, and gaseous separation processes. In all cases, research is focused on quantification of the physical phenomena and provision of necessary data base for future designs. Research on stability as well as the mechanics of laminar-turbulent transition receives continuous support. Other aeronautics-related investigations include work in numerical fluid mechanics and vortex dynamics.

### **Materials Research**

Research areas of significance to aerospace applications include processing, structural aspects, and electronic properties of technological materials. In the area of processing, cutting materials and machining metals and alloys to yield desirable products are enormously expensive, from both materials resource and energy consumption perspectives. Research on materials for carbide tools and on oxide and diamond abrasive grains for grinding wheels has extensive support, as well as the study of basic mechanisms of chip removal during cutting and grinding. Through periodic meetings of university grantees with members from the metal cutting industry, close correlation of effort is maintained between university research and industrial demands on cutting materials. In the area of composite materials, requirements of increased performance of materials used in aircraft engines and air frames tax to the limit many conventional alloys and ceramic materials. Basic studies are supported involving solidification and fabrication of materials that yield controlled composite structures having desirable properties for particular applications. In the semiconducting materials area, research topics receiving significant support include basic studies of compound semiconductors, including multi-component systems, of potential use in new heterojunction devices. Such devices include light-emitting diodes, heterojunction lasers, picosecond infrared detectors, and materials and junctions for solar voltaic conversion.

Materials research in the solid state sciences is active in a number of areas which will affect future aeronautic and space technologies. Investigations of the fundamental mechanisms for defect formation and migration in metals, insulators, and semiconduct-

ors have an obvious bearing on the future development of materials with structural, electronic, and thermal properties suited to the extreme thermal and radiation environments encountered in space. Related research on ionic diffusion in nonstoichiometric solids bears on the development of solid state batteries and fuel cells for possible use in space vehicles. Research in low temperature physics, on high temperature superconductors, and cryogenic coolers now in progress point to possible future use of superconductors in space applications as sensors and microwave components. Other research on new materials with unusual electronic and optical properties such as amorphous semiconductors, organic charge transfer salts, and liquid crystals may develop ways of using these materials in electronic and electro-optical components for space applications.

## **Chemistry**

Although terrestrially based and aimed largely at solving Earthbound problems, NSF-supported research in modern chemistry creates knowledge that is essential for progress in the aeronautics and space sciences. For example, the research in spectroscopy, reaction dynamics, and photochemistry provide significant input to the body of information required for modeling of the atmospheres that surround celestial bodies, including the atmospheric pollution modeling problems on Earth. This research also contributes to the development of lasers. Research in chemical synthesis, structure, and reaction dynamics provides a significant component of background information from which potential propellant systems can be evaluated. Research in chemical analysis and spectroscopy leads to improved methods for characterizing and understanding matter, ranging from new materials for space vehicles to determining the chemical composition of interstellar space. The information gained from fundamental studies in chemistry is essential to the elucidation of how molecules are formed in space.

## **Research Applied to National Needs**

### ***Solar Thermal Conversion***

Two types of selective coatings with high absorption and low emission characteristics are being developed for use in solar collector systems. These coatings will efficiently convert solar energy to heat and minimize subsequent heat loss. Since spacecraft require thermal management systems to insure that no difficulties arise from incident solar energy, from internally generated heat, and from excessive radiation of thermal energy to deep space, the two coatings may have important applications in spacecraft design.

### ***Wind Energy Conversion***

The objective of NSF's Wind Energy Conversion Systems program is to advance the technical and economic performance of wind energy systems as a viable alternative source of energy. The advances in aeronautical technology, in recent years are being applied with the help of NASA to the design of advanced wind energy systems. Aerodynamic research is being undertaken in, or as part of, several projects to increase the performance and capability of wind energy systems.

### ***Photovoltaic Conversion***

The Photovoltaic Energy Conversion program is designed primarily to develop economically viable photovoltaic electric power systems capable of providing a significant amount of the Nation's energy requirements by the year 2000. While this program is geared for terrestrial applications of solar cells, many of its achievements should readily find applications in the Nation's space program. This program is being carried through close collaboration with numerous Government laboratories, such as the NASA-Lewis Research Center, the Jet Propulsion Laboratory, and the Goddard Space Flight Center. Examples of recent program achievements include successful experiments which have produced ribbons of crystalline silicon with sufficient quality to be made into solar cells with efficiencies as high as 10 percent. Cadmium sulfide/copper sulfide solar cells have been prepared with up to 6 percent efficiency. Other experiments have shown the possibility of producing extremely low-cost solar cells based on a semiconducting glass-silicon heterojunction. There are strong indications that such cells will have efficiencies up to 16 percent for single crystal silicon, and up to 8 percent for polycrystalline silicon cells.

## **Education Activities**

In fiscal year 1974 the Foundation's Education Directorate placed \$740,392 in support of 47 awards for activities related to the aeronautic and space sciences. The greatest proportion of these funds supported the training of 27 graduate students in NSF's Graduate Fellowship program. Funds also helped upgrade the aeronautic and space sciences subject matter background of seven college and university faculty members through the Faculty Research Participation program. Also, projects helped 141 superior secondary school students and 28 undergraduate students obtain unusual independent study and research experiences related to the aeronautic and space sciences. Eleven projects designed to improve instructional programs in these disciplines were supported at the undergraduate level of education.



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

## Introduction

Modern science and technology are sufficiently complex and interwoven that continuing analysis of their directions, problems, and interactions is necessary to assure that they will properly serve society at appropriate cost.

The charter of the National Academy of Sciences (NAS), a Congressional Act of Incorporation signed by Abraham Lincoln in 1863, calls upon it to serve as an official adviser, upon request and without fee, to the Federal Government on any question of science or technology. The National Academy of Engineering (NAE) was established in 1964, under the charter of the NAS, as a parallel organization of distinguished engineers, sharing with the NAS its Federal advisory responsibilities. Most of the activities undertaken by the two Academies are carried out through the National Research Council (NRC), which is representative of the major scientific and technical societies, and whose members are derived from universities, industry, and the scientific agencies of the Federal Government.

The advisory work of the Academies-Research Council is normally carried out by individual committees or through special studies. That related to aeronautics and space in 1974 is briefly described below.

## Aerospace Science

### *Space Science Priorities*

The *Space Science Board*—(NRC) adopted as its principal work in 1974 a study of priorities in space science. The study involved the year-long collaboration between the Board and three of its major committees, Space Astronomy, Space Physics, and Planetary and Lunar Exploration, in a critical examination of space mission strategies on the basis of scientific merit. Preliminary reports containing mission models for the disciplines involved were prepared by the committees and mailed to a representative segment of the scientific community for criticism and comment. The reports were revised to accommodate the comments

received and submitted to the Board for cross-ranking of priorities among the various disciplines. The Board's findings and recommendations will be issued early in 1975. As a part of this exercise, a special study on strategies for the exploration of Mars was carried out during the summer. Some 20 scientists participated in the 8-day study.

The Board's Exobiology Panel participated in the priorities study by proposing strategies for the biological exploration of Mars and other solar system objects. In addition, the Panel addressed itself to the issue of the possible hazard to the earth of a sample returned from Mars (back contamination) and the possibility that earth organisms brought by spacecraft might contaminate other planets (planetary quarantine).

The Committee on Space Biology and Medicine proposed directions for future life sciences research in the space shuttle era based on an evaluation of experience to date. The Committee on International Relations assisted the Board in carrying out its commitments as Academy representatives to the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU).

### *Solar-Terrestrial Research*

The *Committee on Solar-Terrestrial Research*—(CSTR; NRC) 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. In April 1974, the President's Science Adviser announced that the U.S. will participate in the International Magnetospheric Study (IMS), an international cooperative enterprise to be conducted in 1976-1978. This was a result of recommendations of a joint study by CSTR and the Space Science Board in 1973 and a report by a panel of CSTR in 1974 outlining a specific plan for U.S. participation in the IMS. The chief objective of the IMS is to obtain a comprehensive quantitative understanding of the dynamical processes operating on plasmas in the geomagnetic field. The operational

basis of the IMS is an international plan of coordinated observations from spacecraft, ground-based facilities, aircraft, balloons, and research rockets. The Interdepartmental Committee on Atmospheric Sciences of the Federal Council for Science and Technology in consultation with the CSTR panel is preparing to coordinate technical and procedural aspects of the U.S. participation. To this end a program office to coordinate U.S. activities in IMS has been established in the National Science Foundation.

### *Atmospheric Sciences*

The *Committee on Atmospheric Sciences*—(NRC) encourages research and development that will provide a balanced national program in the atmospheric sciences. Recent studies in weather modification, atmospheric chemistry, air quality, and weather dangers have focused on the necessity to develop a system of regional and global observations to cope with national needs for improved short- and long-term weather predictions, improved understanding of the complex chemical and photochemical processes occurring in the atmosphere, a greater understanding of the small- and large-scale interaction of the atmosphere with underlying surfaces—oceans, snow and ice fields, and mountains. Many of the needed observations for these studies must be obtained by remote sensing devices, through an integrated system of ground-based, satellite, and aircraft-borne sensors. Current studies by the Academy, the government, and research centers are converging on the potential contributions that experimental and field studies in severe weather conditions can provide to the safety and welfare of our citizens. Scientists, administrators, and public officials, now more than ever before, recognize the need for the prompt application of observational measurement capabilities available to the nation for working on these problems. Such programs also require the utilization of advanced computers to allow theoretical and experimental analyses and diagnoses to be carried out in prompt and effective ways.

The *Global Atmospheric Research Program*—(GARP) is an international research effort to develop an understanding of the atmosphere and oceans in order to understand and to predict the transient behavior of weather and the statistical characteristics of climate. The program stems from resolutions of the United Nations and is vigorously supported by the nations of the world. An international Joint Organizing Committee sets overall scientific objectives and defines subprograms of observation and research. These are expanded and implemented within each participating country by groups in the scientific community and the government. In the United States, the *U.S. Committee for GARP*—(USC-GARP) and its panels are the principal mechanism for defining

and expressing U.S. inputs to international planning and for assisting the government relative to U.S. participation in the program.

The first major GARP field observational programs were executed during 1974. In the spring, the Air-Mass Transformation Experiment (AMTEX) was conducted in the South China Sea to study air-sea interactions between the warm Kurochio current and cold Asian air masses. Although principally led by the Japanese, a number of U.S. groups contributed. In the summer of 1974, the GARP Atlantic Tropical Experiment was conducted off the coast of Africa. This field program, the largest such effort undertaken, was designed to study the interaction between various scales of dynamic weather systems in the tropics with a view to realistically incorporating these processes in numerical models of the global atmosphere. Ships, aircraft, and over four thousand people from ten contributing nations took part in the program. Geostationary and polar-orbiting satellites were indispensable elements in both GATE and AMTEX, providing cloud imagery, wind estimates from cloud motions, sea-surface temperature measurements, and vertical atmospheric temperature profiles. These experiments were precursors to the First GARP Global Experiment now scheduled for 1978-79. This will be a 12-month period of intensive observation of the global atmosphere and oceans by surface-based systems, satellites, and special observing systems. Planning and preparation for U.S. participation in this program will be a major concern of the USC-GARP for the next several years.

The *Climatic Impact Committee*—(CIC; NAS-NAE) is a multi-disciplinary group concerned with inadvertent climate modification that might result from those activities of man that affect the upper atmosphere and particularly the stratosphere. The Committee has been advisory to the Department of Transportation (DOT) and other federal agencies on research priorities in this area. It is now preparing a report to assess the state of knowledge developed by DOT's Climatic Impact Assessment Program (CIAP) and related studies around the world on possible effects of stratospheric pollutants on the earth's climate, and the biological, social, and economic ramifications. The scope of problems considered by the CIC include possible hemispheric changes in ultraviolet light at the earth's surface due to ozone depletion from natural and man-made pollutants (e.g., volcanoes, aircraft, space shuttle, atmospheric nuclear testing, and chlorofluoromethanes used as aerosol propellants and in refrigeration systems) in the stratosphere and troposphere. Also considered are problems of possible climate changes in temperature and precipitation due to oxides of Nitrogen and particulates introduced into the stratosphere, corresponding bio-

logical effects, and the economic and social costs of such changes. The study's tasks include uncertainty analyses for various climatic and agricultural models and consideration of possible international regulatory constraints on high-altitude aircraft coupled with a geophysical and biological monitoring program to measure harmful effects. The conclusions of the 1974 study will be published as an NAS-NAE report in early 1975.

### *Life Sciences*

The *Advisory Center on Toxicology*—(NRC) serves as a central source of information and technical staff to enable the Committee on Toxicology to answer the specific questions of a toxicologic nature presented by its ten sponsoring agencies, one of which is the National Aeronautics and Space Administration. The Committee is continuing its study of the potential environmental health effects associated with the use of a mercury ion engine in the Solar Electric Propulsion System. Attention is being focused on the consequences of a remotely possible on-pad or early-launch abort. The study should be completed around the first of the year and is intended for use in preparing the environmental impact statement.

The Committee has recently undertaken an evaluation of the health hazards from fires involving various materials of construction (plastics) for aircraft, to serve as a basis for material selection. Following last year's study of the health effects of ozone on flight crews of high altitude aircraft, the Committee is now directing its attention to the effects on the general public, including aircraft passengers, of short exposures to ozone. This report, to be completed in 1974, will indicate the extent, if any, of public health hazards. The Director of the Center will discuss the health hazards of hydrazine type rocket fuels at the Annual Conference of NASA Clinical Directors, Environmental Health Officials, and Medical Program Advisors.

The *Committee on Vision*—(NRC) has written reports on the following aerospace-related problems: visual elements in flight simulation, air-to-air visual detection, visual problems in head-up and element-mounted displays, loss of distant vision in pilots, misleading visual information in night landings, visual evaluation of light-emitting diode displays, and visual problems in certification of pilots. In addition, a report is in progress on procedures for testing color vision. A symposium was held during the year on psychological aspects of eye movements.

The *Committee on Hearing, Bioacoustics, and Biomechanics*—(NRC) is working on the following aerospace-related problems: evaluation of environmental impact of noise, guidelines for pure-tone, air-

conduction, audiometric testing, longitudinal studies of hearing, development of a test for speech reception of aviators, principles for testing speech reception, retirement standards based on speech reception in noise, transportation noise, military problems in ear disease and hearing, criteria for hazardous exposures to impulse and continuous noise, permissible noise for vibration levels in aircraft cabins and cockpits, adoption of a single noise scale, airport noise survey instruments, and speech reception as affected by aging. The Committee has published the following aerospace-related report. Research Facilities in Audition within the Armed Forces.

### **Space Applications**

The *Space Applications Board*—(NAE-NRC) provides advice and recommendations to the Federal Government on applications of space techniques and capabilities and stimulates collaboration among the pertinent components of the government and industry. The Board's membership is extremely broad, encompassing natural and social sciences, public affairs and communications. During 1974, the Board continued to investigate institutional inhibitions to achieving widespread benefits from space applications. In addition, the Board interviewed a number of government and private organizations to gain an understanding of the implications of the phase-down of NASA's activities in satellites communications research and development.

During the summer of 1974, the Board conducted a two-week study of space applications. The study was organized around use-oriented panels whose assignments included reviewing progress in space applications and defining user needs capable of being met by the application of space systems. Potential users drawn from federal, state, and local governments and from business and industry were impanelled in the fields of weather and climate, uses of communications, land use, agricultural resources, water resources, extractable resources, environmental quality, maritime activities, and materials processing in space. *The user panelists were unanimous in their conclusion that practical uses of space systems offer significant potential benefits and that these benefits could be very large.* A summary report and reports of the summer study panels are expected to be released by the NRC early in 1975.

The *Committee on Remote Sensing Programs for Earth Resource Surveys*—(CORSPERS; NRC) is an advisory committee on the use of remote sensing from spacecraft and aircraft to survey earth resources and to monitor the environment. The Departments of Interior (USGS), Commerce (NOAA), Agriculture, Navy, and Army (Civil Works, US Army

Corps of Engineers), the Environmental Protection Agency, the Agency for International Development, and the National Science Foundation are sponsors for the Committee. CORSPERS has completed an 18-month study of the results obtained by the Earth Resources Technology Satellites, ERTS-1. The Committee was impressed by the significant resource and environmental information that the investigators were able to extract from the ERTS data. This was in spite of the fact that the ERTS sensors and the data handling facilities now in use are not representative of what could be done with current technology. The Committee concluded that the technology used in the ERTS program is readily extendable to optimized operational systems that can satisfy major data requirements of many different categories of resource managers and environmental monitors.

During the course of this review it became evident to the Committee that the operational user community was quite often reluctant to commit itself to using the ERTS data. There were two basic reasons for this. First, there is no assurance that the program will be continued beyond the technology demonstration phase. Any major investment in personnel training, specialized equipment, decision model changes, etc., needed to shift to the use of space imagery must be viewed as speculative until there is assurance of continuity of data. The second reason is that the strength of repetitive synoptic space imagery, with selective spectral range and resolution but with relatively low spatial resolution, does not readily fit into the information process and decision models currently used by many operational managers. A joint effort by the user community and remote sensing technologists is needed to bridge this gap. The Committee endorses the recent efforts by the user agencies and NASA to initiate joint quasi-operational or demonstration projects.

The *Committee on Radio Frequencies*—(CORF; NRC) and its Subcommittees on Space Science, Radio Astronomy, and Earth and Life Sciences, coordinate the views of the U.S. scientific and engineering communities regarding the 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 meeting held in Geneva in March 1974.

Upon CORF's recommendations, tests were conducted by several radio astronomy observatories to study the interference to the observatories by transmissions from ATS-6 and determine what measures can be taken to protect radio astronomy from broadcast satellites. CORF and its subcommittees are re-

viewing the international radio regulations and are preparing recommendations on allocations of frequencies for space research and radio astronomy for submission to the Federal Communication Commission for use in preparing the U.S. position for the 1979 World Administrative Radio Conference.

The *Panel on the Geochemical Environment in Relation to Health and Disease*—is aware of a possible usefulness of remote sensing technology in studying trace elements distribution in plants and as a consequence in man's food chain. The ERTS program is making it possible for hydrologists around the world to realize the usefulness of remote sensing imagery and provide new insights into how it can be used in water resources studies. Remote sensing information continues to be useful for geodetic work and offers possible techniques that will be useful in earthquake hazard studies.

### **Aerospace Engineering**

The *Aeronautics and Space Engineering Board*—(ASEB; NAE) in 1974 concentrated its efforts on NASA's proposed aeronautical research and development programs and systems. An ASEB ad hoc Committee on Alternative Aircraft Fuels was established to consider possible alternatives to current jet fuels now in common use by commercial and military aircraft. A great amount of effort has been expended also in the Board's consideration of V/STOL technology, advanced transport technology, and the long-range practicability of hydrogen as a future fuel for aircraft. In space engineering, Board efforts have been focused on NASA's progress in engineering and management of the space shuttle program. An ad hoc committee was established to review one of the important planetary programs under way in NASA in an effort to determine how cost effectiveness in this and similar programs could be improved.

To ensure optimum utilization of funds allocated by Congress to the nation's space research, engineering, and applications activities, the Chairman and staff of the ASEB expend continuing effort to coordinate activities with the NRC's Space Science and Space Applications Boards. As an example of this cooperation, the Chairman of the ASEB served as Deputy Director of Systems Implications during the Space Applications Board's two-week Summer Study of Space Applications (see above). The Board will continue its emphasis on research and development activities critical to the achievement of national aeronautical and space engineering programs oriented well into the future.

The *National Materials Advisory Board*—(NMAB; NRC) is concerned with the advancement of materials science and engineering in the national

interest. The scope of the activity covers the entire life-cycle from raw material through finished product and the recycle of the spent product into the processing system. A significant portion of the Board's activities pertains to aerospace materials. The NMAB completed several studies in 1974 which address specific problems in aerospace materials technology and propose potential solutions. In February a two-day workshop was conducted on Nondestructive Evaluation (NDE) of Composites. The objective was to identify technology gaps, problems, and opportunities in the NDE of composites. The problems associated with inspecting advanced composites were placed in perspective by the invited presentations. In the proceedings of the workshop (NMAB-316) the committee made four principal recommendations concerning flaw detection, measurement of strength, standardization, and further research.

The report of the ad hoc Committee on Materials for Radiation Detection (NMAB-287) surveyed the available information on detectors for the electromagnetic radiation spectrum in four wavelength groups: x and gamma rays; ultraviolet, visible, and near-infrared; infrared radiation from 2 to 200 micrometers; and far-infrared and millimeter wavelength radiation. Recommendations included the need for fundamental studies and further research on selected materials for specific applications. Another NMAB ad hoc committee completed its study of metal matrix composites (NMAB-313). The objective was to review all aspects in the design and production of advanced composite parts with the view of making them cost-competitive so that the full advantage of their superior performance can be realized.

NMAB has a long-term study to address multi-agency interests in the fire safety aspects of polymeric materials. The first volume of the committee's report (NMAB-318) was published this year. It addresses the fire safety aspects of polymeric materials in the furnishings of aircraft (civil and military). Late in the year, the ad hoc Committee on Structural Adhesives for Aerospace Use completed its report (NMAB-300) in which consideration was given to the state of the art and future needs in the synthesis and formulation of adhesives. Recommendations included the need for an improved data base, the extension of research in the application of fracture mechanics, development of nondestructive test methods, and better techniques for design and analysis of adhesive-bonded joints.

## Education

The *Commission on Human Resources*—(NRC), formerly the Office of Scientific Personnel, administers on behalf of NASA the NRC-NASA Resident Research Associateship program of postdoctoral and senior postdoctoral awards. In this program, awardees conduct scientific or engineering research in NASA laboratories as visiting investigators. The activity of the postdoctoral Associates contributes to the research effort of the NASA Centers. Publication of the results of the Associates' research is encouraged, and thus research results from NASA are made available to the general scientific and technical communities of the United States. On August 31, 1974, there were 179 Associates on tenure.

**X**

# Office of Telecommunications Policy

## Introduction

The Office of Telecommunications Policy (OTP) is an independent agency within the Executive Office of the President. As established by Reorganization Plan No. 1 of 1970 and further specified by Executive Order 11556, OTP has three major functions: (1) to serve as the President's principal adviser on communications policy; (2) to establish policies and provide coordination for the Federal Government's communication systems; and (3) to serve as spokesman for the Executive Branch on communication matters, enabling the President to act as a more effective partner in discussions of communications policy with the Congress, the Federal Communication Commission and the public at large. In furtherance of its charter, OTP develops plans, policies, and programs with respect to communications that are 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 communication technology.

During 1974, OTP was active with a range of communication matters involving the application of space technology. International discussion on mobile satellite communication services continued to focus on aeronautical and maritime programs. In accord with OTP policy guidance, a Memorandum of Understanding was signed by the U.S. Federal Aviation Administration, the European Space Research Organization (ESRO) and the Government of Canada for an experimental aeronautical satellite system to serve international civil aviation flights over the Atlantic.

Talks continued during the year, primarily within the Intergovernmental Maritime Consultative Organization (IMCO) Panel of Experts, regarding the need for establishing an international maritime satellite service designed to improve communication to ships at sea. The Office also forwarded to Congress proposed amendments to the Communications Satellite Act of 1962 to reflect changes that have oc-

curred since the time the original legislation was enacted into law.

The potential future use of communication satellites to broadcast television transmissions directly to home receivers is a subject which has continued to generate debate within the United Nations. At the Fifth Session of the U.N. Working Group on Direct Broadcast Satellites held in Geneva in March of 1974, the United States tabled draft principles on direct broadcast satellites in the interest of identifying and building on areas of common agreement. Although some progress was made in this regard, there nevertheless continues to be wide differences of opinion on the principles which should govern the use of direct broadcast satellites.

An integral part of OTP's mandate is the continuing review of the space telecommunications demands for use of the radio spectrum which is a limited natural resource. This goal is accomplished through the frequency management program within the office. During 1974, the Office participated in the World Maritime Administrative Radio Conference of the International Telecommunication Union held in Geneva. OTP, along with the Federal Communications Commission and the Department of State, is involved with the preparation of the U.S. position for the 1977 Broadcast Satellite Conference of the International Telecommunication Union for the use of the frequency band 11.7-12.2GHz. Also during the year, the Office, continued to monitor development on the question of insurance coverage for the launch of communications satellites.

## Aeronautical Satellite Experiment

Policy guidelines were issued by OTP in early 1971 for the development of a national program on satellite communications for international civil aviation operations. Operating within the OTP policy framework, extensive negotiation with foreign authorities have been carried out by the Department of Transportation, Federal Aviation Administration (DOT/FAA) and the Department of State. After three years of negotiation, a Memorandum of Under-

standing was signed in 1974 by the DOT/FAA and Canada concerning a joint program to test the use of satellites for improving air traffic control. The experimental AEROSAT program will explore ways of using satellite capabilities to improve the cost effectiveness of oceanic en route services, including the possibility of combining or reducing air traffic control facilities. The planned experimental system will consist of two geosynchronous satellites over the Atlantic Ocean and two ground stations in Europe and North America. Each satellite will contain five L Band communication channels, and two VHF channels. The space segment will be jointly owned by ESRO and Comsat (the U.S. private sector participant) each owning 47 percent, and Canada owning 6 percent. Consistent with U.S. policy guidelines, the space segment will not be government owned and the FAA as a systems user will lease circuits from COMSAT, a private commercial carrier. The first satellite is scheduled for launching in the 1977-78 time period and the second will follow at a later date.

### **Maritime Mobile Satellite Service**

The Intergovernmental Maritime Consultative Organization (IMCO) continues to be the principal international forum for discussions concerning the provision of international satellite telecommunications to merchant ships at sea. The Panel of Experts of IMCO met again in London in September 1974 to review the economic, technical, and institutional issues that the creation of such a system raises. The U.S. continues to analyze user requirements in relation to the establishment of maritime satellite telecommunications services while at the same time reserving judgment on the institutional means of providing such service. A world conference initiated by IMCO is scheduled for April 1975 to consider the desirability of creating a new international organizational structure to provide maritime satellite services. OTP is coordinating the development of the U.S. Government's position for this conference and, in concert with other interested parties, is formulating the Administration's maritime communications satellite policy.

As a related matter, the development of a maritime satellite system (MARISAT), designed to meet the needs of the U.S. Navy between 1974-76, continues to be an area of policy review by OTP. The MARISAT program which has a five year design lifetime, will also provide limited commercial services for maritime users during the initial years of use. Later when Navy use is terminated, the entire satellite will be capable of providing commercial maritime service.

### **Proposed Amendment to Communications Satellite Act of 1962**

OTP submitted legislation to Congress that would amend the Communications Satellite Act of 1962. The 1962 Act called for the creation of a commercial communications satellite system as part of an improved global communication network, and it created the Communications Satellite Corporation (COMSAT) as the chosen instrument of the United States for accomplishing the purposes of the Act. The amendments are designed to update the Act to reflect current conditions in international communications but do not change the basic policy premises underlying the original legislation. In 1962 there were a number of technical and operational uncertainties regarding the creation of COMSAT to serve as the chosen instrument of the United States in a global system. These uncertainties gave rise to the inclusion of several provisions in the Act relating to COMSAT's ownership and the conduct of its affairs, provisions not normally associated with a private communications common carrier enterprise. With the successful establishment of the International Telecommunications Satellite Organization's (INTELSAT) global communications satellite system and the emergence of COMSAT as an established and mature corporation, it is appropriate to remove a number of these special provisions. Such changes would:

- (1) Eliminate the requirement that COMSAT incorporate in the District of Columbia.
- (2) Repeal the provision calling for Presidentially appointed and common carrier elected directors.
- (3) Eliminate the special class of common carrier stock.
- (4) Reduce permissible common carrier shareholdings to five percent.
- (5) Permit COMSAT to issue par value stock.
- (6) Repeal the requirement for COMSAT to obtain FCC approval prior to obtaining additional capital.

In addition, the possible emergence of specialized international satellite systems that would be separate from the INTELSAT system is also recognized. One amendment would make explicit that COMSAT could participate in such new international systems, on a non-exclusive basis, thus legislatively affirming an FCC rule-making decision to the same effect in the context of domestic satellite systems. Another amendment clarifies the Executive Branch role in the planing, implementation, and operation of new international satellite systems that are developed pursuant to international agreement in which the United States is a party.

## Direct Broadcast Satellites

The possibility of the use of telecommunications satellites for broadcast of television programs directly into home receivers continues to generate interest, particularly in the United Nations. The United Nations Committee on the Peaceful Uses of Outer Space and its two subcommittees have been studying this question for a number of years.

Although there are international legal instruments which impact on the question of direct broadcast satellites already, for example, the United Nations Charter, the Outer Space Treaty, applicable provisions of the International Telecommunications Convention and Regulations, certain relevant principles expressed in the Universal Declaration of Human Rights and Resolutions of the General Assembly, the desirability of a particular convention to govern this type of direct broadcast has been expressed. The United Nations General Assembly has called for the elaboration of principles to govern states using satellites for direct television broadcasting.

Among the many problems involved in creating such an agreement, the most crucial one is related to the principle of freedom of information. Two opposing views emerged in the debates on this issue. One view, shared by the United States, stresses the concept of the free flow of information; the other view stresses the concept of prior consent, that is, the notion that no state should be allowed to engage in such broadcasting without the prior approval of the state which may be the intentional or unintentional recipient. The United States voted against the resolution calling for creation of a Convention to govern states using satellites for direct television broadcasting, and is fundamentally opposed to any legal regime inhibiting the free flow of information.

The United States, however, has been receptive to discussing general principles that could appropriately apply to the use of direct broadcast satellites. The United States tabled a set of voluntary principles in March 1974 at the fifth session of the U.N. working group on Direct Broadcast Satellites in Geneva. While some support for U.S. views was evidenced, there nevertheless continues to be wide differences of opinion over the formulation and application of appropriate principles to govern the use of this technology. These differences continued to be apparent when the Legal Subcommittee failed to achieve agreement on principles at a subsequent meeting in May 1974. Debate continues on this issue, and the matter is unresolved.

OTP participated in the deliberations of both the U.N. working group of Direct Broadcast Satellites and the Legal Subcommittee, and will continue to work with other interested U.S. agencies in formulating and presenting U.S. policy views on this issue.

## Frequency Management

The radio spectrum consists of that portion of the electro-magnetic spectrum by which radio communications are conducted. This resource, shared by all countries of the world, requires coordination, not only on a national basis but also on an international basis to ensure mutual compatibility of radio frequency usage.

National spectrum planning, known as frequency management, is carried out by the staffs of the OTP and the Federal Communications Commission (FCC) with assistance from the Interdepartment Radio Advisory Committee (IRAC), the latter being made up of representatives of major Federal Government departments and agencies using radio. International spectrum planning is done under the auspices of the International Telecommunication Union (ITU), a specialized agency of the United Nations located in Geneva, Switzerland, and composed of 148 member Administrations.

Satellite systems are dependent upon access to radio frequencies for their successful operation. Spectrum management procedures referred to in the paragraph above have been refined to accommodate the unique requirements of satellite and space services. The system review procedure established over a year ago is proving itself as the number of satellite systems increase, each competing for spectrum in which to operate. Considerable experience has now been gained with this review procedure whereby each new proposed satellite system is studied to ensure the availability of spectrum prior to the expenditure of funds for development and procurement. This same review procedure is used to assess the compatibility of satellite systems proposed by other countries with those of the U.S.A.

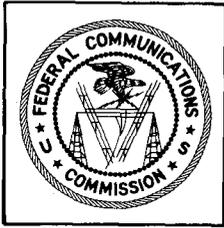
Under OTP guidance, the IRAC, including a liaison representative of the FCC, completed the development of U.S. proposals for the ITU World Maritime Administrative Radio Conference that was held in Geneva, Switzerland, from April 22 to June 9, 1974. Also proposed were position papers for use by the U.S. Delegation to that Conference in considering the proposals of other countries. The Final Acts of the Conference included several additions to the International Radio Regulations to permit the orderly introduction of maritime satellite communications.

## Satellite Launch Insurance

The financial costs associated with the launch of communication satellites is a significant factor in the development of operational systems. Experience has shown that the possibility of launch failure poses considerable business risks to private communications

companies interested in deploying commercial systems. In 1974, OTP surveyed both prospective system operators and the insurance industry to determine whether the availability of commercial insurance against launch failure is a significant barrier to entry by potential suppliers of service. Limited experience to date indicates that insurance coverage,

at reasonable rates, is commercially available from the private sector. Recent experience has been exceptionally encouraging, with insurance coverage being initiated in 1974 for the first launch of a multi-launch program. Consequently, it appears that alternative arrangements for providing suitable insurance coverage will not be necessary.



# Federal Communications Commission

## Introduction

The objective to provide the new and expanded telecommunications services offered by the global satellite system to all countries and areas of the world is continually being furthered with the increase of membership in INTELSAT. An addition of three countries in 1974 has brought the total membership of this international organization to 86. Three of the five domestic satellite systems authorized by the Commission under the domestic satellite policies adopted during 1972 were placed into commercial operation during 1974. Arrangements were made to establish an experimental satellite system in the North Atlantic Area for the provision of an aeronautical mobile satellite service. The first of three maritime satellites ordered in 1973 is scheduled for a late 1974 delivery for launch early in 1975.

## Communications Satellites

### *INTELSAT*

The INTELSAT system presently consists of three INTELSAT IV satellites (two operational and one spare) in the Atlantic Ocean Region, two INTELSAT IV satellites (one operational and one spare) in the Pacific Ocean Region and one INTELSAT IV satellite in the Indian Ocean Region. A spare INTELSAT IV satellite in both the Pacific and Indian Ocean Regions is scheduled to be launched in early 1975. The "Follow-on" program to the IV series is planned for use in the Atlantic Ocean Region and is scheduled for operation in 1975.

The worldwide network of earth stations has grown to 94 antennas at 74 station sites in 55 countries. Additional stations are planned for completion by end-1974 for a total of 108 antennas at 86 station sites in 62 countries. Additional earth station antennas were authorized in 1973 and are under construction at two earth station sites (Etam, West Virginia and Andover, Maine) on the east coast of the United States. The continued construction of earth station facilities around the world indicate the

growing reliance on satellites for international communications.

### *Domestic Satellites*

The interim domestic satellite system of RCA Global Communications, Inc. and RCA Alaska Communications, Inc., using Telesat Canada Anik satellites on a temporary basis until RCA's domestic satellites are placed in orbit during 1975, was placed into service in late December 1973. By the end of 1974, the RCA companies plan to have six earth stations operational in Alaska and three earth stations operational in the lower 48 states. Additionally, in a comprehensive Alaska service plan filed this year, RCA Alaska Communications indicates its intention to construct a total of 38 major (10-meter) and 38 minor (5-meter) earth stations by 1980 to provide message telephone service and television service to 284 communities in Alaska with populations greater than 25 persons.

The first United States domestic satellite, the Westar I of the Western Union Telegraph Company, was successfully launched into the geostationary satellite orbit on April 13, 1974 and commercial service using this satellite was begun by Western Union on July 26, 1974. The second Western Union satellite, Westar II, was launched October 10, 1974. Five earth stations, with nominal 50-foot diameter antennas, are now in operation serving the New York, Texas, California, Chicago and Atlanta areas.

The third domestic satellite system placed into commercial operation during this year was the American Satellite Corporation's system using the Western Union's Westar satellite. Commercial service was begun in early August 1974, between earth stations in California, New York and Texas, with another earth station in the Chicago area planned to be placed into service later in the year. In addition, another five earth stations will be in operation by the end of 1974 to provide digital, high-speed channel service to the Defense Communications Agency.

The American Telephone & Telegraph Company (AT&T) domestic satellite system authorized in

1973 using satellites owned by Comsat General Corporation is under construction and should be placed into service by late 1975 or 1976. In addition, a proposal filed in 1974 by GTE Satellite Corporation to use these satellites together with AT&T instead of the system using satellites authorized in 1973 to National Satellite Services (a subsidiary of Hughes Aircraft Company) was set for hearing.

Although no new domestic satellite systems were proposed to the Commission during 1974, a proposal for a major restructuring of the CML Satellite Corporation, who has domestic satellite applications pending before the Commission, was received. The proposal, if approved by the Commission, would result in an ownership of CML by Comsat General of 45% and by IBM of 55%.

Another major issue before the Commission is the use of small earth terminals, i.e., earth stations with antennas of diameters less than about 10 meters, and the impact on orbit utilization. Proposals with regard to two specific types of applications of such terminals, on offshore drilling platforms in the Gulf of Mexico and in small communities in Alaska, were pending before the Commission at the end of 1974. Studies on orbit spacing requirements for the presently authorized domestic satellite systems should be completed during the first half of 1975, with definite orbital location assignments made soon thereafter.

### **Specialized Satellite Services**

#### *Maritime Mobile Satellite Service*

The Commission is continuing to work both nationally and internationally to further the development of a maritime mobile satellite service. Such a service will significantly improve maritime communications in terms of accuracy, reliability, speed and variety of transmission modes, which will, in turn, enhance maritime safety and management.

Internationally, the Intergovernmental Maritime Consultative Organization (IMCO), 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. An initial meeting of the governments is planned early in 1975 to consider the report of the Panel of Experts. In preparation for this meeting, the Commission instituted in December 1974 an inquiry to help formulate the U.S. position on the establishment of an international maritime satellite system.

In April 1973, the Commission issued waivers allowing the construction of three satellites that will be part of a five-year system intended to provide service

to the Navy as well as to maritime users beginning in early 1975. One satellite is planned for deployment over the Atlantic and another over the Pacific with the third held as a spare on the ground. In August, the Commission authorized a consortium of four carriers to participate in this Navy/Maritime system.

The Navy communications services will be provided in the UHF band on a lease basis for a period of years beginning in 1975. The satellite capacity used by the Navy will be under its control and will be used to provide fleet communications. The satellite design is such that during the period of the Navy service, most of the satellite power will be required to meet the Navy service requirements; only limited power will be available for commercial maritime use. When the Navy service is completed, however, the entire satellite power can be utilized to provide 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 (ESRO), and the Canadian Government on the basic arrangements for the establishment of an experimental satellite system in the North Atlantic Area. Comsat General Corporation has been chosen as the U.S. partner in the joint system which is expected to be operational in early 1978.

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. Between satellite and aircraft, 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.

### **International Telecommunications Union**

During 1974, Commission personnel served as members of the U.S. Delegation to the World Administrative Radio Conference on Maritime matters convened in Geneva, Switzerland. That Conference continued to provide the necessary guidance and planning, building on that which was already in progress for an international maritime mobile satellite service along many of the lines proposed by the United States.

The Administrative Council of the International Telecommunication Union, which met during the summer of 1974, agreed to the convening of a General World Administrative Radio Conference be-

tween 1979 and 1980. This major conference will deal with overall revisions to the current international Radio Regulations governing all radio services, including the aeronautical and space services.

The last such conference was held in Geneva in 1959, lasting over four months. ITU World Administrative Radio Conferences held since that date have been limited to considerations involving only one radio service.

Because of the wide scope of the forthcoming General Radio Conference, the very extensive preparatory work required is already under way, taking into account the frequency requirements of all radio services and the many other international technical and operating regulations which will be involved. The Commission expects to initiate a proceeding to obtain public comments on the various U.S. proposals as they are developed.

Preparatory work was initiated for the 1977 Broadcasting World Administrative Radio Conference scheduled to plan for the use of the frequency band 11.7–12.2 GHz now allocated for use by terrestrial radio services and direct satellite broadcasting.

## **Frequency Allocation and Coordination**

The Federal Communications Commission, through an informal working group of technical personnel from government and industry, sponsored the development of computer programs for calculating the coordination areas, and for determining the likelihood of precipitation scatter interference between proposed earth stations for satellites and conventional microwave terrestrial stations using the same frequencies. Employment of these computer programs will enhance the ability to share the crowded radio frequency spectrum between space and terrestrial radio services.

In response to the radio astronomy community's concern of possible harmful interference from adjacent band space-operations, a new U.S. footnote to the Table of Frequency Allocations has been proposed in a Notice of Proposed Rule Making released August 30, 1974. The new footnote would urge the radio astronomy community and planners to minimize potential interference to the radio astronomy operations.



## Introduction

The Smithsonian Institution continued its unique support of national aeronautics and space goals through basic research in diverse fields of modern astronomy combined with far-reaching programs of education and information designed to heighten public awareness and understanding of the role of space science and exploration in the advancement and betterment of human life.

During the past year, Smithsonian observing stations gathered astrophysical and geophysical data to describe the Earth as a planet and to define the space environment in which it exists. Laboratory analyses of extraterrestrial materials continued in the search for clues to the origin of the Earth and the evolution of the solar system. Experiments aboard satellites, balloons, and rockets observed celestial sources unattainable from the ground in an attempt to understand the basic physical processes underlying the generation of energy and the creation of matter, including life itself.

The complex story of life's emergence on Earth and the search for its possible existence elsewhere in the universe was presented in a new museum exhibit prepared for general audiences.

## Smithsonian Astrophysical Observatory

The Smithsonian Astrophysical Observatory (SAO), in cooperation with the Harvard College Observatory, continued to pursue a broad program of investigations designed to increase man's understanding of the universe. Specifically, this program included participation in international studies of earth dynamics, the analyses of extraterrestrial materials, and active participation in space flight missions.

### *Geoastronomy.*

Smithsonian's research in Earth dynamics is an integral part of NASA's Earth and Ocean Physics Applications Program (EOPAP), and has as its primary objective the definition of an operational

earthquake Hazard Assessment and Alleviation (EHA) model and system by 1983. Necessarily, a basic goal of this program is to create the vast data base required to define the kinematics, bulk dynamics, and mass distribution of the Earth.

Observational data is provided by laser ranging on satellites, as well as from photographic and visual observations of satellite motion, and other precision tracking techniques. SAO's own global network of satellite tracking stations supports the geophysical investigations and analyses, as well as related research on the physics of the upper atmosphere. For example, detailed studies of satellite motion are used to investigate the density and temperature of the upper atmosphere, leading to an improvement in mathematical models for predicting atmospheric conditions based on solar and geomagnetic parameters observed on the ground.

Mapping of major structures of the African rift system based on ERTS-1 imagery is essentially completed. Features such as faults, lineaments, volcanic craters, and lithological boundaries for an area including Ethiopia, Somalia, and Yemen are shown on a composition map of 1:5 million scale. The studies have revealed both unsuspected crustal features and new geological activity that may provide clues to the region's formation.

### *Extraterrestrial Materials*

Various investigations continued on lunar rock and soil samples returned from Apollo and Luna sites. Techniques employed included optical microscopy, x-ray diffraction, and isotopic measurements. One important goal was the detection and identification of the composition and textural relationships of the minerals and glasses of lunar crustal rocks as an aid to eventual deductions about the original and subsequent history of these materials. To this same end, a special investigation of an Apollo 17 breccia boulder is being carried out by a large consortium of scientists led by a Smithsonian geologist. A second aim of the consortium is to learn more about the large-scale processes involved in the

generation of these breccias (rocks consisting of sharp fragments embedded in a fine-grained matrix).

Similar investigations were begun on 46 selected particles from the Allende Meteorite, recovered from northern Mexico, in an attempt to understand better the distribution of elements in the early solar system.

During the early months of the past year, SAO served as a major clearinghouse for information related to the international program to observe and study Comet Kohoutek. Ground-based radio observations conducted by a Smithsonian-Harvard team detected the presence of organic molecules in the tail of this comet.

### ***Space Flight Experiments***

In February, a balloon-borne 40-inch lens diameter telescope constructed by SAO in collaboration with Harvard College Observatory and the University of Arizona was successfully flown from Palestine, Texas. It was carried to an altitude of 90,000 feet, where, by remote command, it mapped the intensity of far-infrared radiation of selected regions of the Milky Way, including NGC 7538, Mars, Orion A, and W3. The observations represent the highest resolution (0.5 arcmin) ever obtained at these wavelengths.

Smithsonian scientists were involved in observations from the Harvard-designed Extreme Ultraviolet Spectrometer on Skylab to study physical conditions in the solar chromosphere and corona. Analysis of the resultant data has led to the discovery of coronal holes as well as contributing to a better understanding of sunspots, prominences, flares and the Sun's basic energy-generation processes.

Solar studies also continued with the analysis of far-ultraviolet spectrum data obtained by a series of rocket-borne Ebert spectrometers. The fifth successful flight in May 1974, aboard an Aerobee 200 rocket, yielded very high spectral resolution at the center of the disk and near the solar limb.

### ***High-Energy Astrophysics***

The field of x-ray astronomy continues its rapid development as one of the most promising areas for potential understanding of basic physical processes. SAO programs in this field represent major contributions to understanding the extraordinary cosmic sources of energy that appear to be greater than nuclear. Analysis of data obtained by the UHURU satellite continued in an effort to complete an in-depth survey of the x-ray sky. Studies of the time variation, size, and spectrum of x-ray sources, as well as their luminosity and spatial distributions and correlation with other astrophysical phenomena, led

to the detection of Circinus X-1, a second possible "black hole" (a collapsed star of such overpowering density that its gravity field will not allow light to escape).

SAO prepared the United States experiment aboard the Astronomy Netherlands Satellite launched August 30, 1974, to measure energy spectra of the stronger x-ray sources, to detect the silicon line emission, to observe the time variability of stronger sources, to improve the position measurements of selected intermediate strength sources, to observe the surface brightness of extended sources, and to observe x-ray sources simultaneously with ground-based radio and optical instruments.

SAO experiments now being prepared for the NASA HEAO-A and B missions, are designed as the first precision x-ray observatories in space. The first experiment will locate x-ray sources to a precision of 5 arcsec as an aid in their identification with optical and radio sources. The experiment will also measure the size and spatial structure of the sources in three x-ray energy bands.

The second experiment (HEAO-B, scheduled for launch in June 1978) will produce high-resolution spatial, spectral, and temporal observations of galactic and extragalactic x-ray sources, as well as of the diffuse x-ray background. That experiment will be a collaborative effort among five research institutions including SAO.

Smithsonian is also conducting x-ray studies from rockets. One experiment has observed the structure of the Vela-Puppis region in x-rays, another observed the Perseus Cluster and determined the location of a high-galactic-latitude source so far unidentified.

A second rocket experiment carrying a high-resolution x-ray telescope with an x-ray image intensifier will be flown in mid-1975 to observe the x-ray source Cas A, a supernova remnant.

### **National Museum of Natural History**

Research on extraterrestrial materials, particularly the relationship between recovered meteorites and returned lunar soil samples, continued in the Museum's Department of Mineral Sciences. Analysis of lunar material concentrated on Apollo 17 samples, while meteoritical research concerned the analysis and description of several recently fallen objects.

### **Center for Short-Lived Phenomena**

The Smithsonian Center for Short-Lived Phenomena receives and rapidly disseminates news of transient geophysical, biological, and astrophysical events of major scientific importance. The Center

is a facility of the Office of International and Environmental Programs.

The Center's participation in astrophysical and space activities in 1974 included the reporting of six fireballs observed in Austria, Germany, Ireland, Minnesota, Ohio, and Wales; and three meteorite falls in Connecticut, Iran, and the U.S.S.R. The Center assisted in efforts to recover the meteoritical material and to distribute samples to the scientific community.

During the flight of SKYLAB 4, the Center coordinated a "Short-Lived Event Alert Program" by which the orbiting astronauts were notified of major, on-going, natural earth events with potential visibility from the spacecraft. Among the events reported by the program were volcanic eruptions, insect irruptions, oil spills, earthquakes, and forest fires.

### **National Air and Space Museum**

In addition to serving as both the repository and display center for this country's artifacts on space exploration, the National Air and Space Museum (NASM) supports programs of active research through its Center for Earth and Planetary Studies.

A major part of the Center's research this year concerned Earth-oriented studies in support of the Apollo-Soyuz Test Project (ASTP). The Center will coordinate the visual and photographic observations from space designed to yield basic information in the fields of geology (mineral resources), oceanography, hydrology (including deserts and drought areas), and meteorology. Activities included planning and execution of a training program for the American astronauts, establishment of observational requirements, and selection of potential sites for observation and photography based on a review of all available data from the Skylab and the ERTS programs.

Lunar research focused on the geological mapping of the Moon using Apollo photographs. In cooperation with the U.S. Geological Survey, a geological map of the east side of the Moon was completed and mapping was begun of ridges and arches in the Angstrom region, sinuous rilles in the Prinz region, and unique multi-ringed craters in Mare Smythii. An atlas of Apollo photography, to be published in cooperation with the U.S. Geological Survey and NASA, is in preparation.

In a related project, global stratigraphic units of the Moon were correlated with results of the orbital geochemical sensors and geophysical experiments, including the Lunar Sounder.

Center personnel participated in a joint US-USSR meeting in Moscow to study possible cooperation between NASA and the USSR Academy of Sciences in lunar cartography. Subsequent to this meeting, materials were prepared for the exchange of technical opinions regarding:

- a) the basic principles for compiling lunar maps;
- b) establishment of a unified selenodetic control system; and
- c) a joint production of a map of the Moon at 1:5,000,000 scale.

In cooperation with the International Astronomical Union, a revision of the lunar nomenclature system was undertaken. Names were assigned to craters and other lunar features on lunar maps at 1:250,000 and larger scales that serve as a base for geological studies of the Moon.

Construction on the new Air and Space Museum facility proceeded on schedule. In preparation for its opening July 4, 1976, a new exhibit entitled "Life in the Universe", describing the origin of life on this planet and the search for its existence elsewhere in the universe, was completed. Among other diverse education and information activities, the Director of the Earth and Planetary Center conducted a lecture tour of five Arab nations in cooperation with the USIA.



## Introduction

The Environmental Protection Agency (EPA) is involved in an extensive program to identify critical monitoring requirements and the aerospace technology which can fulfill these requests. A comprehensive series of plans and programs have been undertaken in 1974 which will cause proven technology to be focused on the problems at hand and provide environmental decision makers with data and information which represents the practical state-of-the-art in overhead remote sensing monitoring systems.

The goals and requirements of the EPA program to provide Regions, States and local agencies with a comprehensive monitoring program are:

### Goals—

- Provision of information and records for definition and establishment of an environmental quality data base;
- Provision of data to support enforcement standards;
- Fulfillment of other statutory requirements, including examination and substantiation of environmental impact statements;
  - Alerting the public, the academic community, and industry to environmental hazards;
  - Assuming the role of a reliable source for comprehensive environmental data;
  - Providing point source and non-point source data to demonstrate and evaluate the results of EPA programs;

### Requirements—

- Identification of pollutants and categorization of important components and interactions of selected subsystems within the study areas;
- Conduct of pilot investigations at representative locations within critical study areas to establish "ground truth" to verify remote sensing data;
- Plans for area wide collection of environmental data;
- Initiation of a system for acquisition and storage of environmental data related to individual ecosystems or large geographical areas.

Recognizing that it is presently impossible for remote sensors to quantify pollution levels sufficiently for enforcement actions, the EPA is involved in exhaustive tests on photographic systems, lasers, multi-spectral scanners and spectrometers to identify trends, quantify specific pollutants and evaluate compliance to standards, in air, water and land environments for the environmental decision maker. It is anticipated that the program will lead to a full appreciation of the technology required to monitor the 3.5 million square mile area of the United States.

## Organization of Remote Sensing Activities

The direction and management of the EPA airborne and satellite monitoring program is provided by the Office of Research and Development (OR&D), EPA. The primary organization conducting monitoring research and applications for OR&D is the National Environmental Research Center (NERC) in Las Vegas, Nevada. The facility, along with the Environmental Photographic Interpretation Center (EPIC), Warrenton, Virginia, is responsible for the test and demonstration of new sensors and for the demonstration of applications to the EPA Regions and State and local environmental organizations. During 1974 the two organizations were involved in more than 40 projects:

Examples include:

- Test and development of multi-spectral scanner, laser and camera systems to detect and monitor point and non-point pollution sources;
- Emergency oil spill response to locate oil spills and other hazardous spill materials;
- Test and evaluate techniques, methods and sensors required to support enforcement of Regions;
- Identify, locate and track and identify pollution from landfills, mine drainage and thermal power plants;
- Perform inventories of water discharge sites and other industrial and urban pollution sources;
- Monitor land degradation and land use activities of energy related extractive and processing industries.

The resources within EPA to demonstrate new sensors and applications are limited. Therefore, EPA has undertaken a series of interagency agreements with mutually interested Federal agencies. The objective of this program is for EPA to gain an accelerated position by realizing some of the scientific and technological achievements of the participating organizations. This approach is derived from Federal statutes which direct the Administrator to pursue coordinated activities with other agencies that will improve the development of techniques for monitoring environmental quality.

Formal agreements have been established with the National Aeronautics and Space Administration (NASA), the Departments of Interior and Army, the Air Force Systems Command, Naval Ordnance Laboratory and the Corps of Engineers. In addition, programs with several universities and with the Iowa Geological Survey have been undertaken to expand the Agency scope.

An interagency program of specific interest is now being formulated between EPA and NASA. The purpose of the project is to encourage NASA to demonstrate its developed remote sensing and data management technology and capabilities which may significantly assist Region V, Chicago, in its mission to monitor the water quality of the Great Lakes. The pilot project will enable EPA and NASA to demonstrate, by project application, the type of support capability that could be derived by interagency agreements. It is envisioned that the project will assist in the refinement of management and interagency coordination and enable the two agencies to expand the plan to aid other EPA Regions.

### **Aircraft Oriented Research and Applications**

During 1974 a number of significant programs were undertaken and important advances were made. A summary of the most important aircraft oriented projects follows:

1. The NERC at Las Vegas is involved in a major research program to utilize new and existing data to detect, locate and analyze the significant spectral signatures of the major pollution sources in the United States. It is expected that the program will result in the development of an operational data collection, processing and analysis capability at the NERC at Las Vegas and at the EPIC. The facilities will be available to EPA Regions for special requirements, i.e., enforcement documentation and emergency response where outside contracts are not feasible. The other major result of this program will be the formulation of a set of procedures and a system of technology transfer to private industrial organiza-

tions for their application to EPA operations as a contractual service.

2. Aerial surveillance by EPA was utilized by the State of Illinois to show how heated water spread into Lake Michigan from Indiana Harbor. Through the use of camera systems, infrared scanner data and skylab imagery, EPA scientists identified and traced a heated plume of polluted water into an area of Lake Michigan where the city of Chicago draws its drinking water supplies. The case is significant because it is the first use of infrared data in an enforcement action by EPA.

3. A 2,500 square mile area of southwestern Louisiana was studied and a series of thematic overlays were keyed to topographic maps to depict potential pollution sources associated with industrial complexes, solid and liquid waste dumps, petroleum fields, urban landfills, car dumps and industrial landfill areas.

The data utilized were taken from existing files of other government agencies and analyzed from the EPA viewpoint and needs. In addition, aerial photography of selected areas was obtained and the data incorporated into the final product.

It is envisioned that products similar in scope and size can be prepared for all Regions on a priority basis to meet water and air discharge permit requirements. Such programs can be prepared on an emergency basis by EPA or routinely by private firms under contract.

4. NERC/Las Vegas, EPIC and Region VIII, Denver, are participating in a major program to obtain photographic records of 30 mining sites and the majority of the oil shale lease lands of the Western United States. The objective of the program is, to provide, for public review, data that allows for visual evaluation of disturbed areas and the environmental conditions involved with the strip mine areas in the northern Great Plains. The program will provide color and color infrared photography of all sites and thermal imagery of selected power plant sites. The Region envisions that the existing data base and newly acquired data will be invaluable in its enforcement and discharge permit programs and for planning and monitoring purposes.

In conjunction with the High Plains Project, the NERC at Corvallis, Oregon and EPIC are involved in a project to monitor, over a period of four years, a major coal mine and an associated power plant to ascertain what effects development and expansion have on the environment. The task involves detailed analysis and ambient monitoring of vegetation, water and air and an analysis of effects on groundwater.

5. EPIC, Region VII, Kansas City, and the Iowa

Geological Survey are involved in a joint program to inventory an eleven county area of south central Iowa. The inventory was specifically designed to identify feedlot operations, all existing waste disposal sites and all surface water resources. The data will be presented on overlays keyed to uncontrolled photo mosaics.

The results of this cooperative effort will be utilized by the Region for its outfall permit program, by the State for its inventory of surface and sub-surface water resources and by the Office of Research and Development in its research program for monitoring of groundwater pollution and the direct effects that land use has on the quality of groundwater.

6. EPIC, Cornell University, the New York Department of Conservation and the New York EPA Regional Office are participating in a joint program to determine the application of camera systems and infrared sensors to detect, and track effluents from landfills. The project is comprised of 16 sites located in central New York. The program will take six months to complete and require 14 flights at varying altitudes in three seasons with a series of film-filter combinations.

7. Other programs of interest include two surveys of thermal power plants in New England and Iowa and a project to determine to what extent aircraft acquired data can be utilized to establish evidence for enforcement cases.

### **Space Programs and Applications**

The EPA has an active program to establish the use of Earth Resources Technology Satellite (ERTS) and Skylab data in its research and applications programs. A number of EPA scientists have been active in the program since its inception. In particular, the Director of EPIC acts as a principle investigator for both the ERTS and Skylab programs in EPA. Under his guidance a number of applications have been made available to the Regional EPA user organizations and data have been provided to researchers at the NERC at Corvallis and EPIC. The most significant programs of 1974 are:

1. The EPA Region V, acting as coordinator for the Great Lakes Commission, contracted with the Laboratory for Applications of Remote Sensing, Purdue University, to map 133,000 square miles of the

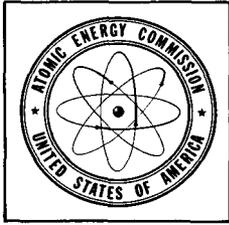
Great Lakes drainage basin. The project calls for the mapping, through digital processing, of seven categories of land use. The data will be ground checked and correlated with aircraft acquired data. The program was undertaken after feasibility was shown in a pilot project produced by the EPA Office of Research and Development and the NASA University Affairs Office.

2. The EPA has been involved in a three year program to ascertain and monitor the physical state of 1000 lakes in the United States. During the past year, the NERC at Corvallis, has performed intensive research with ERTS computer compatible tapes to determine possible monitoring applications. The program is attempting to determine if ERTS data are useful in locating and estimating lake surface area and determining if correlation exists between the red band data and chlorophyll A; the IR bands and chlorophyll A, and the green band and the clarity of the water. In addition, regression models are being developed for estimating the physical state of a number of lakes and attempts have been made to map major occurrences of surface and sub-surface micro-organisms.

3. In the summer of 1974, EPA scientists and managers participated in the "Summer Study of Space Applications" originating from a request by Dr. Fletcher, NASA Administrator, and sponsored by the Space Applications Board of the National Academy of Engineering. The EPA personnel were not formal members of the various panels, but were consultants to the following:

- a. Environmental Quality Panel
- b. Marine/Maritime Panel
- c. Land Use Planning Panel
- d. Inland Water Resources Panel

The needs and requirements of the EPA were stressed in particular the timely organization and delivery of data and the concern for higher resolution. Topics of concern to the EPA were land use planning as a critical tool in environmental enhancement; the monitoring of pollutants in surface and groundwater resources; the agricultural impact (pesticides, fertilizers, feedlot wastes, irrigation) on surface and groundwater; the development of suitable means to measure, monitor and record environmental effects from space; and a means to monitor ocean dumping and its effects on the dynamic ocean environment.



# Atomic Energy Commission

## Introduction

With termination of the nuclear propulsion program in 1973, the AEC's space nuclear program has been concentrated on the development of nuclear space electric power generators. These nuclear power generators have made possible many of the past major United States scientific accomplishments in lunar and interplanetary exploration and they will be essential elements in enabling the future exploration of the solar system to be accomplished. The Apollo lunar surface and Pioneer Jupiter missions of the recent past are notable examples of nuclear electric power as a major and critical element of the success of space programs. In the next few years nuclear electric power will make possible the first scientific exploration of the surface of Mars, the first spacecraft journey to the planet Saturn and beyond, and the testing of a defense satellite where compact and reliable power is a principal determining factor in mission viability. Additional highly sophisticated missions are anticipated in the 1970's and 1980's and higher performance, lower-cost technology is being pursued to prepare for the increased performance demands of these missions.

In each of these applications, it is the unique characteristic of nuclear energy to operate for long periods of time without relying on the sun, along with related attributes such as small size, low weight and long lifetime, which has resulted in the need for nuclear power sources. It is these characteristics which will make possible the exploration of the outer planets. Without nuclear power, exploration of these planets cannot take place as solar power is inadequate at such distances. Likewise, nuclear power sources will make possible and economically practical many high powered missions in Earth orbit which require minimum size but maximum freedom from any sun orientation restrictions.

Specifically, fourteen spacecraft powered totally or in part with nuclear power have been successfully launched in the past, and six more spacecraft are scheduled for launch during the next three years. During 1974, significant progress was made on the

development of the generators for these six spacecraft and on the technology for future, more sophisticated applications. Progress was also made towards expanding and applying the technology base generated in the space program to terrestrial energy related applications.

## Jupiter Spacecraft

On 3 December 1974, the Pioneer 10 isotopically (nuclear heat source) powered spacecraft completed its 18 month journey and passed by the planet Jupiter. It followed its predecessor, Pioneer 10, in providing close range scientific observations of the largest planet in our solar system. Unlike Pioneer 10, however, the trajectory of Pioneer 11 has been targeted to carry it close by the planet Saturn, as the spacecraft continues on its celestial journey out into interstellar space. The Pioneer 10 and 11 missions have been important milestones in the continuous search for knowledge concerning the history and origin of our solar system.

Both the Pioneer 10 and 11 spacecraft are powered by four plutonium 238 isotopically fueled thermoelectric generators. Each generator was designed to provide a minimum of 30 watts or a total of 120 watts per spacecraft during the nearly 2-year journey to the planet Jupiter. All of the generators have exceeded this design goal by several watts and are continuing to operate in excess of the 30 watt minimum. At the end of 1974 the Pioneer 10 spacecraft was about 700 million miles from earth and the Pioneer 11 spacecraft was well on its way to its extended journey by the planet Saturn.

## Lincoln Experimental Satellite

As a part of its program to develop a survivable defense communications network, the DOD will launch in late 1975 two experimental satellites powered by thermoelectric radioisotope generators (RTG's). These satellites, designated LES 8 and LES 9, will each be powered by two multi-hundred watt (MHW) generators providing a minimum total

power requirement of 250 watts, or 125 watts per generator, after five years.

Thermoelectric degradation problems were encountered during tests in late 1973 and a major effort during the first half of 1974 was directed towards understanding the degradation mechanisms and towards design changes to alleviate the problem. The basic problem was a continual decrease in the shunt resistance between the thermoelectric couples and the surrounding insulation foils. Based on accelerated module tests, the selected design fix was to coat the thermoelectric couples with a silicon nitride coating. Fabrication of flight hardware was reinitiated during the early part of the summer on the thermoelectric couples for the four flight and one spare RTG's. Thermocouple fabrication for all of the generators was nearing completion by the end of the year and assembly of the first three RTG's was also nearly complete.

### **Viking Mars Lander**

During the late summer of 1975, NASA will launch two Viking spacecraft with the goal of travelling to Mars, orbiting the planet and descending for a soft landing on the Martian surface. The lander vehicles will each be powered by two Pioneer-type isotopically fueled thermoelectric generators. Each generator will provide a minimum of 35 watts or a total of 70 watts after 90 days on the Martian surface. The ability of these isotopically fueled generators to operate in the harsh environments postulated for the surface of Mars will enable the extended operation of scientific experiments aimed at understanding the composition and history of our closest planetary neighbor. A major goal is to try to answer questions concerning the presence of life.

The modified Pioneer-type generators are being developed by the AEC laboratory and industrial contractors organizations. Three electrically heated test generators were delivered to NASA for systems testing during the year. Effort was also completed on the Final Safety Analysis Report; on the final design freeze of the flight generators; and on fabrication of the flight units except for final assembly and system testing.

### **Mariner/Jupiter Saturn (MJS)**

The next major program to extend man's exploration out into the solar system will involve launching two Mariner spacecraft in the late summer of 1977 to fly past the planets Jupiter and Saturn. These spacecraft will be relatively sophisticated in comparison to the Pioneer 10 and 11 spacecraft and will enable scientists to gain a much more com-

plete understanding of the atmospheres, surface features and physical properties of these two large planets.

Each spacecraft will be powered by three MHW isotopic generators providing a minimum of 385 watts at the time the spacecraft reaches Saturn approximately four years after launch. The 1974 effort was directed towards analytical and design studies to optimize the basic MHW/LES design for the MJS mission. The principal changes involved removal of the heat source can in order to reduce weight and the substitution of a different graphite to improve reentry protection. With the incorporation of the required design modifications and the freezing of the design, fabrication of test hardware was initiated.

### **Generator Technology**

Projected missions of the late 1970's and 1980's will impose increased performance requirements on the nuclear power sources. Weight and overall system unit cost will become extremely important, particularly on repetitive DOD missions. Also, power levels on several missions are anticipated to increase into the low kilowatt range where dynamic conversion systems rather than static (no moving parts) systems are most applicable. Current emphasis is directed towards the Selenide thermoelectric materials for the lower power static systems and towards the Brayton or Organic Rankine cycles for the higher power dynamic systems.

As with all thermoelectric conversion systems, the Selenide technology involves the development of two thermoelectric legs (parallel heatflow path for converting heat to electricity). One of these has been under development for several years and significant progress was made during 1974 on the development of the other leg. Several thermo-couples using both legs were placed on test early in the year. A 20-watt module will be tested during 1975 to help identify and understand any technology problems which might exist in flight system applications. Related effort was also carried out on a heat source which would be compatible with this Selenide module.

Effort on the dynamic technologies will be initiated early in 1975. Procurement actions for system contractors for dynamic conversion system technologies were nearing completion at the end of the year.

### **Terrestrial Power**

Wherever possible, technology is being applied or considered for terrestrial energy related applications.

The following two examples are illustrative of the effort in this area.

The Department of Defense has requested AEC support of a lower power ( $< 1$  watt) Pu-238 isotopic generator which would involve multiple units in an operational system. The generator is being designed by DOD contractors and the AEC will provide the heat source—including the isotopic fuel. Several prototype heat sources were fabricated during the year and will be provided to the U.S. Navy for generator system evaluation testing. Additional heat sources will be fabricated in 1975.

A concerted effort is being pursued to apply the thermionic technology developed in the space pro-

gram to terrestrial energy-related applications. The space technology was optimized for weight and other parameters rather than efficiency so that efficiencies of 10–15% were adequate. However, for terrestrial applications, efficiency is a primary criteria. The ultimate goal is thermionic efficiencies in the range of 30–40% which, if achieved, could provide the technological basis for topping cycles to increase the central station electric power plant efficiencies up to the range of 50%. The 1974 effort has made significant progress in improving the diode parameters which control efficiency. Parameters associated with 20% efficient thermionic devices were experimentally demonstrated during the year and actual efficiency tests will be conducted during 1975.



## Introduction

During 1974 the U.S. Department of Agriculture (USDA) continued its efforts in the development and evaluation of aerospace remote sensing technology for the improvement of its agricultural and forestry programs concomitant with national priorities. This involved additional research on the feasibility and operational utility of utilizing aerospace-acquired data to accomplish more accurate quantitative predictions of food and fiber resources, along with better evaluations of land productivity; and to further monitor changes affecting the total production and quality of our natural resources and environment, including man-environment interactions.

## Remote Sensing Activity

Remote sensing is viewed by the USDA as basically a potential tool that may further assist in addressing its agriculture, forestry, wildlife, and other requirements mandated by Federal charter. The Department also has a substantial interest in the ultimate operational use of remote sensing data for better resource and inventory management, environmental controls, and crop, forest, and range protection. The current state-of-the-art, with respect to USDA mission responsibilities, is presently limited to research and development. A large part of the research is continually being devoted to a better understanding of the interaction of radiant energy with plant tissue, soil, and water parameters. This research is in continued collaboration with NASA and other Federal and State agencies.

## Research and Development

An experimental feasibility, long-range study to develop automated techniques for estimating wheat acreages, yield, and crop vigor from ERTS data, is being conducted by a joint effort with the Canadian Department of Agriculture and the Agricultural Stabilization and Conservation Service of USDA.

A related study over the Great Plains wheat-producing region, will utilize spacecraft-acquired data in a statistical sampling experiment. This Large Area Crop Inventory Experiment (LACIE), involving the joint efforts of NASA, NOAA, and the USDA, will determine whether computer-analyzed satellite data can improve the accuracy and timeliness of crop forecasts. Initially, wheat will be the test crop, and if the results prove successful the experiment will be extended to other regional crops.

The results of these investigations may eventually prove the feasibility of utilizing remote sensing technology for more accurate and timely inventories of worldwide crop acreages and yield estimations, a potential development of considerable import in light of the world food problem.

Another investigative study is being conducted by the Forest Service to test the feasibility of utilizing multispectral data with multistage sampling and computer processing. This may result in the ability to generate useful thematic overlays for such problems as urban encroachment, agricultural inventory, recreation impact, water pollution, geologic hazards, and natural resource location.

In cooperation with NASA, a Forestry Applications Project (FAP) is investigating the application of remote sensing technology for the inventory of forest resources. The project addresses data collection and interpretation in the categories of timber, soils, and range.

ERTS Follow-on-Investigations by USDA will involve studies on: (1) the spectral measurement of watershed runoff coefficients in the southern Great Plains, (2) soil, water, and vegetation condition in south Texas, (3) monitoring forest and range resources in Georgia, and (4) development of an area sampling technique for an agricultural information system in Nicaragua.

Significant work is continuing in establishing the capability of using small and large scale color infrared photography to detect and correctly identify incipient crop, forest, and wildland vegetation infestations due to diseases, insects, and other pests.

### *Applications*

The compilation of a cloud-free ERTS mosaic of conterminous United States and Alaska, at a scale of 1:1,000,000, by the Soil Conservation Service (SCS) in collaboration with NASA, has generated considerable interest and sales from Federal and State agencies, academia, and numerous private concerns. Over 970 orders, totalling more than \$90,000 have been received. The SCS in collaboration with the Department of the Interior will soon make available inexpensive lithographs of these mosaics.

Ground surveys made in conjunction with ERTS data provided a replicated sample that permitted calculation of Hidalgo County, Texas, acreage estimates, and standard errors of estimate, for 18 vegetable crops produced in that county. Utilizing remote sensing techniques, a first classification map of the county with significant land use discrimination capability has been produced.

The results of a study have shown that ERTS resolution is sufficient for practical applications in the detection of chlorotic sorghum in otherwise uniform fields at least 1.1 hectares (2.8 acres) in size.

### **Providing Expertise to Other Nations**

The potential of agricultural aerospace remote sensing techniques has been recognized internationally and the USDA continued to provide expertise to the international community. In addition to participating in various symposia and workshops, briefings were provided to visitors from Australia, Belgium, Canada, Gambia, Germany, Indonesia, Israel, Italy, Japan, New Zealand, Peru, South Africa, Thailand, and Turkey. Briefings were also given to numerous students at a two-day international workshop sponsored by the Bureau of the Census.



## Arms Control and Disarmament Agency

The interest and involvement of the Arms Control and Disarmament Agency in space activities is threefold. First, and foremost is ACDA's interest in maintaining space as an environment in which no weapons and military forces are emplaced. Second, ACDA is interested and involved in preserving the free use of space for purposes related to peacekeeping, crisis defuzing and treaty monitoring. Third, ACDA seeks to discourage other countries from utilizing space technology and equipment to develop strategic offensive weapons and to improve weaponry. In each of these areas ACDA participates in the formulation of US policy, in the negotiations required to reach international agreement, and in monitoring the effects of such policies and agreements on arms control and disarmament issues.

The Outer Space Treaty bans the emplacement of "weapons of mass destruction" in space, on celestial bodies, or in earth orbit and bans military bases, forces, maneuvers, and weapons testing on celestial bodies. The Treaty was opened for signature in 1967. As of the end of 1974 69 countries have ratified it and 34 have signed but not yet ratified.

Preserving and protecting the use of space for peace-keeping activities such as crisis defuzing and treaty monitoring are ACDA interests embodied in several international agreements. The "Hotline" modernization agreement and the technical activities associated with this agreement provide the secure, direct communication link between the US and

Soviet governments so important for peacekeeping and crisis defuzing. ACDA is interested and involved in this utilization of space for the transmission of urgent information, notifications and requests for information in situations requiring prompt clarification. The secure, spacebased communications link between the two governments exploits the capabilities of the Intelsat and Molniya communication satellite systems. ACDA's interest in utilizing space for monitoring compliance with Treaty obligations is based on the provisions of the strategic arms limitation agreements with the USSR. These provisions specify that neither country will interfere with the national technical means of verification of the other.

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. ACDA participates in the reviews which precede the export of U.S. space technology and hardware as well as those concerned with the export of U.S. avionics systems. In the latter case, ACDA is particularly concerned with systems such as inertial navigation systems which could be used in strategic weapons. ACDA seeks to institute and maintain safeguards which will minimize the possible exploitation of such technology and hardware for undesirable military applications but will not curtail legitimate trade or discourage international cooperation.



## Introduction

The United States Information Agency (USIA) took advantage of the continued high level of interest abroad to review and assess recent U.S. space projects and to preview and analyze those for which preparations were underway during the year.

Every indicator showed that the appetite remained nearly undiminished abroad for media materials explaining and interpreting U.S. space activities and objectives. For many foreign audiences U.S. space projects continued to symbolize both the potential and the excellence of U.S. science and technology. Thus information about U.S. space operations continued to exert a strong influence on the image the United States projects abroad.

As in earlier years, USIA used speakers, exhibits, films, radio, television, photos and the printed word to reach target audiences with the U.S. space story.

This story began for USIA with its interpretation of the final operations of Skylab, the U.S. space station, which were already underway when 1974 arrived. The story continued with the analysis of visits by automated Mariner-10 spacecraft to the vicinity of Venus and Mercury, and the launching and early operation in orbit of new types of advanced satellites.

These new satellites were of particular interest to USIA because they are potentially very powerful tools for the economic and social advancement of hundreds of millions of persons. One of these was the Applications Technology Satellite-6 (ATS-6), which could well be the forerunner of communication satellite systems offering health care and education in regions where opportunities for these services are scarce or absent.

Another such system was the first stationary weather observation satellite—the Synchronous Meteorological Satellite (SMS)—which almost at once commenced around-the-clock observations of the Western hemisphere and surrounding areas.

Most of the year's USIA space output was devoted to analytical summaries of past accomplishments and of others in the making.

## Press and Publications

Space as a new resource for man's welfare and advancement was the theme of much of the output of the Press and Publications Service.

In words and pictures, the Agency dramatically depicted the technical sophistication and human ingenuity involved in space exploration, and the growing impact of space developments upon everyday life.

After the return to earth of the last Skylab crew, a 5,000-word, 16-page illustrated color pamphlet entitled "Skylab: What It Did and What It Means," was sent to the field. The pamphlet described the U.S. space station as a highly instrumented modern research laboratory in orbit, and called the mission "by far the most comprehensive project for finding what uses man can and cannot make of outer space in the foreseeable future."

Skylab, it was pointed out, "confirmed and extended two key findings of earlier space explorations: 1) That the resources of space may indeed offer new approaches to some of mankind's most pressing problems and 2) that living conditions on the earth can be improved through space operations." The pamphlet, which explained in detail the potential benefits from Skylab's pioneering experiments, was distributed in English, Spanish, French and Arabic.

Another pamphlet on major aspects of the space program was prepared from the wrap-around four-color cover and five articles on space which had appeared in *Al Majal*, the Agency's Arabic magazine. This pamphlet was distributed at the Damascus Trade Fair (78,000 copies).

Two major feature articles mailed to posts focused on significant contributions to non-space activities of the space program. "The Great Invisible Legacy of the U.S. Manned Space Program" explained the successful use of new management techniques developed in Apollo moon-landing preparations in managing large scale business and social projects. The second article, "What We Learned: Science and the Manned Space Program," analyzed the "explosion" of scientific information that has resulted

from space exploration. In three articles entitled "A People's Satellite," the experience and potential of the ATS-6 for bringing educational and medical services to underprivileged regions was emphasized.

Much of the space output was carried on the wireless file, the Agency's radioteletype system that connects USIA's headquarters in Washington with its 189 USIS (United States Information Service) posts in 110 countries. The file transmitted interpretive articles on all major U.S. space events for reproduction in foreign newspapers and magazines or Agency-produced publications.

These headlines from the file indicate the range and treatment of subjects:

"New U.S. Satellite Promises Social Changes in Developing Nations" (for an article on ATS-6's educational and medical-care potential).

"Satellite Users Assess the 'Teacher-in-the-Sky,'" (also on ATS-6).

"New U.S. Satellite to Expand Commercial Use of Space" (on Westar, the first domestic U.S. communications satellite).

"Second Look at Mercury and a New Moon for Jupiter" (on scientific discoveries resulting from the first close visit by spacecraft to these planets).

"A Pause to Remember: Five Years Ago Man First Stepped on the Moon" (an anniversary story on one of the great events of all time), and "The Moonmen: Where Are They Now" (a look at yesterday's astronauts).

The wireless file transmitted a total of 18 articles on space. The Pictures Branch supplied posts with 20 pictures of the Skylab mission and sent 129 terrain views photographed in color by Skylab crews to 64 countries. The Pictures Branch shipped more than 250 views, selected from the many thousands radioed to earth by the Earth Resources Technology Satellite (ERTS-1). These were distributed to 21 countries requesting photos showing their territories. The Branch magnified ERTS-1 views to 30-by-30 inches for presentation by US ambassadors to chiefs of state of host countries.

*Horizons*, the Agency's bimonthly general magazine appearing in English and 16 other languages, published "Countdown for the 1980's", an article outlining the Space Shuttle program.

*Economic Impact*, an Agency quarterly published in English and Spanish, ran an article on ERTS-1, "Exploring World Resources From Space." *Dialogue*, the Agency's quarterly journal of opinion, published two articles, "The Ultimate Speed Limit," by the distinguished science writer, Isaac Asimov, speculating on how fast a body can move through space, and "News About the Universe," by Edward Edelson, award-winning science journalist, on recent as-

tronomical discoveries that throw new light on the origin and probable fate of the universe.

The Magazine Reprint unit obtained reprint rights for posts of three articles: Cornell University Astronomer Carl Sagan's "Space Exploration as a Human Enterprise," predicting a wealth of practical benefits from space; Edward Edelson's "The Outer Limits of Space" on how the most distant reaches of space permit astronomers and cosmologists to look back to the beginning and ahead to the end of the universe, and "Space Garden," an interview with space pioneer and theoretician Dr. Kraft A. Ehrlicke, who sees space exploration as preserving the planet Earth for a future garden of the solar system.

## Radio

The Agency's Voice of America broadcasted fully 1,151 different reports and feature programs on space subjects. Space received a total of 374 hours of air time, providing an estimated 50 million weekly listeners a comprehensive understanding of the activities, plans and purposes of the U.S. space community.

These reports and features were broadcast in addition to news accounts on current space developments, such as newscasts during space missions.

A large portion of the VOA broadcasts were devoted to covering the final Skylab mission. There was also heavy concentration on the Mariner mission to Venus and Mercury, international cooperation in space science, and preparations for the joint U.S.-Soviet manned spaceflight: the "Apollo-Soyuz Test Project" (ASTP), planned for July 1975.

The variety of the coverage is indicated by these sample broadcast titles: "Project Viking" (on the automated craft which is to land on Mars and search for life there in 1976), "Rendezvous With Venus," "Envoy to Mercury," "Skylab Situation Report," "Highlights of Skylab," "Skylab III Crew the Healthiest Yet," "Space Plans Through the Year 2000," "Discovery Supports Life-on-Jupiter Theory," "NASA's New Flying Observatory," "Women as Shuttle Passengers," "U.S. Space Team at Soviet Center," "Space Shuttle Progress Report," "Space Technology Aids Heart Research," and "Space and the American Spirit."

Employing the realism, intimacy and immediacy that are unique to radio, the Voice transmitted live and recorded interviews with key space officials and with astronauts on Earth and in space. Also transmitted were live broadcasts from launch sites, and from spacecraft in flight.

Voices of astronauts were heard by listeners in "Skylab Crew Reports", "Skylab News Conference," and "Interview with Skylab Pilot Bill Pogue."

Among interviews aired was one with Dr. George M. Low, NASA deputy administrator, and another with Dr. James Dunne, chief scientist for Mariner 10.

### Motion Pictures and Television

Films, television programs and TV news clips, acquired from outside sources or made by the Agency's Motion Pictures and Television Service, were used in a wide variety of ways.

A 17-minute color documentary film, "Skylab Outpost in Space," was produced by the Service and distributed to 116 countries for use by local TV stations immediately after the return to Earth of the third Skylab crew. The film focused chiefly on research performed by the astronauts in orbit, particularly their experiments in medicine, metallurgy, and solar physics. A 30-minute color documentary film, "Apollo Decade," reviewing highlights of the U.S. Apollo moon-landing program and the meaning of the program for mankind, was produced by the Agency for world-wide distribution.

The Agency-produced TV series, "Science Report," devoted seven of its twice-monthly 15-minute segments to space subjects. "Science Report," is released by the Agency in over 100 countries and is broadcast in 22 languages from over 600 television stations abroad.

Among its productions related to space were "Man's Longest Journey Into Space" (on the third Skylab mission), "The First Mission to Investigate the Planet Mercury," "Medical Spinoffs From Space," "The Space Shuttle and the European Space Lab," and "U.S. and USSR Move Closer to Historic Cooperation in Manned Spaceflight."

The monthly TV series, "Realidades," in which Brazilian correspondents interview American specialists, included four programs on space. The series is specially produced for the 22-station Tupi network which has outlets in all major Brazilian cities and reaches 1,500,000 viewers. Featured were two programs on communications satellites, a third on Skylab's observations of the comet Kohoutek, and a final program commemorating the first landing by men on the moon.

"Now," the Arabic version of the highly popular Spanish-language "Ahora" TV series, used "Windfall From Space," a half-hour production on the practical benefits of space exploration, and "Crusade Against Cancer," a documentary on the contributions of space exploration to the fight against the disease. "Now" is distributed to 15 USIS posts where Arabic is spoken.

"Vision," a monthly pictorial review of American personalities and events, offered segments featuring Earth resources technology satellites, and space-de-

veloped miniaturization techniques that have helped make possible quartz wrist-watches and improved electronic heart-pacemakers.

In response to post requests for space film materials fitting their local needs, the Motion Pictures and Television Service produced or obtained nine films on space subjects. Three of them were half-hour interviews in color with leading space figures: science-fiction writer Isaac Asimov on "Science Fiction and Space;" astronaut-geologist Harrison Schmitt on "What We Have Learned from the Moon," and NASA Associate Administrator Rocco Petrone on "The Future of Space." The films were shown in connection with the opening of a new United States Consulate at Cracow, Poland, where NASA's "Eyewitness to Space" exhibit of space art was also shown.

All USIS posts with television outlets were supplied with six sets of 85 space-feature slides. The sets told the story of the Space Shuttle, Space Station, Apollo-Soyuz Test Project, Man on the Moon, Johnson Space Center, and Cape Kennedy.

The Agency also provided posts with TV news clips on events of special interest to posts. Thus, news clips of the Indian ambassador inspecting the ATS-6 satellite and viewing its launch were sent to India which in mid-1975 will use the satellite for a year of extensive educational broadcasting to Indian villages. News clips on the visit of Soviet cosmonauts to Washington, D.C. were sent to Moscow. News clips on Skylab and on the fifth-anniversary observance at Cape Kennedy of the first manned moon landing were distributed to practically all posts.

Twenty-three USIS posts received, on their request, a 43-minute videotaped interview with experts on the use of space photography in developing and conserving Earth resources. Two films made for the Damascus Fair—one containing scenes of Apollo astronauts on the moon, the other on the organization of the Apollo program—were reduced to 8mm cassettes for continuous showings at the fair.

The Agency itself participated in the telecasting via satellite of 14 programs to countries abroad. Among them was a 12-minute program reporting the visit of Ivory Coast President Felix Houphouet-Boigny to Washington that was transmitted to the Ivory Coast, and a 30-minute program to Romania showing the welcoming ceremonies in Washington for the Romanian President, Nicolae Ceausescu.

Through the U.S. Mission to International Organizations in Geneva, three NASA films were offered to European and Asian television networks. Agency facilities were used to transmit the remarks by NASA Administrator James C. Fletcher to a regional seminar on use of the Earth Resources Technology satellite by Southeast Asian countries,

sponsored by USIS in Bangkok. The Washington studios were also used by foreign newsmen and commentators for telecasts and production of various documentaries on space subjects.

The Agency selected and entered 11 U.S. films on space subjects in 30 international exhibits and film festivals. Thus, USIA's "Skylab—Outpost in Space" was seen at film festivals in Australia, New Zealand, Milan, Paris, Rio de Janeiro, Rome, and Trieste.

### **Information Centers and Exhibits**

U.S. astronauts continued to enjoy overwhelming popularity abroad. So did exhibits built around space accomplishments.

Astronaut Russell L. Schweickart quickly became the principal presence at a regional fair at Marseille, France. He was seen at the fair by several hundred thousand persons, and over a million Frenchmen were aware of his presence through press coverage. His appearance added luster to the exhibit of Skylab hardware and a model of the Lunar Rover at the Fair.

Two almost identical exhibits of important space artifacts, traveling under the title of "Treasures of Space," were bolstered at science and trade fairs in North Africa, the Near East and Latin America by the appearance of prominent space personalities.

The exhibit items, all on loan from the National Air and Space Museum of the Smithsonian Institution, consisted of a space suit, a lunar rock, lunar hand-tools, a reproduction of the Pioneer-10 plaque addressed to inhabitants of other planets, and models of ERTS-1, Skylab, the Space Shuttle, and the Apollo-Soyuz in docked configuration. One set of these artifacts was shown at the Damascus Fair, the Cairo Student Fair, and in Jidda, Kuwait, Tunis, and Algiers, while the other was exhibited at the Bogota Fair, the Asuncion Trade Fair, and in Buenos Aires, Lima and Quito.

A series of seminars on "ERTS-1 and Southeast

Asia" brought together scientists from five nations in that region and two NASA experts, Dr. Nicholas Short, NASA's senior geologist, and Mr. John Boeckel, Assistant Director for Operations in the Applications Directorate of the Goddard Space Flight Center.

At the first of the seminars, in Bangkok, the two NASA representatives met with 60 delegates from Thailand and 11 from Laos, Singapore, Malaysia and Indonesia. The three-day seminar was jointly sponsored by the USIS Bangkok, the Thai National Research Council and the Applied Scientific Research Corporation of Thailand.

The NASA experts used numerous color slides to explain the many aspects of ERTS applications. Delegates from Thailand and Indonesia, which have extensive ERTS programs, also used space photos to report on the benefits derived and expected from ERTS. These include measurements of insect infestations, and cartographic interpretations that have already led to important revisions in regional maps.

The Bangkok seminar was followed up by a two-day symposium on ERTS in Jakarta in which 150 officials participated. In addition to the two NASA representatives, speakers included three Indonesians who showed how ERTS data could help in that country's current efforts to inventory national resources. At a one-day seminar in Kuala Lumpur, the two NASA representatives addressed 70 scientists, technicians, government administrators and business executives on the use and potential of ERTS.

Ten titles on space subjects were carried in the monthly "Current Books" lists which recommend acquisition for USIS libraries.

"Dividends From Space" by Frederick I. Ordway and his associates was published by the Agency in English for Malagasy and Kannada. John Noble Wilford's "We Reach the Moon" was published in the Lao language. A variety of NASA publications were distributed by USIA to posts, libraries, and target audiences.

# Appendixes

## APPENDIX A-1

### U.S. Spacecraft Record

Year	Earth orbit		Earth escape		Year	Earth orbit		Earth escape	
	Success	Failure	Success	Failure		Success	Failure	Success	Failure
1957.....	0	1	0	0	1966.....	95	12	5	<sup>1</sup> 1
1958.....	5	8	0	4	1967.....	78	4	10	0
1959.....	9	9	1	2	1968.....	61	15	3	0
1960.....	16	12	1	2	1969.....	58	1	8	1
1961.....	35	12	0	0	1970.....	36	1	3	0
1962.....	54	12	4	1	1971.....	45	2	8	1
1963.....	60	11	0	0	1972.....	33	2	8	0
1964.....	69	8	4	0	1973.....	23	2	3	0
1965.....	94	8	3	0	1974.....	29	2	1	0
					Total.....	800	122	62	12

<sup>1</sup> This earth escape failure did attain earth orbit and therefore is included in the earth-orbit success totals.

tainment 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.

NOTES: The criterion of success or failure used is the at-

## APPENDIX A-2

### World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond

Year	United States	U.S.S.R.	France	Italy	Japan	Chinese Peoples Republic	Australia	United Kingdom
1957.....		2						
1958.....	5	1						
1959.....	10	3						
1960.....	16	3						
1961.....	29	6						
1962.....	52	20						
1963.....	38	17						
1964.....	57	30						
1965.....	63	48	1					
1966.....	73	44	1					
1967.....	57	66	2	1			1	
1968.....	45	74						
1969.....	40	70						
1970.....	28	81	2	<sup>1</sup> 1	1	1		
1971.....	30	83	1	<sup>1</sup> 2	2	1		1
1972.....	30	74		<sup>1</sup> 1	1			
1973.....	23	86						
1974.....	22	81		<sup>1</sup> 2	1			
Total.....	618	789	7	7	7	2	1	1

<sup>1</sup> Includes foreign launchings of U.S. spacecraft.

NOTE: This tabulation enumerates launchings rather than

spacecraft. Some launches did successfully orbit multiple spacecraft.

## Successful U.S. Launches—1974

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and perigee (in kilometers)— Period (minutes) Inclination to equator (degrees)	Remarks
Jan. 19 Skynet IIA 2A Thorad-Delta	Objective: To be placed in geostationary equatorial orbit over the Indian Ocean to provide in orbit x-band military communications for British forces. Spacecraft: Drum-shaped satellite 209-cm high and 190-cm in diameter; 6 solar panels cover fiberglass outer shell; two batteries. Contains S-band circular array antenna; 17-watt communications transponder and horn antenna system; attitude and orbit control subsystem; thermal control system; monopropellant hydrazine reaction control unit; apogee boost TE-M-604-1 solid fuel motor. Weight at liftoff: 435 kg.	3,406 95 121.6 37.6	First of two U.K. second generation operational communications satellites. Launched into extremely low eccentric orbit by NASA. Failure in Delta second stage electronics package placed spacecraft in deteriorating low orbit. A second firing of third stage on Jan. 24 failed to boost spacecraft into higher orbit and it decayed over the southwestern Pacific Jan. 25, 1974.
Feb. 13 Defense 7A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	404 128 89.8 110.4	Decayed March 17, 1974.
Feb. 18 San Marco 4 9A Scout	Objective: To obtain measurements of the diurnal variations of the equatorial neutral atmosphere density, composition, and temperature. Spacecraft: Sphere 70 cm in diameter with 4 canted 48.5 monopole antennas for telemetry and command. Series of mica windows is provided on the equator of the outer shell for solar cells; 2 nickel-cadmium batteries. Spacecraft structure forms an integral part of the air density balance. Contains 3 experiments: neutral mass spectrometer, omegatron mass spectrometer, and atmospheric drag density accelerometer. Weight: 170 kg.	917 244 96.3 2.9	Fourth spacecraft in joint Italian-U.S. cooperative space program. Italian-built satellite launched successfully with NASA Scout vehicle by an Italian launch crew from Indian Ocean platform off coast of Kenya. Two U.S. experiments working properly; Italian atmospheric drag density experiment malfunctioned.
Mar. 9 UK X-4 (Miranda) 13A Scout	Objective: To test the development of a three-axis gas stabilization system; to measure the performance of silicon type solar cells. Spacecraft: Rectangular structure 83.5 cm high and 66.5 cm wide; two deployable solar array panels extend from the main body sides and increase spacecraft span to 250 cm. Floor and side panels of the rectangular body are made of aluminum honeycomb sandwich construction. Solar array contains 1800 solar cells and consists of four panels stowed in a folded accordion form during launch and deployed by nitrogen gas-operated telescopic booms. Four antennas, each 46.5 cm long, fold out at the corners of the satellite facing earth. Contains five experiments: attitude control system, infrared horizon sensor, single-axis star sensor, albedo horizon sensor, and silicon solar cells. Weight: 93 kg.	918 712 101.1 97.8	U.K.-built satellite launched successfully by NASA. Spacecraft performing satisfactorily except for malfunctioning regulator in the propane gas control system.
Mar. 16 Defense 15A Thor-Burner II	Objective: Practical applications of space-based technology. Spacecraft: Not announced.	878 781 101.4 98.9	Still in orbit.
Apr. 10 Defense 20A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	288 152 88.0 94.0	Decayed July 28, 1974.
Apr. 10 Defense 20B Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	Still in orbit.	829 783 101.0 94.0

## Successful U.S. Launches—1974

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (in kilometers)— Period (minutes) Inclination to equator (degrees)	Remarks
Apr. 10 Defense 20C Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	528 502 94.0 94.0	Still in orbit.
Apr. 13 Westar 1 22A Thorad-Delta	Objective: To provide transmission of television, voice, and other data throughout the United States. Spacecraft: Cylindrical 1.8-m diameter and 3.7-m high including 1.5-m optically transparent antenna affixed to top of spacecraft; spin stabilized. Provides 12 color TV channels or up to 14 400 one-way telephone circuits; 20,500 solar cells. Weight at launch: 572 kg.; weight in orbit: 300 kg.	35,950 35,553 1,434.3 0.0	Launched by NASA for Western Union Telegraph Company into transfer orbit. Apogee kick motor fired April 16 and spacecraft placed in stationary equatorial synchronous orbit just west of Galapagos Islands in Pacific (99° west longitude). First in a series of three; spacecraft became first U.S. commercial domestic communications satellite. Commercial operations began July 16, 1974. Made first U.S. mail delivery via satellite Sept. 5, 1974.
May 17 SMS 1 33A Thorad-Delta	Objective: To launch spacecraft into a synchronous orbit of sufficient accuracy to enable the spacecraft to accomplish its operational mission requirements, conduct an in-orbit evaluation and checkout of the spacecraft and, upon completion of this evaluation, turn the operational control of the spacecraft over to NOAA/NESS, to provide regular and useful daytime and nighttime meteorological observations in support of the national operational meteorological satellite system. Spacecraft: Cylindrical 190.5 cm in diameter and 344 cm long from the top of the magnetometer to the bottom of the apogee boost motor. Thrust tube located in center supports radiometer/telescope instrument. Scanning mirror looks out through an opening in cylindrical solar array whose panels cover outer walls of spacecraft. Instrumentation consists of a visible infrared spin-scan radiometer (VISSR) to provide high quality day/night cloud cover data and to measure radiance temperatures of the earth/atmosphere system, a meteorological data collection and transmission system, and a space environmental monitor (SEM) system to measure proton, electron, and solar x-ray fluxes and magnetic fields. Spin stabilized. Weight at launch: 628 kg; weight in orbit: 272 kg.	35,519 35,455 1,420.8 2.0	First meteorological satellite to be placed in synchronous orbit. Will provide continuous images of cloud cover over the U.S. and Atlantic Ocean both day and night for the first time. After launch into transfer orbit by NASA, apogee boost motor fired and spacecraft placed in stationary equatorial synchronous orbit off coast of Brazil (45° west longitude). Spacecraft remained at 45° until September to participate in GARP's (Global Atmospheric Research Program) Atlantic Tropical Experiment; moved to 75° west longitude by mid-November to become part of NOAA system. Has produced most highly resolved weather pictures ever taken from space.

## Successful U.S. Launches—1974

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (in kilometers)— Period (minutes) Inclination to equator (degrees)	Remarks
May 30 ATS 6 39A Titan IIIC	Objective: To inject the spacecraft into a near geostationary orbit; to erect a large antenna structure (nominally 9.14 m) in orbit which, with its associated communications system is capable of providing a good quality TV signal to small, inexpensive ground receivers, and to measure and evaluate the performance of such a system; to stabilize the spacecraft using a three axis control system, with a slewing capability in roll and pitch, permitting antenna pointing with an accuracy commensurate with the antenna characteristics; to support and demonstrate user oriented applications experiments utilizing the spacecraft capabilities. Spacecraft: Consists of a rectangular Earth Viewing Module (EVM) 137 cm wide and 160 cm high connected by a 4 m long tubular truss support to a 9 m diameter deployable parabolic reflector. Two structural booms each supporting a solar array are mounted horizontally on the top of the parabolic reflector and measure 16 m end to end. The spacecraft, in its orbital configuration, is 8.5 m high from the top of the magnetometer boom to the bottom of the EVM. The communications system is a multi-frequency transponder, a redundant transmitting/receiving device containing six receivers and nine transmitters. Attitude control system uses hydrazine monopropellant thrusters. Two solar panels contain 21,600 solar cells covering a total area of 20 sq m. Carries more than 20 technological and scientific experiments. Weight: 1402 kg.	35,818 35,763 1,436.3 1.8	Most complex, versatile, and powerful of ATS series. High power receiver/transmitter can relay color TV and other signals to a large number of small inexpensive stations over a large area. Placed in synchronous orbit by NASA at 94° west longitude over Galapagos Islands. Began beaming educational programs to eight Appalachian states July 1974. Also broadcast educational and medical programs to Alaska and Rocky Mountain states. Spacecraft will finish domestic program by end of school year (May 1975) and will be moved eastward to second station 35° east longitude over Lake Victoria, Kenya to beam programs to 5000 villages in northern India. Move will take about 45 days. Spacecraft will be on second station about beginning of July 1975; will also support ASTP mission.
June 3 Hawkeye 1 (Explorer 52) 40A Scout	Objective: To study the plasma properties of the magnetosphere in the vicinity of the magnetic neutral point over the earth's north polar cap. Spacecraft: Eight-sided truncated cone with 75-cm dia base, 25-cm dia top, and 75-cm high contains solar cells mounted on sides and bottom of outer shell. Spin stabilized spacecraft contains a magnetometer boom which extends 1.6 m from the spacecraft's center line; two electric field antenna booms, each extendable to 23 m, through which VLF-ELF receivers will measure frequencies; and a search coil mounted on a 1.6-m boom. Orbiting configuration is 46-m tip-to-tip of the electric field antennas and 3.2-m tip-to-tip of the telescopic booms. Orbital weight: 27 kg.	126,793 638 3,078.1 89.8	Sixth in "Injun" Explorer series, satellite was designed and built by the University of Iowa which tracks and controls the spacecraft during flight. Launched by NASA into highly elliptical orbit using first five-stage Scout vehicle. All spacecraft booms and antennas deployed in orbit and all experiments turned on and operating satisfactorily.
June 6 Defense 42A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	410 120 89.8 110.4	Decayed July 23, 1974.
July 14 NTS 1 54A Atlas F	Objective: Practical applications of space-based technology. Spacecraft: Not announced.	13,762 13,440 468.4 125.1	Navigation Technology Satellite originally was known as Timation 3. Still in orbit.

## Successful U.S. Launches—1974

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and perigee (in kilometers)— Period (minutes) Inclination to equator (degrees)	Remarks
July 16 Aeros 2 55A Scout	Objective: To measure the main aeronomic parameters of the upper atmosphere and the solar ultraviolet radiation in the wavelength band of main absorption. Spacecraft: Circular cylindrical shell welded to a bottom conical shell to form a structural unit 916 cm in diameter and 710 cm high. Flat honeycomb solar cell array lid is attached to spacecraft cylinder top. Carries five scientific instruments: Mass Spectrometer (MS), Retarding Potential Analyzer (RPA), Impedance Probe (IP), EUV-Spectrometer (EUV), and Neutral Atmosphere Temperature Experiment (NATE). Spin stabilized; four telemetry antennas; two batteries. Weight: 127 kg.	853 220 95.3 97.4	West German-built satellite launched by NASA into nearly polar orbit. All experiments turned on but spacecraft operating in real-time mode only because of tape recorder failure. Returning; good data.
Aug. 9 Defense 63A Thor-Burner II	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	875 805 101.6 98.8	Still in orbit.
Aug. 14 Defense 65A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	407 123 89.8 110.4	Decayed Sept. 29, 1974.
Aug. 30 ANS 70A Scout	Objective: To increase the scientific knowledge of stellar ultraviolet (UV) and x-ray sources. Spacecraft: Rectangular double bar configuration 123 cm high and 61 cm wide; measures 144 cm wide with wing-like solar paddles deployed. Contains three scientific experiments: a cassegrain type telescope with a spectrometer and five UV-sensitive photomultipliers for a range of 1500 to 3000 Angstroms; a two detector soft x-ray instrument for the spectral range of 0.2 to 5 keV; and a two detector hard x-ray instrument sensitive in the spectral range of 2 to 15 keV and a Bragg Crystal spectrometer sensitive for x-ray live radiation around 2 keV. Three-axis stabilized satellite contains 2,050 solar cells, one nickel-cadmium battery, and four antennas. Weight: 130 kg.	1,167 254 99.0 98.1	First Netherlands/U.S. cooperative satellite launched by NASA Scout vehicle into polar orbit. Scout guidance package anomaly placed spacecraft into highly elliptical rather than near-circular orbit. All experiments turned on and returning data.
Oct. 10 Westar 2 75A Thorad-Delta	Objective: To provide transmission of television, voice, and other data throughout the United States. Spacecraft: Cylindrical 1.8-m diameter and 3.7-m high including 1.5-m optically transparent antenna affixed to top of spacecraft; spin stabilized. Provides 12 color TV channels or up to 14, 400 one-way telephone circuits; 20,500 solar cells. Weight at launch: 572 kg.; weight in orbit: 300 kg.	35,766 35,244 1,421.7 0.5	Launched by NASA for Western Union Telegraph Company into transfer orbit. Apogee kick motor fired Oct. 13 and placed spacecraft in stationary equatorial synchronous orbit over Pacific Ocean (90° west longitude). Second in a series of three satellites in U.S. commercial domestic communications satellite system.
Oct. 15 Ariel 5 77A Scout	Objective: To investigate the galactic and extragalactic x-ray sources. Spacecraft: 16-sided cylinder 86.4 cm high and 95.8 cm in diameter consists of an assembly of aluminum honeycomb panels which house experiments and control instruments. Spin stabilized spacecraft has four 54.4-cm long telemetry antennas; 4536 silicon solar cells are mounted on the outside panels which cover 14 of 16 sides. Carries six x-ray experiments, four designed for pointing and two for scanning information. Weight: 130 kg.	557 512 95.3 2.9	Fifth satellite in cooperative U.S./U.K. series. Mission involved three nations—U.K.-built satellite carrying five U.K. experiments and one U.S. experiment was launched by an Italian crew from the San Marco platform off the coast of Kenya using a NASA Scout launch vehicle. All experiments are operating and spacecraft is performing well in near-circular orbit.

## Successful U.S. Launches—1974

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (in kilometers)— Period (minutes) Inclination to equator (degrees)	Remarks
Oct. 29 Defense 85A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	279 152 88.8 96.7	Still in orbit.
Oct. 29 Defense 85C Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	542 540 95.3 96.1	Still in orbit.
Oct. 29 Defense 85D Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	3,711 147 125.4 97.0	Still in orbit.
Nov. 15 NOAA 4 (ITOS G) 89A Thorad-Delta	Objective: To place spacecraft in a Sun-synchronous orbit having a local equator crossing time of approximately 8:40 am, 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.	1,457 1,443 114.9 101.7	Fourth operational satellite of a series of second generation meteorological satellites launched by NASA. Part of NOAA global weather watch program. Spacecraft functioning normally and turned over to NOAA on Dec. 4 for operational use.
Nov. 15 OSCAR 7 89B Thorad-Delta	Objective: To provide noncommercial public service and educational use by the amateur radio community; to conduct an experimental program of multiple-access communications techniques using a large number of relatively low-powered earth terminals. Spacecraft: 8-sided cylindrical configuration with solar cells covering the exterior; 42.4 cm in diameter and 43.4 cm high. Carries a 2-to 10-meter repeater with input frequency between 145.85 and 145.95 MHz and output frequency between 29.40 and 29.50 MHz; also carries a second repeater with input frequency between 432.125 and 432.175 MHz and output frequency between 145.975 and 145.925 MHz. Each repeater operational on alternate days. Weight: 29.5 kg.	1,459 1,445 114.9 101.7	Built by American, Australian, Canadian, and German amateur groups working through the Radio Amateur Satellite Corporation (AMSAT). Launched by NASA as secondary payload. Spacecraft functioning normally and used heavily by amateurs around the world.

## Successful U.S. Launches—1974

Launch date (G.m.t.) Spacecraft name Cospas designation Launch vehicle	Spacecraft data	Apogee and perigee (in kilometers)— Period (minutes) Inclination to equator (degrees)	Remarks
Nov. 15 Intasat 89C Thorad-Delta	Objective: To obtain measurements of ionospheric total electron content, ionospheric irregularities, and ionospheric scintillations. Spacecraft: 12-sided cylindrical body measures 41 cm high and 44.2 cm in diameter; antenna array consists of 4 monopoles (49 cm each) mounted on spacecraft bottom; beacon antenna goes through center of spacecraft and measures 4 m from end-to-end. 660 solar cells are mounted on the spacecraft's 12 side panels; nickel-cadmium battery. Magnet stabilized. Weight: 15 kg.	1,457 1,440 114.9 101.7	First Spanish satellite, carries beacon experiment for ionospheric study. Launched by NASA as secondary payload, magnetically stabilized spacecraft is functioning normally.
Nov. 21 Intelsat IV F-8 93A Atlas-Centaur	Objective: To provide equivalent of 3,000 to 9,000 telephone circuits simultaneously or 12 color TV channels or a combination of telephone, TV, and other forms of communications traffic. Spacecraft: Cylindrical 2.38-meter diameter and 5.28-meter high; spin stabilized; 12 communications repeaters (transponders); 6 antennas (2 global transmit antennas, 2 global receive antennas, and 2 steerable spot-beam antennas); 45,012 solar cells. Weight at liftoff: 1387 kg. Weight after apogee motor fire: 700 kg.	35,780 35,630 1,431.9 1.8	Launched by NASA for Comsat Corp., manager of Intelsat. 6th satellite in improved Intelsat IV series. Apogee motor fired by Comsat on Nov. 23 and satellite stationed at 174° east longitude over Pacific Ocean. Commercial operations began Dec. 18, 1974.
Nov. 23 Skynet IIB 94A Thorad-Delta	Objective: To be placed in geostationary equatorial orbit over the Indian Ocean to provide in orbit x-band military communications for British forces. Spacecraft: Drum-shaped satellite 209-cm high and 190-cm in diameter; 6 solar panels cover fiberglass outer shell; two batteries. Contains S-band circular array antenna; 17-watt communications transponder and horn antenna system; attitude and orbit control subsystem; thermal control system; monopropellant hydrazine reaction control unit; apogee boost TE-M-604-1 solid fuel motor. Weight at liftoff: 435 kg.	36,595 35,896 1,459.4 2.2	Second of two U.K. second generation operational communications satellites. Launched by NASA for U.K. Apogee motor fired Nov. 24 and satellite stationed in synchronous orbit above the Indian Ocean.

## Successful U.S. Launches—1974

Launch date (G.m.t.) Spacecraft name Cospar designation Launch vehicle	Spacecraft data	Apogee and perigee (in kilometers)— Period (minutes) Inclination to equator (degrees)	Remarks
Dec. 10 Helios 1 97A Titan IIIE-Centaur-TE-M-364-4	<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 12 experiments. Weight: 370 kg.</p>	Helio-centric orbit	First operational use by NASA of Titan - Centaur configuration. 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 (45 million km). Results will contribute major new information on the dynamics of the solar corona and physical processes active on the Sun.
Dec. 19 Symphonie 1 101A Thorad-Delta	<p>Objective: To test and demonstrate communications equipment for TV, radio, telephone, telegraph, and data transmission; to provide equivalent of 2 color TV channels and 8 voice channels, or 1,200 telephone circuits between Europe, Africa, and South America.</p> <p>Payload: Flat hexagonal cylinder 1.85 m in diameter and 0.5 m high. Three solar panel wings folded against satellite body are deployed in geosynchronous orbit and extend 2.5 m from spacecraft. Apogee motor engine and nozzle, super high frequency antenna feed and reflectors, reception horn, and solar sensors are mounted on spacecraft top; VHF antennas are on underside. Three axis stabilized by cold gas system; 2 nickel-cadmium batteries. Weight: 402 kg.</p>	40,918 38,705 1,646.6 1.2	First of two experimental communications satellites developed by France and Germany. Launched successfully by NASA into transfer orbit. Apogee motor was fired by Germany on Dec. 21 and placed spacecraft in synchronous equatorial orbit over the Atlantic off the west coast of Africa.

## U.S. Applications Satellites 1970-1974

Date	Name	Launch Vehicle	Remarks
COMMUNICATIONS			
Jan. 15, 1970	Intelsat III (F-6)	Thor-Delta (TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, Latin America, and the Middle East.
Jan. 23, 1970	Oscar V (Australis)	Thor-Delta (TAT)	Ham radio satellite built by amateur radio operators at Melbourne University, Melbourne, Australia.
Mar. 20, 1970	NATOSAT-I (NATO-A)	Thor-Delta (TAT)	First NATO satellite, stationed over Atlantic to carry military traffic between the United States and other NATO countries.
Apr. 23, 1970	Intelsat III (F-7)	Thor-Delta (TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, North Africa, and the Middle East.
Jul. 23, 1970	Intelsat III (F-8)	Thor-Delta (TAT)	Spacecraft failed to achieve the proper orbit. Not usable. Last launch of Intelsat III series.
Aug. 22, 1970	Skynet II (IDCSP-B)	Thor-Delta (TAT)	Launched for the United Kingdom in response to an agreement to augment the IDCSP program. Spacecraft failed to achieve the proper orbit.
Jan. 26, 1971	Intelsat IV (F-2)	Atlas Centaur	First in Intelsat IV series of spacecraft; 3-9,000, 2-way voice circuits or 12-color TV channels. Positioned over the Atlantic.
Feb. 3, 1971	NATOSAT-II (NATO-B)	Thor-Delta (TAT)	Second NATO satellite, stationed over the Atlantic to carry military traffic.
Nov. 3, 1971	DSCS 2-1, 2	Titan IIIC	Operational defense communications satellites launched as a pair to 24-hour synchronous orbits to provide high capacity voice, digital, and secure voice communications for military networks.
Dec. 19, 1971	Intelsat IV (F-3)	Atlas Centaur	Second in new high-capacity series. Positioned over Atlantic.
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.

## U.S. Applications Satellites 1970-1974

Date	Name	Launch Vehicle	Remarks
<b>WEATHER OBSERVATION *</b>			
Jan. 23, 1970	ITOS I (Tiros M)	Thor-Delta	Second generation operational meteorological satellite.
Apr. 8, 1970	Nimbus IV	Thor-Agena	Fifth in a series of 7 advanced research and development weather satellites.
Dec. 11, 1970	NOAA-1	Thor-Delta	Second generation operational meteorological satellite.
	(ITOS-A)		
Aug. 16, 1971	Eole (CAS-1)	Scout	French satellite to gather data from constant density surface balloons relaying meteorological data for the study of the characteristics and movements of air masses. New balloons are released daily from 3 sites in Argentina, for this cooperative French/United States project.
Oct. 15, 1972	NOAA-2 (ITOS D)	Thor-Delta	Second generation operational meteorological satellite.
Dec. 11, 1972	Nimbus V	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.
<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.
<b>GEODESY</b>			
Apr. 8, 1970	Topo I	Thor-Agena D	
<b>NAVIGATION</b>			
Aug. 27, 1970	NavSat O-19	Scout	
Sept. 2, 1972	Triad OI-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.

\* Does not include Department of Defense weather satellites which are not individually identified by launch.

## U.S.-Launched Scientific Payloads 1970-1974

Date	Name	Launch Vehicle	Remarks
Nov. 9, 1970	OFO 1	Scout	Measure vestibular nerve activity of two frogs, otolith system.
Nov. 9, 1970	RMS	Scout	Radiation meteoroid measurements, pickaback to OFO 1.
Nov. 30, 1970	OAO	Atlas Centaur	Orbiting astronomical observatory Shroud did not separate, failed to reach orbit.
Dec. 11, 1970	CEPE	Thor Delta	Cylindrical Electrostatic Probe Experiment, pickaback to NOAA 1.
Dec. 12, 1970	SAS (Explorer 42)	Scout	Study of celestial x-ray sources. (Italian launched.)
Mar. 13, 1971	IMP 8 (Explorer 43)	Thor Delta	Study of solar-lunar-terrestrial relationships in the radiation environment of the interplanetary magnetic field.
Apr. 1, 1971	ISIS 2	Thor Delta	Electron production and loss, and large scale transport of ionization. (Canadian payload.)
June 8, 1971	SESP 1	Thor Burner II	Defense scientific experiments.
June 8, 1971	Solrad 10 (Explorer 44)	Scout	Monitor sun's x-ray and UV emissions.
Aug. 7, 1971	OV 1-20	Atlas Satar	Defense scientific experiment.
Aug. 7, 1971	OV 1-21	Atlas Satar	Defense scientific experiment.
Aug. 7, 1971	AVL 802	Atlas Satar	Defense scientific experiment.
Sep. 29, 1971	OSO 7	Thor Delta	Observe active physical processes on the sun.
Oct. 17, 1971	STP (SESP 71-2)	Thor Agena	Defense scientific experiments.
Nov. 15, 1971	SSS (Explorer 45)	Scout	Investigate ring current and magnetic storms, acceleration of charged particles (Italian launched.)
Dec. 11, 1971	Ariel 4	Scout	Investigate interactions among the plasma, charged particle streams, electromagnetic waves. (United Kingdom payload.)
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 1	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 field 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.

## U.S.-Launched Space Probes 1970-1974

Date	Name	Launch Vehicle	Remarks
May 8, 1971	Mariner 8	Atlas Centaur	Mars orbital photographic mission. Launch failure.
May 30, 1971	Mariner 9	Atlas Centaur	Mars orbital photographic mission. Entered orbit of Mars Nov. 13, 1971. Returned 6,876 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 3,712 pictures in several wavelengths. Passed Mercury on Mar. 29, 1974 returning good quality pictures. Passed Mercury again on Sep. 21, 1974, returning 500-600 good quality pictures. Will pass 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.

## 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 250 mi 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 4 mi of Vostok 3.
Mercury-Atlas 8	Oct. 3, 1962	Walter M. Schirra, Jr.	9 h 13 min.	Landed 5 mi 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 3 mi 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 Virgil I. Grissom	26 h 2 min.	First extravehicular activity (Leonov, 10 min).
Gemini 3	Mar. 23, 1965	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 1 ft 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-orbit rendezvous; first tethered flight; highest Earth-orbit altitude (853 mi).
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 47,000 ft 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 hr 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 pin-point landing capability and continued manned exploration.
Soyuz 10	Apr. 22, 1971	Vladimir Shatalov Aleksey Yeliseyev Nikolai Rukavishnikov	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	Georgiy Timofeyevich Dobrovolskiy Vladislav Nikolayevich Volkov Viktor Ivanovich Patsayev	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	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 hr 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	672 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	1,427 h 9 min.	Docked with Skylab 1 for over 59 days.
Soyuz 12	Sept. 27, 1973	Vasiliy 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	2,017 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.

## U.S. Space Launch Vehicles

Vehicle	Stages	Propellant <sup>a</sup>	Thrust (in thou- sands of lbs)	Max. dia. (ft)	Height (ft)	Max. Payload (lb)		
						300NM orbit	Escape	First launch
Scout.....	1. Algol IIIA.....	Solid.....	108.3	3.67	72.0	* 410	* 85	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.....	205	8	116	* 3,900	* 1,050	1973(60)
	2. Delta (DSV-3).....	N <sub>2</sub> O <sub>4</sub> /Aerozine.....	10.3					
	3. TE 364-4.....	Solid.....	15					
Atlas-Agena.....	1. Atlas booster and sustainer (SLV/3A).	LOX/RP-1.....	503	10	133	* 7,700	* 1,430	1968(60)
	2. Agena.....	IRFNA/UDMH.....	16					
Titan IIIB-Agena.....	1. LR-87.....	N <sub>2</sub> O <sub>4</sub> /Aerozine.....	464	10	159	* 7,200	* 1,500	1966
	2. LR-91.....	N <sub>2</sub> O <sub>4</sub> /Aerozine.....	102					
	3. Agena.....	IRFN/UDMH.....	16					
Titan IIIC.....	1. Two 5-segment 120-in diameter.	Solid.....	2,400	10x30	133	* 27,700	* 6,900	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.....	102					
	4. Transtage.....	N <sub>2</sub> O <sub>4</sub> /Aerozine.....	15.7					
Titan IIID.....	1. Two 5-segment 120-in diameter..	Solid.....	2,400	10x30	154	* 10,500	.....	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.....	102					
Titan IIIE-Centaur....	1. Two 5-segment 120-in diameter..	Solid.....	2,400	10x30	160	.....	* 11,300	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	* 2,500	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	.....	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—IRFN/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

18-YEAR BUDGET SUMMARY—NEW FISCAL YEAR OBLIGATIONAL AUTHORITY  
 [In millions of dollars (may not add due to rounding)]

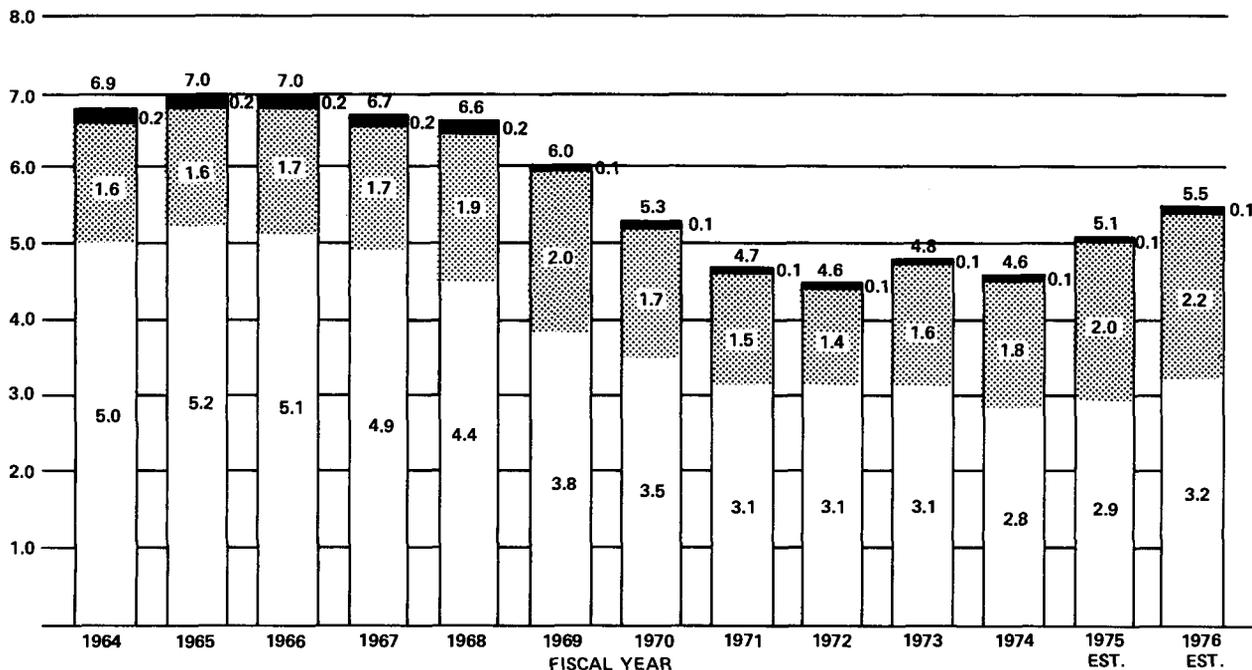
	NASA		Department of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total space
	Total	Space <sup>1</sup>							
1959	305.4	235.4	489.5	34.3					759.2
1960	523.6	461.5	560.9	43.3				.1	1,065.8
1961	964.0	926.0	813.9	67.7				.6	1,808.2
1962	1,824.9	1,796.8	1,298.2	147.8	50.7			1.3	3,294.8
1963	3,673.0	3,626.0	1,549.9	213.9	43.2			1.5	5,434.5
1964	5,099.7	5,046.3	1,599.3	210.0	2.8			3.0	6,861.4
1965	5,249.7	5,167.6	1,573.9	228.6	12.2			3.2	6,985.5
1966	5,174.9	5,094.5	1,688.8	186.8	26.5			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 Est.	3,228.8	2,920.3	2,011.0	40.2	64.6	8.3	3.9	2.0	5,050.3
1976 Est.	3,536.6	3,222.4	2,191.0	43.8	73.7	8.3	5.8	2.4	5,547.4

<sup>1</sup> Excludes amounts for air transportation.

Source: Office of Management and Budget.

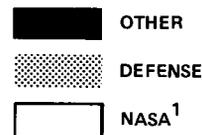
### U.S. Space Budget—New Obligational Authority—1964-1976

BILLIONS OF DOLLARS



<sup>1</sup> EXCLUDES AMOUNTS FOR AVIATION TECHNOLOGY

SOURCE OFFICE OF MANAGEMENT AND BUDGET



**Space Activities Budget**

(In millions of dollars)

	New obligational authority			Outlays		
	1974 actual	1975 estimate	1976 estimate	1974 actual	1975 estimate	1976 estimate
<b>Federal space programs:</b>						
NASA <sup>1</sup> .....	2,758.5	2,920.3	3,222.4	2,960.4	2,903.1	3,181.7
Defense .....	1,766.0	2,011.0	2,191.0	1,777.0	1,904.0	2,133.0
AEC .....	41.7	40.2	43.8	38.8	43.6	46.8
Commerce .....	60.2	64.6	73.7	64.0	67.3	68.9
Interior .....	9.0	8.3	8.3	9.3	7.8	8.2
NSF .....	1.8	2.0	2.4	1.3	1.7	1.8
Agriculture .....	3.1	3.9	5.8	3.1	3.9	5.8
Total .....	4,640.3	5,050.3	5,547.4	4,853.9	4,931.4	5,446.2
<b>NASA:</b>						
Manned space flight .....	1,408.9	1,505.8	1,781.5	1,473.1	1,537.6	1,705.4
Space science, applications and technology .....	1,020.6	1,084.2	1,118.8	1,168.1	1,040.5	1,127.3
Air transportation .....	278.4	308.5	314.2	291.9	304.4	316.3
Supporting operations .....	334.3	334.2	325.0	324.6	328.6	351.9
Less receipts .....	-5.3	-3.9	-2.9	-5.3	-3.9	-2.9
Total NASA <sup>2</sup> .....	3,036.9	3,228.8	3,536.6	3,252.3	3,207.2	3,498.0

<sup>1</sup> Excludes amounts for Air transportation.

Source: Office of Management and Budget.

<sup>2</sup> The detail shown for NASA reflects a change in the budget functional classification used in previous years, and is consistent with NASA's FY 1976 budget documents.**Aeronautics Budget**

(In millions of dollars)

	New obligational authority		
	1974 actual	1975 estimate	1976 estimate
<b>Federal aeronautics programs:</b>			
NASA <sup>1</sup> .....	278.4	308.5	314.2
Department of Defense <sup>2</sup> .....	1,677.5	1,615.5	2,123.3
Department of Transportation <sup>3</sup> .....	73.6	70.4	97.9
Total .....	2,029.5	1,994.4	2,535.4

<sup>1</sup> Research and Development, Construction of Facilities, Research and Program Management.<sup>3</sup> Office of Secretary of Transportation and Federal Aviation Administration Research and Development.<sup>2</sup> Research, Development, Testing, and Equipment of aircraft and related equipment.

Source: Office of Management and Budget.