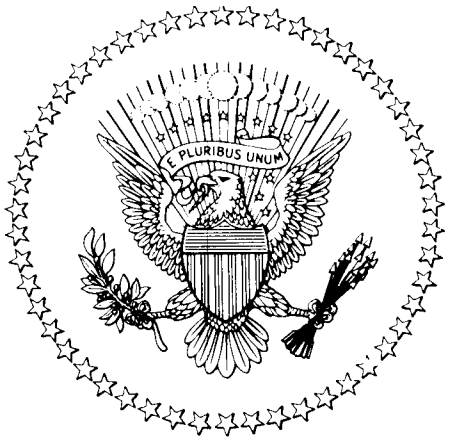

Aeronautics and Space Report of the President

1973 Activities

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Aeronautics and Space Report of the President

1973 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 our Nation's progress in aeronautics and space activities during 1973.

This year has been particularly significant in that many past efforts to apply the benefits of space technology and information to the solution of problems on Earth are now coming to fruition. Experimental data from the manned Skylab station and the unmanned Earth Resources Technology Satellite are already being used operationally for resource discovery and management, environmental information, land use planning, and other applications.

Communications satellites have become one of the principal methods of international communication and are an important factor in meeting national defense needs. They will also add another dimension to our domestic telecommunications systems when the first of four authorized domestic satellite systems is launched in 1974. Similarly, weather satellites are now our chief source of synoptic global and local weather data. Efforts are continuing to develop capabilities for worldwide two-week weather forecasts by the beginning of the next decade. The use of satellites for efficient and safe routing of civilian and military ships and airplanes is being studied. Demonstration programs are now underway aimed at improving our health and education delivery systems using space-age techniques.

Skylab has given us new information on the energy characteristics of our sun. This knowledge should help our understanding of thermo-nuclear processes and contribute to the future development of new energy sources. Knowledge of these processes may also help us understand the sun's effect on our planet.

Skylab has proven that man can effectively work and live in space for extended periods of time. Experiments in space manufacturing may also lead to new and improved materials for use on Earth.

Development of the reusable Space Shuttle progressed during 1973. The Shuttle will reduce the costs of space activity by providing an efficient, economical means of launching, servicing and retrieving space payloads. Recognizing the Shuttle's importance, the European Space Conference has agreed to construct a space laboratory—Spacelab—for use with the Shuttle.

Notable progress has also been made with the Soviet Union in preparing the Apollo-Soyuz Test Project scheduled for 1975. We are continuing to cooperate with other nations in space activities and sharing of scientific information. These efforts contribute to global peace and prosperity.

While we stress the use of current technology to solve current problems, we are employing unmanned spacecraft to stimulate further advances in technology and to obtain knowledge that can aid us in solving future problems. Pioneer 10 gave us our first closeup glimpse of Jupiter and transmitted data which will enhance our knowledge of Jupiter, the solar system, and ultimately our own planet. The spacecraft took almost two years to make the trip. It has traveled over 94,000 miles per hour—faster than any other man-made object—and will become the first man-made object to leave our solar system and enter the distant reaches of space.

Advances in military aircraft technology contribute to our ability to defend our Nation. In civil aeronautics, the principal research efforts have been aimed at reducing congestion and producing quieter, safer, more economical and efficient aircraft which will conserve energy and have a minimum impact on our environment.

It is with considerable satisfaction that I submit this report of our ongoing efforts in space and aeronautics, efforts which help not only our own country but other nations and peoples as well. We are now beginning to harvest the benefits of our past hard work and investments, and we can anticipate new operational services based on aerospace technology to be made available for the public good in the years ahead on a routine basis.

The WHITE HOUSE,
Nineteen Hundred and Seventy-four.

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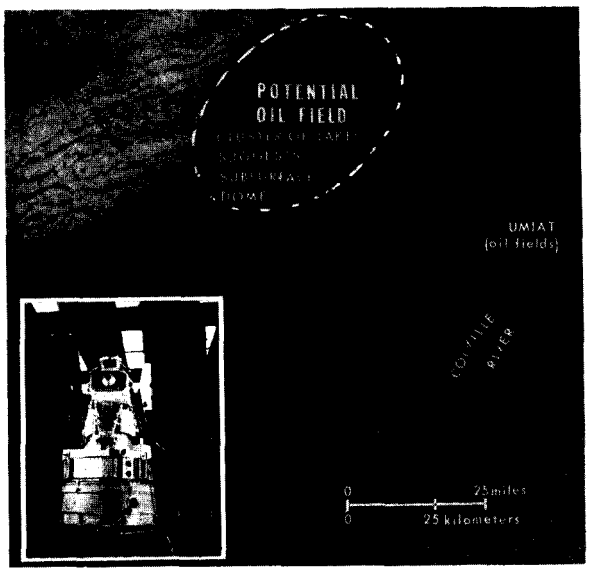
Appendixes

Benefits From Space

Space provides a unique vantage point, a unique base for operations and a unique environment. Each of these elements has been employed as a basis for Earth applications.



Mineral and Energy Exploration

For example, the unique capability provided by satellite imagery for detecting large scale geological features not readily detectable by any other known means, makes such imagery particularly applicable for mineral and energy exploration. Thus, in a Northern Alaska area where petroleum exploration was not currently underway, this Earth Resources Survey Satellite imagery identified geological trends which may indicate substantially larger oil reserves than previously assumed.

Space Processing

The unique zero gravity environment of space is now being explored for the processing and pioneering of materials and products that we have thus far been unable to produce on Earth due to effects induced by gravity. The picture on the left is that of an Indium-Antimonide Crystal that was grown to near chemical perfection aboard Skylab 3. These first experiments show the way to process more complex and important materials in space. For example, manufacture on Earth of integrated circuits for computers and other electronic devices has been hindered by the poor yield of acceptable quality electronic crystals. Structurally and chemically more perfect crystals could substantially widen their use.

I United States Aeronautics and Space Activities in 1973

Introduction

The year 1973 has been one of substantial advancement and achievement in aeronautics and space, contributing toward the fulfillment of national goals in science, the advancement of knowledge, and applications. In addition to the civilian sector, many Federal agencies are now using the products and systems of both aeronautical and space programs in the execution of their specific missions. This report covers the space and aeronautics activities of 17 Federal departments and agencies.

This year especially significant advances have been made in demonstrating the potential benefits to be gained from space activities. In 1973, great progress has been made in the application of the knowledge and technology, acquired in previous years in the Nation's research and exploration programs, to solving our problems here on Earth.

Notable strides have been taken in developing the technologies for acquiring and analyzing information about the Earth, its environment, and its resources from aircraft and spacecraft. This brings closer the day that information will be available to enable man to manage intelligently Earth's environment and resources. The Department of the Interior Sioux Falls Earth Resources Observation Systems (EROS) Data Center is now in its second year serving the public as the major distribution mechanism for remote sensing data. The great potential of these technologies has been demonstrated most convincingly this year by the data derived from the Earth Resources Technology Satellite (ERTS–1), launched in mid-1972.

In addition major accomplishments were made in 1973 in other areas of the application of space technologies to benefit man on Earth. Substantial progress also took place in planetary and deep space exploration, in the understanding of man's ability to live and work in space for extended periods, and in aeronautics.

1973 Defense activities included further development and implementation of satellite based communications and navigation systems, development of new military aircraft, and construction of Advanced Medium STOL Transport Prototypes, which may have important implications for civil transport as well.

In addition to its basic research and scientific exploration missions, NASA's role has been to develop the knowledge, technology, spacecraft and launch services necessary to support Federal organizations in their assigned tasks. This complements NASA's role of helping to pioneer new space services.

This chapter reviews the activities in the U.S. space and aeronautic programs in 1973, and summarizes the progress.

Space

Space activity is no longer primarily exploration, but has become increasingly applications oriented. Some half-dozen Federal agencies now look to space as an economical way, and in many cases the only way, to carry out portions of their missions. In 1973, as for the past several years, over half the Federal money spent on space has been directed toward the development, operation and support of civil and military space applications such as meteorology, communications and Earth observations. As the years go by it can be expected that the percentage spent on applications will increase even further, particularly as States and local governments become involved in utilizing remote sensing for their own resource, hydrological, environmental, and demographic management.

Resources and Environmental Monitoring and Management.—The ability to manage elements of the earth's environment and its resources is a long sought-after goal of increasing importance which may now be nearing the possibility of achievement. A major factor helping to attain this end is the ability to monitor remotely various environmental and resource characteristics from aircraft and spacecraft. The ERTS–1 spacecraft, launched in 1972, is providing environmental and resource data which are being used throughout the world. In this country, cooperative efforts among the many involved departments and agencies have led to the use of ERTS imagery for land use and environmental impact studies, for monitoring hydrological and snow-pack parameters, and for

mapping. During 1973 the feasibility and operational utility of applying remote sensing from space to efficient management of our agricultural and forestry resources were tested. ERTS data were also used to determine the feasibility of detecting water pollutants from space to aid in environmental monitoring and management. The utility of ERTS imagery in showing changes induced by man's activities, such as strip mining, has been recognized by elements of both Federal and State governments.

In Alaska, trends of faults extending off-shore from the North Slope oil fields and geological formations revealed by ERTS imagery near the Umiat Oil Field indicate promising areas for future petroleum exploration. In addition, six prospective copper bearing formations have been discovered from ERTS imagery in the mountains of central Alaska, two of which are now being drilled by a private mining company.

The launch of NOAA–3 on November 6, 1973, provided for the first time an operational satellite for obtaining direct readout of vertical temperature profile data on a global basis. The satellite carries sensors that provide data for measuring snow cover useful in river and flood potential forecasting, determining sea surface temperatures helpful in fishery management, and determining weather and ice conditions for ship routing. NOAA–3 adds to the growing list of satellites used in operational weather prediction and is a step toward 2-week global weather forecasting. Insight into Earth's atmospheric processes, obtained from the study of the Mars and Venus atmospheres, also promises to be a significant factor toward achieving long-term weather prediction as well as toward understanding atmospheric pollution mechanisms.

During the year, accurate measurements of the lunar orbit, utilizing the laser retroreflector placed on the moon earlier by Apollo astronauts, have been used to derive information about Earth dynamics such as polar motions, rotation and large-scale crustal movements. The relation of these parameters to earthquakes is being studied. Earth dynamics programs have been established to combine satellite tracking and geophysical research programs to aid in the understanding and ultimately the predicting of earthquakes.

Communications.—Space communications technology, pioneered by NASA, has advanced to the point where civilian communications by satellite is now a private sector activity. 1973 saw the fifth in the series of INTELSAT IV Satellites successfully launched. Construction was also commenced on a new series of INTELSAT IV–A Satellites which will provide vastly increased capability in 1975. Authorizations were granted for construction of four U.S. domestic satellite systems, and for two U.S. entities to provide interim domestic U.S. satellite services using the Canadian Telsat Satellite System. Communication satellites have provided the world with a substantial advance toward conserving scarce resources such as copper. One communications satellite is capable of replacing large amounts of scarce materials required by conventional systems to provide the same capability. Pressed by a shrinking world and increased interdependence the world's nations seeking to meet their growing communications and education needs have developed an explosive interest in communications satellites. In 1973, 83 countries entered into Definitive Agreements for INTELSAT thereby permanently establishing the global commercial satellite system envisioned in the Communications Satellite Act of 1962.

In April 1973, NASA launched, on a cost reimbursable basis, a second ANIK satellite for Canada's Telesat system, thus establishing the world's second operational domestic satellite system, the first being the Soviet Union's Molniya system. Brazil and Japan are actively considering domestic communication satellite systems while other countries have also expressed interest. India is working towards the implementation of an operational system—INSAT—as a follow on to the ATS–F Satellite Instructional Television Experiment (SITE) to be conducted cooperatively with NASA in 1975. India is spending a substantial sum to establish the necessary SITE ground receivers in some 2000 remote villages to serve several million people. France and Germany continued negotiations with NASA to launch two jointly owned experimental communications satellites in 1974 and 1976.

The United States has continued to assist in the development of a future aeronautical mobile satellite system, negotiating with European and Canadian authorities to establish an initial developmental satellite system in the North Atlantic. Similarly, the United States has been working to further the development of an international maritime mobile satellite service. Such a service will significantly improve maritime communications thereby enhancing maritime safety and management. Meanwhile U.S. entities have been authorized to establish a developmental system for use by the Navy and commercial maritime users prior to implementation of an international maritime system.

Over the past year, satellite communications played a significant role in space activities for national defense. The Defense Satellite Communications System continued to provide secure communications in support of critical command, control, intelligence, and warning needs. Excellent progress was made during the year on the future Fleet Satellite Communications System in support of tactical communications requirements of the Navy and Air Force. The engineering model is in design and fabrication, and a contract has been let for the production of fleet broadcast receivers.

Extensive studies, analysis, and experiments have confirmed the feasibility of the DOD satellite NAVSTAR Global Positioning System.

Exploration.—The most significant and exciting planetary exploration of the year was the flyby of Jupiter by Pioneer 10 in December. It survived the intense radiation field of Jupiter to give us our first close-up glimpse of the solar system's largest planet with its spectacular red spot. The resultant data may well produce a shift in thinking about Jupiter, the solar system, and planetary energy processes. Data indicate that due to Jupiter's own internal heating, the day and night temperatures are the same. The unusual disc-like radiation region of Jupiter suggests an interaction of the solar wind with the planet's magnetic field that is quite different from Earth's case.

Mariner Venus/Mercury was successfully launched in November and is on its way to giving us our first closeup glimpse of Mercury, the planet closest to the Sun.

Making use of the experiments left on the Moon and the treasure trove of lunar data and samples gathered during the historic Apollo project, efforts will be continuing internationally for many years to come, to determine the nature, origin, history and dynamics of our sister planet and to further our understanding of the Earth.

Physics and Astronomy.—Accomplishments in the physics and astronomy program in 1973 have added significantly to our knowledge and understanding of the physical processes governing the Earth, the solar system, and even the universe.

The Atmospheric Explorer Satellite (AE–C) was launched successfully in December to investigate photochemical processes in Earth's upper atmosphere. The knowledge gathered from this mission should be a substantial contributor to understanding pollution processes in the atmosphere. To maximize the data gathered with a single satellite, the spacecraft is capable of changing perigee using onboard propulsion.

An Interplanetary Monitoring Platform, IMP–J, was successfully launched in October. It will acquire additional measurements of the cislunar radiation environment over a significant portion of the solar cycle, as well as measurements of the interplanetary magnetic field and the Earth's atmosphere. It is expected that the results of this mission will be useful in developing a solar flare prediction capability and will enable us to continue the long term assessment of the varying radiation hazards for space missions.

Galactic and solar radio noise is being measured by Explorer 49, launched into lunar orbit in June. This unusual satellite is stabilized by employing gradients in the Moon's gravity field to maintain the alignment of the satellite, and utilizes 750-foot antennas for its measurements.

Exhaustive observations of the Sun were taken by the crews of the Skylab during 1973 and the data are now undergoing analysis. Observation of spectacular X-ray flares emerging from the Sun was one of the first accomplishments. There is evidence of fundamentally different flare mechanisms than previously theorized. There is reason to believe that analysis of the solar astronomy data will establish a revision of our understanding of the Sun and its effects on Earth.

Lower altitude and ground-based measurements have also made major contributions. One of the most important discoveries was the observation by ground-based telescopes of two quasars with the largest red shifts ever observed. These objects provide information on the state of the universe in its very earliest stage. Other important work includes theoretical calculations on how a star develops into a supernova which has improved our understanding of the mechanism of stellar explosion.

The knowledge acquired from these programs, while of great importance to science in its quest for understanding, is potentially of far greater importance to the future of man on Earth. This knowledge will contribute to our understanding of atmospheric processes and ultimately to our ability to forecast and control weather and to manage the environment in which we live. Knowledge of stellar and solar physical processes may provide new insight into nuclear processes and thereby aid us in developing new sources of energy.

Skylab.—Skylab was 1973's largest and most visible space program, making important contributions in many application and science areas. The program was established for four explicit purposes: (1) to further extend the science of solar astronomy beyond the limits of Earth-based observations; (2) to develop improved technologies for surveying Earth resources from space; (3) to increase man's knowledge in a variety of other scientific and technological regimes; and (4) to determine man's ability to live and work in space for extended periods.

The Skylab program has proven to be one of the most exciting and useful of all the space programs to date. The ability to repair the laboratory and return it to a habitable condition after major thermal excursions and power failures, resulting from loss of the meteroid shield at launch, demonstrated the importance of man employing his skills in certain space activities. The program revealed no specific upper limit to man's ability to live in weightlessness.

Data acquired by the huge solar telescope are still being analyzed as part of our important studies of the Sun. Imagery of the Earth's atmosphere and surface characteristics was acquired and provides a new dimension in the technology of surveying resources and monitoring pollution through remote sensing. One of the significant results is the identification of a potential mineral deposit near Ely, Nev. Onboard experiments to further determine the utility of space for exotic manufacturing of materials and mechanical

parts have also awakened worldwide interest. One biological experiment was designed to use weightlessness to alter the life cycle of the gypsy moth in the hope that a means could be found to control this insect pest which has been killing millions of valuable trees in Eastern United States each year.

Space Shuttle.—Recent events have highlighted the interrelation of all parts of the globe in a political, economic, resource, energy, and environmental web. Operations in space enable man to obtain a global perspective which can enhance global cooperation. To enable the United States and the free world to operate routinely in space, the United States has undertaken to build a reusable Space Shuttle. The importance of the Space Shuttle goes considerably beyond reducing launch costs, which it certainly will do. It provides a quick response and a flexibility for civil and defense space operations never before known. With the advent of the Shuttle transportation system and its large payload capability, we will be in a position to trade performance and weight for cost reduction in considering operations in Earth orbit. Because of the capability for repair and retrofitting of space payloads that the Space Shuttle provides, and the considerably more benign launch environment, the cost of developing and building space payloads may begin at last to approach those for use on Earth. In 1973 the Space Shuttle program advanced towards its goal. Contracts were let for propulsion, and the design of the Shuttle itself is proceeding on schedule. Recognizing the importance of the Shuttle, Europe this year committed itself to build a companion space laboratory—Spacelab—to be used for a wide variety of orbital research applications.

International Cooperation.—The United States is working with many other countries to share the benefits of space research. Cooperative activities of broad international scope range from scientific investigations of the farther reaches of the solar system to highly practical applications that affect the lives and well-being of people throughout the world. Cooperation is particularly important in a shrinking world in which such vital activities as communications, transportation, weather forecasting, pollution control, and resource and energy management are increasingly international in extent.

One highlight of 1973 was conclusion of an agreement with nine European countries for the development of a manned orbital laboratory (Spacelab) for use with the U.S. Space Shuttle. Spacelab represents a major European contribution to our national program which will provide opportunities for U.S. and foreign scientists to accompany their experiments into space for the first time.

Another leading development of 1973 was the notable progress made with the U.S.S.R. in preparing for the Apollo-Soyuz Test Project—the joint flight test of compatible rendezvous and docking systems—which is on schedule for a July 1975 launching.

Space applications received new emphasis, with data supplied by the NASA Earth Resources Technology Satellite (ERTS) and the Earth Resources Experiment Package (EREP) on Skylab stimulating new interest at home and abroad. Brazil and Canada have established their own ERTS data acquisition and processing facilities, and other countries hope to do the same. Significant results of ERTS data analysis include location of subsurface water close to usable soils in the Sahelian desert in North Africa, improved charting of the Amazon river system, and major revisions in the forestry map of Thailand.

Meanwhile, the benefits of cooperation in space science continued to be available to NASA and its partners abroad through cooperative scientific satellite and sounding rocket projects and through the flight of foreign experiments on NASA spacecraft. Work went forward on six cooperative satellite projects, while Skylab served as a focus for a great variety of international scientific studies ranging from four foreign flight experiments (one each from Belgium, France, Japan, and Switzerland) to ground-based analytical studies of Earth imagery from EREP and Solar imagery from the Apollo Telescope Mount.

Other important developments of 1973 included the coming-into-force of the INTELSAT definitive arrangements and construction under DOD management of two satellites to be launched in 1974 for the United Kingdom Skynet military communication program.

In support of the U.S.-U.S.S.R. Direct Communications Link, parallel communications channels utilizing the INTELSAT and Molniya systems are planned for 1974. These parallel channels require the construction of an earth station in the Soviet Union to access the INTELSAT system and the construction of an earth station in the United States to access the Molniya system.

Aeronautics

Emphasis in the aeronautics programs was placed on both civil air transportation and on satisfying defense needs. In the former, the objectives were to provide the technology for improved, more efficient, transportation systems while reducing the environmental impact of those systems. Defense objectives centered on maintaining the security of the Nation.

Civil Air Transportation.—The Nation's aeronautical research and development activities are objective-oriented, direct toward the timely development of capabilities in areas of national priority and need. A major effort, aimed at alleviating noise and congestion near airports and removing or reducing other current

growth restraints in civil air transportation such as cost, safety and energy restrictions was continued through the year. This effort included a focused program to provide congestion reduction technology through the development of improved avionics and development of a superior short-haul, high-density STOL and VTOL aircraft technology. These efforts, as are most in the area of civil aeronautical research activities, are conducted with the active cooperation of the National Aeronautics and Space Administration and the Department of Transportation.

The environmental impact of aircraft noise in the vicinity of airports has been the largest single impediment to the orderly growth of air commerce. NASA has vigorously been pursuing several solutions to this important problem. In 1973, noise reduction efforts included the modification of existing jet engines in commercial use, design of acoustic engine nacelles, changing flight procedures and developing quieter engines. NASA's JT8D jet engine refan program is designed to demonstrate the technology to reduce the noise footprint of 727, 737, and DC–9 aircraft by 75 percent. These aircraft account for over 60 percent of the operations of the domestic fleet. The new wide body jets now entering service already have benefitted from NASA's past noise reduction efforts.

Other research on reducing the environmental impact of aircraft and promoting their efficient, economical use further advanced this year. Cooperative studies of the anticipated effects of high altitude supersonic transport aircraft upon the stratosphere were completed and the reports of this program, the Climatic Impact Assessment Program, will be submitted to the Congress in 1974 after it has been thoroughly reviewed. Programs aimed at providing the technology for aircraft engines having lower emission levels of pollutants were continued with the specific goals now relating to standards proposed under the Clean Air Amendments of 1970.

In the area of aeronautical operations and the application of aircraft technologies, the Nation has moved forward rapidly in increasing automation of the air traffic control system in order to promote safety, reduce congestion and increase the number of flights completed on time to the original destination. This will not only be a great time saver and convenience to travelers, but will be a major contribution toward the conservation of air transport fuel. During 1973, installation was completed of 60 automated radar terminal systems at the Nation's busiest terminal areas. Twenty air route traffic control centers have also been automated, supplying the entire country with computerized flight data processing capability.

Federal, State and local governments have been actively increasing their use of aircraft in their routine operations. For example, aircraft are employed in the maintenance of hydroelectric and irrigation system; for location and suppression of forest and mine fires, to acquire mapping photography, and in the regulation of wildlife. Aerial photography has been used for resource survey and revision of inventory maps. Programs of fully operational remote sensing for forest fire detection, prevention, and mapping have been expanded.

Remote sensing from aircraft for environmental quality purposes was accomplished within both operational and research programs. Goals of missions flown included (1) the identification of land misuse as it relates to cultural growth, (2) the identification, tracking, and mapping of oil spills, (3) identifying and monitoring of agricultural runoff, (4) assessing the impact of pollution, (5) monitoring of ocean dumping, (6) monitoring environmental trends, and (7) monitoring changes due to strip mining. Aircraft also served as support for space sensing activities.

Defense.—Development of advanced technology suitable for future military systems is a major goal of both DOD and NASA. Joint efforts were continued in research and in the development and test of experimental and prototype aircraft in order to point the way towards advanced systems of superior capability. NASA also continued to provide direct support to specific military aircraft developments in order to enhance the probability of their successful development.

Significant advances in these military systems were achieved in 1973. A decision was made for full-scale development of the economical (designed to a target cost of $1.5 million) A–10 aircraft which will provide close air support for ground combatants. The B–1 strategic bomber for the 1980's is now scheduled for its first flight in mid 1974. The F/FB–111 development was completed, providing an enhanced all weather attack capability. The Navy F–14 carrier-based tactical fighter is meeting or exceeding design requirements in flight test and in the fleet environment. The Air Force F–15 advanced tactical fighter is on schedule and 11 aircraft delivered to the Air Force are in flight test. Two contractors are in the final fabrication stages of two Light Weight Fighter Prototypes to explore new technology leading to a low cost, high performance, austere fighter. All milestones for the S3A carrier-based antisub warfare aircraft have been met successfully and 45 additional aircraft have been ordered. Progress has been made in providing airborne warning, and command and control systems. Under the Advanced Attack Helicopter development program, two contractors were selected for a competitive fly-off program. The military Utility Tactical Transport Aircraft System development is continuing on schedule. In addition, two contractors are each building two Advanced Medium STOL Transport Prototypes for the military which may also provide a base for future civil STOL transportation systems.

II National Aeronautics and Space Council

The National Aeronautics and Space Council was established in the Executive Office of the President by Section 201 of the National Aeronautics and Space Act of 1958. The same act also established the National Aeronautics and Space Administration. The Council was abolished in the fiscal year 1974 President's budget to the Congress. The Council was abolished because the major policy issues of the past have been largely resolved in the national space program, and a special advisory group in the Executive Office of the President was considered no longer necessary. Interagency coordinating arrangements were considered adequate to handle any future issues that may arise.

The Vice President of the United States was Chairman of the Council. Other members included the Secretaries of State, Defense, and Transportation, the Administrator of the National Aeronautics and Space Administration, and the Chairman of the Atomic Energy Commission. The Council's small staff consisted of an executive secretary who had the supervisory responsibility for the staff. Other staff included permanent members, and detailees from the various agencies that were represented on the Council.

III National Aeronautics and Space Administration

Introduction

The function of the National Aeronautics and Space Administration (NASA) is to plan, direct and conduct aeronautical and space activities. The goal of NASA's space activities is to pursue the peaceful uses of space for the benefit of all mankind. To help achieve this goal, the National Aeronautics and Space Act enunciated a number of contributing subgoals: to expand human knowledge of phenomena in the atmosphere and space, to develop and operate space vehicles, to preserve U.S. leadership in aeronautics and space technology, to discover and apply benefits obtained from space, and to cooperate with other nations on peaceful applications.

In previous years, the emphasis in space has been on the first three goals. 1973 has been the year of "cashing in" on the technology development and knowledge obtained from our lunar and space exploration programs. 1973 is the year in which wider emphasis was placed on the latter goals—space applications, benefits, and international cooperation.

Skylab has been the space exploit most in the news. Not only did Skylab function to demonstrate numerous space applications, but the ability of the astronauts to also rescue the mission by repairing the damaged spacecraft through extra vehicular activities (EVA's) has laid to rest many of the questions on man's ability to think, work, and live in space.

In the unmanned applications area, the Earth Resources Technology Satellite (ERTS) provided data during 1973 useful for land use planning, mapping, identification of farm crops, locating natural resources, and monitoring flooding and pollution.

Satellite communication systems, capitalizing on technology developed by NASA, are now one of the world's chief sources of international communications and are already being applied to domestic communications as well. ATS–F, the final communications-oriented advanced technology satellite planned by NASA, is scheduled for a 1974 launch. In addition to pioneering new communications technology, it will also be used by India to demonstrate satellite supplied education to remote villages and by HEW to demonstrate remote delivery of health consultation and educational television.

Weather satellites pioneered by NASA have now been in use for many years. In November, the NASA developed ITOS–F was launched. Satellites of this class will enable the National Oceanic and Atmospheric Administration (NOAA) to retire many ocean survey vessels which have been using radiosondes to obtain atmospheric vertical temperature profile data. The resultant cost savings will be significant.

Technologies developed for the conduct of aerospace activities are now being applied to such diverse potential uses as earthquake prediction, development of residential solar heating, and economical fuel-saving integrated utility systems for housing.

Despite the surge in applications, science and exploration have not been neglected, for they too provide benefits. Study of other planets helps us understand the Earth. Mars and Venus provide global laboratories for testing atmospheric theories, which will help advance the day when we can make accurate long-range weather predictions, weaken storms, and perhaps even control climate. Understanding the moon's geology helps us understand the Earth's geology with its many implications for locating minerals and comprehending Earth's dynamics and its associated earthquakes.

In December, Pioneer 10 visited the massive planet Jupiter with its huge red spot, its intense radiation and magnetic fields, its multicolored atmosphere, and its dozen moons. The resultant data have already begun to unlock its many mysteries.

With the acceleration of the growth of space applications, inexpensive ready access to space is particularly desirable. The Space Shuttle, designed to provide such access, as well as to reduce other costs of space operations such as payload costs, is moving ahead toward its first test flight in 1977. In 1973, many of the necessary subcontractors were selected by the prime contractor. Europe, recognizing the Shuttle's importance, has this year chosen to build a companion Spacelab.

NASA's vigorous aeronautics research program is concentrating on reducing the environmental impact of aircraft and making air transport more efficient. One

program is designed to demonstrate the technology necessary to reduce the noise of 60 percent of the domestic commercial air fleet through modification of their engines. Another major endeavor is aimed at relieving airport congestion by improving aircraft systems and by development of STOL/VTOL aircraft that can use alternate, less congested, airports. Programs to increase aircraft efficiency, with accompanying fuel savings, include improving aerodynamic design and utilizing weight-saving materials. NASA's efforts to promote aircraft safety and reduce vehicle fire hazards have already been applied in other civil uses.

NASA is also actively working with other Federal agencies and internationally to bring the benefits of aerospace technology and information to ourselves and other nations.

This chapter elaborates on NASA's efforts in these and other areas.

Applications Programs

Space applications programs include Earth observations (meteorological and Earth resources surveys), Earth and ocean physics, and communications. Operational space systems have already evolved in meteorology and communications and, in the latter, private industry has assumed a large share of the responsibility for further exploitation of the communications satellite technology developed by NASA. The final communications-oriented advanced technology satellite planned by NASA, ATS–F, neared completion of its development stage. Planned to be launched in 1974, the spacecraft will then be used by the United States to relay health information and experimental educational programs directly to inexpensive television receivers in remote regions of the Federation of Rocky Mountain States, Alaska, and Appalachia. Remote areas lacking ground communication facilities will derive great benefits in the form of rapid, economical, widespread dissemination of health services information and educational programs.

The Earth resources survey program is the next activity expected to become operational. Earth Resources Technology Satellite 1 (ERTS–1) was launched in July 1972, and has already been highly successful in providing imagery useful in land use planning, rapid mapping of large areas, identifying farm crops, locating natural resources, and warning of flooding and pollution.

NASA's applications programs are not only demonstrating that space has practical uses in daily life, they are also helping people understand where the technology can be put to work for human good.

Earth Observations.—*Earth Resources Technology Satellites.*—The United States made what is proving to be a fundamental advance in the application of technology by launching the ERTS–1 in July 1972. For the first time a wide range of data was routinely being acquired over the entire United States and other portions of the world. This year, we have learned to derive valuable information from this new technological tool. Major advances have been made in petroleum and mineral exploration, identification of major crops and inventory of acreage, and in the evaluation of the environmental impact of man's activities. Satellite technology is proving to be an effective tool for more effective exploration, management, and monitoring of natural resources.

In Alaska, for example, a previously unnoticed regional trend was identified on ERTS–1 imagery near the Umiat Oil Field. The alignment of many small lakes in that area—first detected by ERTS—identified a regional feature similar to the domed structures which form oil traps. Trends of faults were extended offshore from the North Slope oil fields indicating promising areas for future petroleum exploration. In addition, six copper porphyry prospects were discovered from ERTS imagery in the mountains of central Alaska, two of which are now being drilled by a private mining company.

Indentification of wheat, corn, and soybean crops can readily be accomplished. Accuracies exceeding 90 percent were attained for acreage measurement of major crops in many states and several foreign countries.

Land use application of ERTS data also shows major promise. Land use maps and map updates of Connecticut, Massachusetts, Maryland, Michigan, Minnesota, New York, Rhode Island, Wisconsin, and others were prepared using ERTS data. The scale of ERTS maps is regional, and the maps are most effective for State and rural uses. Such mapping is a cost effective way of examining our entire Nation—especially the State of Alaska.

During the major flood of the Mississippi River in the spring of 1973, computer recognition and mapping of surface water from ERTS data were used by the Corps of Engineers to evaluate flooded acreage and flood control structures. Also, circulation and sedimentation patterns observed in ERTS imagery of the coasts are being used by Delaware to develop a deployment strategy for equipment to control oil spills.

The excellent results of this research program encouraged NASA to cooperate with operational agencies in a series of major applications tests. In one, the Department of Agriculture is using ERTS–1 to make a wheat inventory covering the United States and Canada.

Plans were also made for continuing research on new applications of data from earth resources survey satellites to such areas as estimation of crop production; irrigation control experiments; mapping new geologic structures and mineral prospects; detection and mapping of geothermal energy resources; developing interrelations of fish schools and remotely sensed

marine indicators; initial systems to measure environmental changes; and identification of sources of pollution.

NASA and the Department of Interior began studies of ways of achieving a smooth transition from a research and development system such as ERTS–1 to an operational Earth resources survey system.

International interest in directly obtaining and using ERTS data increased markedly. Canada and Brazil installed and began operating ERTS data receiving and processing facilities, Italy announced that it would construct an ERTS station, and several other countries were studying such installations.

Skylab/Earth Resources Experiment Package (EREP).—This Package was carried aboard Skylab 1, launched in May. The EREP sensors were operated during the SL–2 and SL–3 missions, and data were collected for 136 investigators from the United States and 19 other countries. The investigators are using the data to study a variety of Earth resources problems related to agriculture, forestry, geology, hydrology, mineralogy, meteorology, oceanography, demography, and cartography. The particular value of the EREP package to investigators is in the increased spectral coverage and improved resolution of its instruments. Coverage extends to the thermal band and microwave sections of the radiation spectrum. Both improvements will be used to assess new uses for such data and the requirements for new instrument development.

Earth Observations Aircraft Program.—The Earth Observations Aircraft Program (EOAP) served as a complementary source of remote sensing data for the Earth resources survey investigative program, providing continuing support to in-house and interagency surveys and to sensor development efforts. The major portion of the aircraft program effort was devoted to ERTS and Skylab investigation. Aircraft survey flights provided verification data needed by investigators for interpretation of space-acquired imagery. To date, some 497 overflights of ERTS and Skylab test sites have been completed.

The program uses several different aircraft, operating at altitudes up to 21 km (65,000 feet), to test remote sensing instruments and techniques. The high altitude flights simulate conditions resembling those of an orbiting spacecraft and permit sensors in development to be tested and compared without the need for large numbers of costly launches. The range of the sensor's performance capabilities can be established and data handling and analysis techniques can be verified.

Meteorology and Environmental Monitoring.—*Nimbus.*—Nimbus 5, an experimental weather satellite, launched in December 1972, achieved its objectives in February 1973; however, it continued to operate with five of the six major experiments capable of providing useful data. These experiments demonstrated the capability to obtain remote atmospheric sounding from cloudy regions and at altitudes higher than previously possible. Such data could be used to improve long-term weather forecasts and to increase understanding of atmospheric processes. A surface composition mapping radiometer carried on the mission demonstrated that the composition of the surface could be determined by measuring the modification of the thermal emission of igneous rock.

Nimbus-F, scheduled for launch in 1974, will provide improved remote sounding techniques including better vertical range and resolution for atmospheric sounding. It will contribute substantially to the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE) by measuring the lower stratospheric winds in the tropics. This experiment will provide additional knowledge of the movement of atmospheric energy from the tropics to temperate zones.

Development of the new Air Pollution and Oceanographic Observing Satellite (Nimbus-G) was initiated. Its sensors will furnish data for data-use investigations applicable to air pollution, oceanography, the ocean/atmosphere interface, and the Earth and atmosphere heat budget. It is scheduled for launch in 1978.

Improved TIROS Operational System.—In November, the NASA-developed ITOS–F was launched; a Delta launch vehicle boosted the spacecraft into a nearly polar orbit from the Western Test Range. The cost of the spacecraft, instruments, launch vehicle, and launch services were fully reimbursed by NOAA. After successful launch, the spacecraft was designated NOAA–3. Satellites of this class will enable NOAA to retire many ocean survey vessels which have been using radiosondes to obtain atmospheric vertical temperature profile data. The resultant cost savings will be significant. NOAA–3 is the second spacecraft of this series which provides operational atmospheric sounding and very high resolution, day-and-night cloud-cover imaging. Plans for follow-on missions call for launches at the rate of about one per year over the next 4 years.

Synchronous Meteorological Satellites (SMS) Program.—The objective of this program is to develop a geostationary satellite system capable of meeting NOAA's requirements for the National Operational Environmental Satellite System (NOESS). The SMS spacecraft, carrying the large technically sophisticated visible and infrared spin scan radiometer (VISSR) sensor, will be able to take full-Earth disk pictures every half-hour, day and night, thus satisfying the requirement for short-term weather forecasting and continuous viewing. The SMS system can also collect environmentally significant data from up to 10,000 sensing platforms in remotely located surface sites, and relay unprocessed and processed data to regional forecasting

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or warning stations. SMS–A, due to be launched in early 1974, was completely integrated and tested; the fabrication, integration, and test of the follow-on spacecraft, SMS–B and SMS–C/GOES–A, were on schedule.

Global Atmospheric Research Program (GARP).—The major activity in this program was the detailed planning and preparation for the Data Systems Test (DST) scheduled for 1974. NASA was assigned primary responsibility for this test, which will provide an early 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. Progress was made in developing techniques for routine real-time processing and assimilation of satellite sounding data, in developing procedures for determining wind fields from cloud-track images obtained by geostationary satellites, and in the development of a carrier balloon system employing dropsondes to obtain vertical wind profiles in data sparse equatorial regions. The latter will be tested in conjunction with the GARP Atlantic Tropical Experiment during 1974.

Earth and Ocean Physics Program.—This year the Earth and Ocean Physics Application Program (EOPAP), formally established in 1972, made substantial scientific and technical progress.

Sea Measurements from Skylab.—The exploratory Skylab tests of the altimeter and scatterometer measurement techniques were successful. Initial analyses of the altimeter data showed that the sea surface topography was indeed measurable, and that the results correlated very well with the mean sea level determined by observing the gravity field.

Ocean Satellites.—Planning for the proposed SEASAT–A mission was accelerated. The objectives were set and the instrument complement was decided upon in a series of meetings involving NASA and the user agencies, particularly the Departments of Commerce, Defense, and Transportation.

Preparations for the launching of GEOS–C in mid-1974 continued on schedule. This satellite will offer the first opportunity for observing the oceans on a global basis and should be a boon to the shipping industry. The final definition phase of LAGEOS, a passive geodetic satellite for use with high precision laser ranging systems, was started, and actual construction scheduled to begin next year.

Toward Earthquake Prediction.—The preliminary Polar Motion Experiment based on tracking the Beacon Explorer spacecraft with a laser—an entirely new technique—yielded an improved determination of the motion of the pole. An accuracy of one meter was maintained over a 5-month period, and it was possible to determine one component of the pole position using 6-hour spans of data from a single station. The results were comparable with those obtained by conventional techniques using 5-day spans of data from 40 stations around the world. The great decrease in the time required for the measurement by the new technique suggests the possibility of much more refined testing of the hypothesis that certain movements of the pole actually precede large earthquakes.

Studies of satellite orbital data provided the first experimental evidence for the influence of ocean tides upon the solid Earth tides. The results imply that future studies of the dynamics of the oceans and of the Earth's crust should enlarge understanding of earthquake mechanisms.

Development work continued on the Very Long Baseline Interferometry (VLBI) technique for making accurate measurements of crustal motions. First tests were made of a mobile VLBI terminal which will greatly expand the usefulness of this promising technique for making measurements of motions along earthquake faults. Analysis of the data taken during the first observing period of the San Andreas Fault Experiment (SAFE) in 1972 was begun; initial results indicated that measurement accuracy increased.

Advance models of the Earth's gravitational field were generated on the basis of the final sets of data obtained during the national geodetic satellite program, the 10-year effort which provided the foundation for the Earth and Ocean Physics Applications Program.

Communications Applications From Space Research.—As the world grows smaller and nations more interdependent, and as more of the developing nations move into the industrial age, the need for improved communications becomes more urgent. In many cases the most expedient practicable way to establish a capability for such communications is by satellite—to bridge the oceans, the mountains, the jungles, and the plains.

Current experimental use of NASA's Applications Technology Satellites in the remote villages of Alaska is bringing improved emergency medical care. In the wide-flung islands of the Pacific, the satellites are providing for educational and cultural exchange and interplay which can lead to improved international understanding and amity.

In Februray 1972, the President's visit to mainland China was televised live to the rest of the world via INTELSAT using transportable ground stations flown in for the purpose. In 1973, United States-manufactured permanent ground stations were installed for use by the Peoples Republic of China in communicating with the rest of the world through the INTELSAT satellites.

Domestic Applications.—Six applicants have been allowed by the FCC to proceed with the development

of satellites to serve both general purposes and special purpose networks in the United States. This will result in a minimum of 14 reimbursable launches in the next 5 years.

Maritime Satellite Communications.—The U.S. Navy has contracted with Comsat for interim fleet services to be provided by a maritime satellite system beginning in 1974. The satellite system planned by Comsat, called MARISAT, will have sufficient capability to provide, for the first time, a precursor operational service for the U.S. merchant fleet.

International Applications.—NASA launched a second ANIK satellite for Canada on a reimbursable basis in April. This established the second operational domestic satellite system, the first being Russia's Molniya. Several of the approved U.S. applicants for domestic satellite services are leasing channels from the Canadian system in order to initiate U.S. service earlier than would be possible through U.S. owned satellites.

India continued to work towards the implementation of an operational system, INSAT, as a follow-on to the ATS–F Satellite Instructional Television Experiment (SITE) to be conducted in 1975. It is described in more detail below.

Brazil is considering establishing its own domestic satellite system to provide interconnection of the populated regions along the coast with outposts of civilization in the mountain and river-valley regions of the country.

Japan conducted design studies of several satellite systems for domestic communications and direct broadcast service with planned launchings to begin in late 1977. Successful implementation of these systems could give Japan a commanding lead in the ability to sell similar systems to others.

Negotiations were underway for NASA to provide reimbursable launch services for two experimental communication satellites (*Symphonie* in late 1974 and 1976) developed jointly by France and Germany. Similar arrangements were in process between NASA and the European Space Research Organization (ESRO) for launch of two other applications research satellites, one a communications test satellite (OTS in late 1976) and the other a maritime test satellite (MAROTS in 1977). In addition, the United States (Government/Industry) and ESRO were about to enter into an agreement for an aeronautical satellite system (AEROSAT) for the North Atlantic region.

Several other countries have also expressed varying degrees of interest in the possibility of implementing their own domestic or regional satellite systems.

Looking Ahead.—As a result of the projected increase in satellite service, there will be a large number of satellites competing for a limited number of synchronous orbital locations and an already crowded radio spectrum. Continued research and experiment in the United States can help it maintain leadership in this area and reap the resultant benefits.

NASA Communications Programs.—*Applications Technology Satellite (ATS) F.*—ATS–F is a multiuser communications experiments satellite, scheduled for launch in April 1974. During 1973, integration of the various spacecraft elements and experiments was completed and end-to-end testing was in progress.

The ATS–F Health and Education Telecommunications Experiment (HET), which is being conducted in conjunction with HEW, is scheduled to start in April 1974. Educational television programing will be provided via satellite to hundreds of remote villages throughout the Rocky Mountain States, Appalachia, and Alaska. In addition, medical consultation will be provided between health centers and rural areas of the country.

Following the HET experiment, the ATS–F satellite will be moved from the United States to India to support a Satellite Instructional Television Experiment (SITE) which will be conducted by the Indian Government. Instructional television programs will be provided to about 2,000 Indian villages. The Indian ground-station development was successfully completed, and television program production initiated. Upon the completion of the SITE experiment, the satellite will be moved back to the United States for continued experimentation. In addition to these principal broadcast type experiments, a number of other user oriented and technology experiments are carried.

Communications Technology Satellite (CTS).—The Communications Technology Satellite is a joint development of the Canadian Department of Communications (DOC) and NASA. This experimental satellite, scheduled for launch at the end of 1975, is expected to contribute toward developing a capability for routine broadcast services to small, low-cost community terminals. It will pioneer the use of the newly allocated 12 GHz frequency band allocation, which imposes no restrictions on power levels for the satellite. The United States will contribute the Thor/Delta launch vehicle, the super-efficiency 200-watt output Transmitter Experiment Package (TEP), and facilities for environmental testing and launch of the spacecraft being designed, developed, and built by Canada.

After the satellite is successfully placed into geostationary orbit, NASA and DOC will conduct communications experiments, sharing the experiment time equally. Experiments will be performed over a wide variety of potentially beneficial satellite applications. They form the basis for development of low-cost user ground terminals. 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.

Communications Satellite Research Terminated.—On January 5, NASA announced that it was phasing out its communications satellite research work as one of the program reductions needed to adjust activities to a lower agency spending level. On the premise that the satellite communications industry was economically self-viable, NASA felt that further advances in satellite communications research and development, past those envisioned with its flights of ATS–F and CTS, could be accomplished by industry on a commercial basis without Government support.

Advanced Communications Research and Technical Consultative Services.—In 1973, emphasis was placed on providing a sound technological base for future space applications programs. Studies were initiated on frequency allocation, bandwidth, and orbit requirements for future applications missions, particularly for Earth observation satellites. Studies and investigations were initiated to open up new regions of the spectrum for space applications and research. Efforts were continued to develop or improve space systems components and technologies which will facilitate increased efficiency in utilizing the geostationary orbit and radio frequency spectrum including improvements to shaping antenna patterns and better methods of compressing data and reusing available radio spectrum.

Technology and feasibility assessments of spacecraft and telecommunications systems and component problems of domestic and INTELSAT satellites were performed at the FCC's request. Systems evaluations were also initiated for the FCC on INTELSATs IV A and V. Throughout 1973 participation in U.S. Government and international telecommunications committees was continued, particularly in support of NASA's space applications interests in Earth resources and in weather and climatology effects.

Other Applications.—*Data Collection.*—A phenominal growth (several orders of magnitude) in the use of Earth and satellite based sensors is expected within this decade. Efforts have been initiated to provide the techniques, advanced technology, higher frequencies, and interference free environment required to meet these projected needs which will utilize ground-to-satellite, satellite-to-ground, and satellite-to-satellite telecommunications links.

Modular Integrated Utility System.—NASA continued working with the Department of Housing and Urban Development (HUD) to develop a Modular Integrated Utility System (MIUS) for commercial, industrial, or residential applications. This cooperative effort with HUD, which draws upon NASA's experience in developing life support systems for manned spacecraft, represents an important step in applying space derived technology to the needs of man here on Earth.

The MIUS system would provide all of the utility functions such as heating and cooling, electrical power, water treatment, and solid waste management and disposal for integration into a building or building complex (apartments, stores, shopping centers). By combining all of these functions, energy needs can be reduced by about one-third. Significant reductions can also be expected in the amount of water required and the volume of solid waste to be removed.

In 1973, the MIUS systems requirements were established and a conceptual design evolved. Plans were made for NASA to provide HUD with final design and performance specifications for a demonstration system. A demonstration of MIUS in an actual operating environment is expected to be undertaken with private enterprise sometime in 1974. The Federal Government will encourage private enterprise to make integrated utilities systems available on a commercial basis.

Community Uses.—In 1973, special studies were getting under way to identify advanced technologies that will be needed to implement such new applications as disaster warning, communications as a substitute for transportation, microwave transmission of high levels of energy, and electronic mail handling. In all these areas, tremendous growth is expected to overburden the systems now available and it is urgent that the new technologies from the space program be considered as full or partial replacements.

Manned Space Flight

The year 1973 has seen the emphasis in manned space flight turn from exploration to applications. Skylab focused on the use of man in space and the use of space to monitor and survey Earth, to determine our solar environment, and to provide a unique environment for manufacturing and for the study of biological and chemical processes. The reusable Space Shuttle is designed to routinize our ability to employ the advantages of space for Earth observation, communication, navigation, space manufacturing, and environmental, demographic, hydrological, transportation, and resource management.

Skylab Program.—The basic purposes of the Skylab program are: to determine man's ability to live and work in space for extended periods; to further extend the science of solar astronomy beyond the limits of Earth based observations; to develop improved techniques for surveying Earth resources from space; and to increase man's knowledge in a variety of other scientific and technological regimes.

The first Skylab manned mission made significant

contributions to the purposes of the program, and in many cases the crew did more than called for in the flight plans. Among their accomplishments were 267 scientific investigations, 82 hours of telescopic observations of the Sun, and photographs of more than 4 million square miles of the Earth's surface. Skylab's second manned mission added to the successes of the first in the area of scientific experiments and extended the stay time in space to 59 days. This was surpassed by the scheduled 84-day third mission, which again acquired vast quantities of scientific, biomedical, Earth resources, and solar astronomy data.

Data from the Skylab missions has not yet been fully analyzed, but we already know a great deal more about the human body and its behavior in space than we knew before. This knowledge is transferable to medical science and will enlarge our understanding of the functioning of the human body on Earth. We have also increased our information about the Sun and its relationships with the Earth, which may eventually contribute to a better understanding of our weather. The Skylab astronauts have observed the Earth's resources, its atmosphere, its waters, its vegetation, and its pollutants. The EREP (Earth Resources Experiment Package) instruments for remote Earth sensing performed two functions: They advanced the technology and gathered data useful for research in agriculture, forestry, ecology, geology, geography, meteorology, hydrology, hydrography, and oceanography.

Skylab 1, 2.—The first Skylab mission was directed toward establishing the experimental space station in Earth orbit and conducting medical experiments associated with long periods of manned space flight. Emphasis was also placed on solar astronomy, Earth resources, and other technological experiments. Flight crew members were commander Captain Charles Conrad, Jr. (USN); science pilot, Cmdr. Joseph P. Kerwin (USN); and pilot Cmdr. Paul J. Weitz (USN).

The unmanned Skylab 1 was launched by a Saturn V on May 14 and inserted into a circular orbit of 435 kilometers (272 miles). The Apollo Telescope Mount (ATM) solar arrays deployed normally, but the Workshop solar array system did not.

Subsequent analysis and inspection revealed that the meteoroid shield was torn away during boost, carrying one of the Workshop solar wings with it, while a piece of the shield wrapped around the second Workshop solar wing and kept it from deploying. As a result, the Workshop lost power and became overheated, and the launch of the manned Skylab 2 was postponed until May 25. The period between the two launches was used to devise ways of "fixing" Skylab and training the crew to carry out the "fix." At the same time, ground controllers devised an attitude for the Skylab that would provide power and still keep the inside temperature at a reasonable level. The solution finally selected was to have Skylab 2 carry aloft three thermal shields—a "parasol," a "twinpole," and a "sail."

Skylab 2 was launched by a Saturn IB on May 25 and made rendezvous with the Workshop several hours later. As they approached the Workshop, the crew observed that one solar panel was missing and the other was partly deployed, restrained by a piece of the micrometeoroid shield. A standup EVA (extra-vehicular activity) attempt to deploy the array was unsuccessful. After docking, the crew entered and activated the Multiple Docking Adapter and then went into the Workshop. Once in the Workshop, the crew was able to deploy the parasol sunshield through the scientific air lock. The results of deployment were noted almost immediately: Internal temperatures dropped markedly. By mission day 4 the internal temperature had decreased to 90°F.

On mission day 14, astronauts Conrad and Kerwin, in the course of a 3½ hour EVA, used specially devised tools to release and extend the stuck solar wing. Their work was completely successful and recovered approximately 3,000 watts of electrical power.

The Skylab 2 mission concluded with the landing in the Pacific and recovery of the Command Module on June 22.

The first Skylab manned mission accomplished all its primary objectives, including the following specific achievements: Approximately 80 percent of the planned solar data were obtained; 12 of the 15 planned Earth resources data runs were completed; and all 16 medical experiments were conducted as required. The time history of man's adaptation to the zero-g environment was obtained for the first time, and data were taken on 43 experiments, including eight in the Skylab student project.

The 28-day mission—the longest manned space mission to date—was a significant step in developing a capability for extended space flights. Skylab provided the first opportunity in manned flight to collect a vast amount of inflight physiological data. Sixteen separate medical experiments were conducted to determine the time course of the effects of extended space flight. Results showed that the crew experienced no unexpected changes, and the postflight test revealed that the crew returned to preflight conditions in every monitored function.

The five major ATM experiments, constituting the most comprehensive and powerful solar observatory ever built, made sample observations supporting every major solar physics objective identified for the first mission, including, a significant flare in the lower solar atmosphere and transients in the corona, with its million degree temperature, quiescent features such as multimillion-ion prominences suspended in the corona, and the mysterious convection and storm patterns which somehow cause the solar wind.

The EREP remote sensing techniques were used for many hours of intense observations of the Earth. Data were acquired over predetermined ground test sites in 31 States and Puerto Rico; in Mexico, Brazil, Colombia, Nicaragua, Bolivia, and Canada; in the Pacific and Atlantic Oceans, the Caribbean Sea, and in the Gulf of Mexico. Opportunities were taken to observe unplanned events. The crew obtained the first active microwave measurements of a major storm, Hurricane Ava, in the Pacific. Analysis of these data and data acquired by instrumented NOAA and Air Force aircraft which flew through the hurricane are expected to demonstrate that space systems can be used to improve studies of hurricanes. Also, in cooperation with NOAA stations in south central Oklahoma, data were obtained which may provide clues to causes of severe thunderstorms.

One of the outstanding aspects of the mission was the ability of the crew to repair the Skylab space station and leave it in condition for satisfactory completion of the overall Skylab program. It demonstrated clearly that man could function effectively in space and that his presence could be the key to the success of a mission.

Skylab 3.—SL–3—the second manned mission—was launched on July 28 and made rendezvous with the Workshop later that day.

Crew members were Commander Alan Bean (Captain, USN); Science Pilot Owen K. Garriott (Ph. D.); and Pilot Jack Robert Lousma (Major, USMC).

Early in the flight, a series of problems threatened the mission: the crew suffered motion sickness, there were unexplained leaks of oxidizer in the Service Module reaction control system, the Airlock Module primary coolant system lost coolant pressure, and the attitude control rate gyros behaved erratically.

However, the health of the crew improved, and it was able to resolve the other problems so as to permit the mission to proceed. The crew found it could work well ahead of the premission flight plan. The flight control teams and the mission management operated smoothly and flexibly to take advantage of the crew's efficiency to add unscheduled tests and experiments which helped increase experiment data yield above premission planning. Skylab 3 was a highly successful mission that left Skylab in an excellent position to complete the program with the third and final mission.

The first of three periods of extravehicular activity took place on mission day 10. Astronauts Garriott and Bean worked outside the workshop for a total of 6 hours, 31 minutes putting in place a twin-pole sun shield that lowered temperatures and gave more permanent protection to the workshop. The elapsed time was a record space walk.

During EVA–2, on the 28th mission day, Astronauts Garriott and Lousma successfully carried out a number of tasks in a 4½-hour period. Astronauts Bean and Garriott carried out EVA–3 on the 57th day, replacing film and retrieving two experiments and parasol samples in 2 hours 41 minutes.

On the 59th day of the mission, the astronauts returned to Earth, landing in the Pacific Ocean approximately 250 miles from San Diego, California, on September 25.

In addition to its scientific successes and the achievements of the crew, the Skylab 3 mission set a number of major records: longest duration manned space flight: 59 days 11 hours 9 minutes; longest cumulative time in space for one man: 69 days for Captain Alan Bean (Apollo 12—10 days, SL–3—59 days); most miles in orbit for a manned mission: 21,500,000 miles; longest orbital EVA: 6 hours 31 minutes, August 6, 1973; and longest cumulative orbital EVA time: 13 hours 40 minutes for Owen Garriott.

Skylab 4.—SL–4—the third manned mission—was launched November 16. The mission planning for this flight was significantly altered to include major observations of the comet Kohoutek, discovered earlier in the year. Astronauts Gerald P. Carr (Lt. Col. USMC), Commander; Edward G. Gibson (Ph.D.), Science Pilot; and William R. Pogue (Lt. Col. USAF), Pilot, docked with the orbiting Skylab station several hours later to begin the final Skylab mission of 84 days.

The crew carried out Earth resources, solar astronomy, medical, and other experiments. In addition, it used a special camera to photograph features of the Comet Kohoutek not observable from the Earth's surface. The ATM was also used for Kohoutek observations.

At the end of the year, the Skylab 4 crew was well along with its work assignments and large quantities of valuable data were collected and transmitted to Earth.

Skylab Results.—While it is important to remember that Skylab was conceived primarily as a development program in the extension of manned space flight to determine man's capabilities and limitations as well as demonstrate the adequacy of the design and operation of experiment and systems hardware, we have in fact acquired significant new knowledge about the benefits which space observations and experiments hold for man on Earth. This aspect of Skylab promises to be of increasing importance as the data is analyzed and the findings become better known and understood. This is true not only for direct earthly benefits but also for the insights it will give us into the uses of space in the Shuttle era.

Skylab Biomedical Findings.—Preliminary biomedical analyses of the 28-day flight of Skylab 2 and the 59-day Skylab 3 manned missions were completed and

work continued on more detailed analyses of laboratory data. The Skylab 2 and 3 findings appear to validate medical predictions which defined the body systems most likely to be affected in missions of these durations: the cardiovascular system, vestibular system, fluid and electrolyte balance, and blood and blood generation systems.

They did not produce evidence to indicate the involvement of body systems other than those anticipated. From the evidence collected, it was concluded that man can safely perform in spaceflight for up to 60 days.

Earth Resources Experiments Package.—Skylab will have taken over 40,000 photographs and more than 230,000 feet of high density magnetic tape with the EREP sensors by the time the third mission is completed. This is considerably more than originally planned. These data are provided to 145 investigators here and abroad. They are also provided to other U.S. agencies for their use, and are available to the public through the Department of Interior EROS Data Center at Sioux Falls, S. Dak.

Over and above the EREP data, handheld photography and visual observations were attempted for some 50 sites representative of such features as barrier reefs, volcanoes, salt beds, earthquake damage, flooding damage, swamps, deserts, forest areas, vegetated areas, locust damage, geologic tectonics, water pollution, drought areas, and severe storms.

The sequence of EREP data processing, data distribution, analysis, and publication of results is continuing and is expected to last several years. However, some initial results have already been identified by the EREP investigators. Perhaps the most significant, in terms of economic value, is the identification of a potential mineral deposit north of Ely, Nev. Other important results have been the identification of several areas of citrus fruit fly infestations on the Mexican side of the Rio Grande; demonstration of the use of remote sensing for snow mapping; employment as part of a study of land use classification systems of new urbanization patterns associated with the city of Phoenix, Ariz.; and demonstration of the use of EREP imagery for inventory of vegetation patterns using test sites in California.

The high spatial resolution provided by the EREP film systems is particularly applicable to study of regional planning and land use in urbanized areas. Using an EREP color photograph of the Washington, D.C. area taken in September 1973, as an example, the feasibility of identifying individual building structures is clearly evident. Detailed analysis of the original photography, covering 10,000 square miles and including the Baltimore area, will produce a land-use assessment at the highest classification level contemplated by land-use planners. The Baltimore-Washington photograph and similar imagery for 12 other cities are being used by the Department of Interior to test the use of space imagery for updating the 1970 census. High spatial resolution for the identification of fields of an acre or smaller and the detection of impounded water, indicate the value and need for such a selective high resolution capability for future Earth survey systems.

In summary, the Skylab/EREP data proved important in demonstrating the use of remote sensing from space for application studies and providing a basis for the definition of sensor characteristics for future space systems.

Solar Astronomy.—The observing time prescribed for solar astronomy in the preflight plans was exceeded. In the main, the instruments worked very well throughout the missions, and the Sun cooperated by exhibiting unusual bursts of activity from time to time.

The observing program for the second manned missions was changed somewhat as a result of previously unobserved phenomena revealed by the preliminary analysis of the first mission data. There is reason to believe that analyses of solar astronomy data will bring about a revision of our understanding of the Sun and its effects on Earth, for example, the supergranulation network and its role in coronal heating. The highly structured and transient nature observed in the corona calls into question previous theories concerning the relationships between the corona and events in the photosphere. Additionally, there is evidence of several fundamentally different flare mechanisms.

Materials Processing in Space.—Yet another applications area, it promises improved materials for use on Earth. This is especially reflected in the formation of crystals used in the manufacturing of semiconductors. Several experiments in this area have yielded crystals of outstanding size and purity which are unheard of within the realm of our present ground based techniques. At the present time, the use of these semiconductors in power switching and control circuits, and in large integrated circuits for computer and communication systems, is severely limited by the small size and imperfections of single crystals. Larger and more perfect crystals could dramatically widen the use of semiconductors in many applications.

Apollo/Soyuz Test Project (ASTP).—ASTP—a joint U.S.-U.S.S.R. project for the rendezvous and docking in Earth orbit of an Apollo spacecraft with a Soyuz spacecraft—is planned for July 1975. The mission would continue for up to 12 days with the docked portion scheduled to last 2 days.

The ASTP was provided for in an agreement between the United States and the U.S.S.R. signed in Moscow in 1972, which also pledged both parties to cooperate in space science and applications. The proj-

ect is an important step in international cooperation, a move toward developing an international space rescue capability, and a move toward future international space missions that could eliminate duplication and cut costs of space activities.

In 1973, the design of the docking module and the docking system was essentially completed. All the hardware for the Apollo/Soyuz flight mission continued on schedule. The Command and Service Module, built for the Apollo program but not used, was modified slightly to adapt it for use in ASTP, and to accommodate the new docking module.

The U.S.S.R. unit for use in the joint dynamic tests was delivered on schedule in September and joint testing of the two units began at the Johnson Space Center (JSC). A test program for selecting the final configuration of the U.S./U.S.S.R. interface seals for the docking systems was completed.

Apollo/Soyuz hardware was shown in a joint U.S./U.S.S.R. exhibit at the Paris Air Show in May and June, and was one of the most popular exhibits of the show.

The U.S. and Russian flight crews were selected. For the United States the commander will be Brig. Gen. Thomas P. Stafford, an experienced and senior astronaut who participated in the flights of Gemini 6 and 9 and Apollo 10. The command module pilot will be Vance D. Brand, the backup commander for the second and third manned Skylab mission. The docking module pilot will be Donald K. Slayton, one of the original seven astronauts selected by NASA in April 1959, and currently director of flight crew operations. Relieved of assignment as pilot of the Mercury 7 mission because of a heart condition, he was restored to full flight status in 1972. This will be his first space flight.

Two prime crews were selected by the U.S.S.R. for the two space vehicles being prepared by that country. Alexei Leonov who flew on Voskhod 2 and was the first man to walk in space, and Valary Kubasov, who flew on Soyuz 6, were named as crew for the first prime space vehicle. The second prime vehicle will be manned by Anatole Filipchenko who flew on Soyuz 7, and Nikolai Rukavishnikov who flew on Soyuz 10.

Initial familiarization of Soviet crews with Apollo systems took place in Houston in July. Similar familiarization of U.S. crews with Soyuz systems occurred in Moscow in November.

In addition to fulfilling its primary purpose, ASTP offers another opportunity to conduct scientific experiments in space.

Space Transportation System (STS).—The STS consists of a reusable Space Shuttle and an upper stage Space Tug. The system is designed to provide economical and versatile space transportation for future decades to make accessible the full benefits of space.

Space Shuttle.—The Space Shuttle, the major element of STS, will be a reusable manned space vehicle operated as a low-cost transportation system for a wide variety of space missions in low Earth orbit. It will deploy, service, and retrieve scientific and applications satellites of all types. Since it can carry payloads weighing up to 65,000 pounds, it will replace most of the expendable launch vehicles currently used.

The Space Shuttle is needed to make space operations less complex and less costly. It will cut expenses because its major parts are reusable rather than expendable. In addition, it will be easier and more economical to prepare payloads for transportation on the Shuttle because of its volume and weight capacity and its interior space arrangements. The Shuttle will also make it possible to retrieve and repair orbiting spacecraft, lowering costs further and encouraging wider participation in space enterprises.

During the past 3 fiscal years (1972–1974), Congress has authorized a total of $378.5 million for Space Shuttle research and development. As a result, the necessary technology was developed, and systems definition progressed into the design and development phases for the major program elements.

The prime contractor for the design and development of the Orbiter and its integration with all other elements of the Shuttle system was chosen in 1972. This year the prime contractor selected most of the necessary subcontractors.

In August 1973, a contractor was selected to design and develop the Space Shuttle external liquid propellant tank, which will be assembled at the NASA Michoud Assembly Facility in New Orleans.

Spacelab.—Recognizing the importance of the Shuttle, the European Space Research Organization (ESRO) has elected to fund and develop a pressurized manned laboratory module and/or pallet with easy user access for a wide variety of orbital research applications during the Shuttle "sortie" missions. Sortie missions are those where the experiment remains with the Shuttle and returns to Earth with it. These missions may last from 7 to 30 days.

The Spacelab is a key element in the Shuttle-oriented Space Transportation System. It provides a versatile capability for accommodating laboratory and observatory facilities to be carried on the Space Shuttle at the lowest practical investment in both developmental and operating costs. Furthermore, it reduces significantly both the time and cost required for space transportation. Combinations of the several Spacelab elements which meet specific requirements of individual missions will be transported to and from orbit in the Shuttle cargo bay and will be attached to, and supported by, the Shuttle orbiter throughout missions lasting up to 30 days.

Identified in the United States as "Sortie Lab" during the conceptual phases, it assumed the European

designation "Spacelab" when the final commitments were made in September. At that time, it was agreed that ESRO, representing nine European countries, will design and build the Spacelab hardware to U.S. requirements to satisfy the needs of both European and American users. The agreement calls for ESRO to design, develop, manufacture, and deliver one Spacelab engineering model and one flight unit to the United States on a schedule related to Shuttle program requirements. NASA, in turn, will procure all subsequent Spacelab flight hardware from Europe.

The major effort of the two European prime contractors was devoted to finalizing conceptual designs and estimating the costs. When it was determined that the cost would be within previously established budgetary limitations, steps were taken to select a concept and a single prime contractor. June 1974 was set as the deadline for this activity, and at that time final design and development will begin.

Space Tug.—The Shuttle upper stage, or Space Tug, is a proposed high energy unmanned propulsive stage used to extend the operating regime of the Space Shuttle from low Earth orbit to geosynchronous orbit and beyond. The Tug and its payload would be carried into low Earth orbit in the Shuttle orbiter bay. The Tug would then be operated to place the payload into polar, intermediate inclination, or geosynchronous orbit, or for transplanetary injection of planetary spacecraft. Approximately half the payloads anticipated for the 1980's require propulsion in addition to that provided by the Space Shuttle. NASA is, therefore, intensively studying the Space Tug as an integral part of the space transportation system.

During 1973, NASA and the Department of Defense jointly conducted Tug system studies of new stages using cryogenic and Earth storable fuels, and of modifications of existing stages for reuse. The system analyses were complemented by NASA engine studies of new engine designs and modifications of existing engines. A data base for the Space Tug program assessment activity conducted later in the year was derived from the earlier studies. Tentative agreement was reached for DOD to develop an Initial Upper Stage (IUS) with the full capability Tug to be developed later. The IUS will be a modification of an existing stage and without a payload retrieval capability. The agreement makes two things possible: development of upper stage propulsion for initial Shuttle operations; consequent deferral of a decision to begin development of a more expensive full capability Tug.

Mission and Payload Integration.—This function became a leading NASA planning activity during 1973. The Mission and Payload Integration Office (MPIO) assumed responsibility for coordinating the definition of shuttle missions and the other Space Transportation System (STS) elements, and assuring that all users and potential users were coordinating their efforts.

In preparing the Mission Model, NASA asked Shuttle users to project their requirements almost a decade ahead. The users are in the most innovative and rapidly changing fields that exist; the Mission Model should, therefore, be expected to change considerably as the program unfolds. However, the following rough estimates are useful for planning purposes.

MPIO activity focused mainly on the continuing development and updating of the Payload and Flight Summaries that comprise the NASA Mission Model. The 1973 mission model analysis indicated approximately 986 payloads for the years 1980–1991, based on the estimated requirements of prospective users of the STS. Roughly two-thirds of the payloads were for civil and military applications, the balance for science and exploration. The analysis determined that about 725 Shuttle flights would be required to fly these payloads. The economic comparison between the cost of the STS to fly these payloads and the cost of expendable systems to fly equivalent payloads indicated substantial savings in favor of the Shuttle.

Space Biology and Medicine.—U.S./U.S.S.R. Cooperation.—The joint working group of the U.S.S.R. Academy of Sciences and NASA held its third meeting on space biology and medicine early in the year and the fourth meeting in Houston late in the year.

The working group exchanged information on experiences in manned space flight, particularly preliminary biomedical results of the Apollo 17 mission, Skylabs 2 and 3, Soviet experimental research in the modeling of weightlessness and results of Soyuz 12.

Before the meetings, written information was exchanged in several areas in order to develop common procedures for pre- and postflight examination of astronauts and cosmonauts.

During the meeting, the U.S. delegation visited several medical research facilities and the Gagarin Center for Cosmonaut Training, Star City, where the group examined spacecraft trainers, medical equipment used in pre- and post-flight training and evaluation of cosmonauts, and medical intrumentation of the type on the Salyut spacecraft.

Advanced Bioinstrumentation.—Because the effects of gravity profoundly alter the distribution of blood and gases in the lungs, many problems of basic pulmonary physiology can be studied in the weightless state, some much more effectively under zero gravity than under normal gravitation. One of the dividends of space flights in the Shuttle will be the opportunity to carry out such experiments. In preparation for such research, a new system for the thorough and rapid evaluation of pulmonary function was developed and placed under test in a hospital studying patients with chronic pulmonary disease.

Integrated Medical and Behavorial Laboratory Measurement System (IMBLMS).—Work on developing a capability to provide clinical medical care and support to future space crews continued through 1973. It is a form of telemedicine.

Shuttle missions of the 1980's will require routine and emergency medical care for larger and more diverse space crews. They will also present other life sciences requirements in the area of medical research.

Previous work on the IMBLMS was concentrated on developing an inflight medical and behavioral research capability. NASA has now shifted emphasis to the development of an onboard clinical capability, because of the obvious importance of inflight health maintenance. In view of the similarities between providing health care to crews in space and to a remote population on Earth, NASA developed a plan to verify the requirements for a space health care delivery system by building and testing a ground based analog of it. The test will also provide information and procedures which could improve health care and medical services to remote areas on Earth.

NASA contracted for the design, assembly, and operational test of such a ground-based health care system in collaboration with the Department of Health, Education and Welfare (HEW). The latter assumed responsibility for site selection and will provide for a medical evaluation of the ground system. In April, the Health Services and Mental Health Administration of HEW selected the Papago Indian Reservation near Tucson, Arizona, as the site for the IMBLMS field test to begin early in 1975.

A ground medical data base and the expertise of a large hospital are available to assist by telecommunications in the diagnosis and care of remote patients. The system makes optimum use of advanced medical instrumentation, TV, voice and data communications, and modern data processing techniques. With these aids, a specially trained paramedical crewman may examine a patient, transmit medical information to a physician in a control center miles away, and consult with the physician who may diagnose the problem and prescribe treatment.

Advanced Programs.—*Advanced Studies* are used to probe into the future, to seek out new projects which should be considered by NASA, and to study them in sufficient depth to see whether they are feasible and properly related to National Objectives.

During 1973, the major study effort was expended on Space Tug conceptualization. The Space Tug is the reusable upper stage carried into low Earth orbit by the Space Shuttle. Other studies were completed of the interfaces between the Space Shuttle, the Space Tug, and a representative group of potential future payloads.

During the last half of this year, the fiscal year 1974 studies program was begun; this program will shift emphasis from the Space Tug and Shuttle interfaces to future program planning, improvements in the effectiveness and use of the Space Transportation System, and new mission and systems concepts.

The results of *Advanced Development* from previous years has benefited the Space Shuttle program in 1973. In many cases, the selection of materials, subsystems, and systems for the Shuttle program was based on data from the Advanced Development technology effort. It is characteristic of such technology development programs that the application of results is not guaranteed and generally occurs after the lapse of some time. The high payoff that has occurred in the Shuttle should repeat itself with the Advanced Development efforts currently underway when development of the full capability Tug is initiated.

New work initiated this year concentrated on the requirements of the Space Tug, including tasks on new communication systems, inflatable thermal radiators, attitude control propulsion, meteoroid protection systems and thin metal structures. Program planning for fiscal year 1974 was being redirected to emphasize technology work applicable to any of several new projects being considered to follow the Shuttle/Tug/Spacelab program.

Space Science

Man has always been curious about himself and the unknown universe that surrounds him. He has sought answers to such questions as is there life elsewhere, how did the Earth evolve, what is the nature of the solar system, and what are the energy processes of the Sun and the stars. However, the study of space is more than an attempt to satisfy man's curiosity; it is through the knowledge gained by answering these and related questions that he can derive answers to existence here on Earth. A better understanding of the solar system and the universe helps us to develop new physical principles that can be applied to our terrestrial activities. Dynamics and relativity are two of the sciences that emerged largely from the study of celestial objects. The resultant capability to analyze and predict motion and to pioneer atomic power have been major factors in achieving today's civilization and providing energy for tomorrow.

However, space science achieves more than understanding. Its pursuit provides impetus to breakthroughs in technology needed to solve the difficult task of space exploration. Not only has Pioneer 10's voyage to Jupiter unveiled that planet, but it also is a remarkable demonstration of the technical progress achieved in the reliability and capability of its systems. Successful functioning of sensors, propulsion, computers and other equipment, and reliable communications and control over a distance of over half a billion miles after a 2-

year voyage through the rigors of space, is an impressive achievement indeed. Further, space provides a unique opportunity not only to answer questions about distant objects, but to directly observe and study the Earth, its atmosphere, its fields, and its interaction with the Sun and the Moon in a way that was never available before. The resultant understanding of the Earth from direct observation and from information gained from the "galactic laboratory" are now beginning to provide us a greatly improved understanding of the Earth's dynamics, its composition, its atmospheric processes and resultant weather, and its energy balance. But, more than that, it tells us something about ourselves and our place in the universe.

Planetary Exploration.—The basic questions that man has about the solar system—whether life exists elsewhere in it, how the system originated and evolved, and what the other planets are like—are very old and very broad. Until about 10 years ago, knowledge of the solar system was limited to an understanding of its mechanical characteristics, such as the location and the orbits of the major objects in it. For further progress we badly need data on the chemistry, physics, age, and evolutionary history of other bodies in the solar system. Our ability to operate and explore in space has now opened the door to obtaining this type of data. But the answers to these questions go beyond satisfying man's basic curiosity.

Better knowledge of the formation and composition of other planets helps us understand the processes that affect the composition and mineral properties of our own. Improved understanding of the atmospheres of other planets such as Mars and Venus helps us discover and test out theories about the Earth's atmosphere. For example, three factors that have a major influence on the complex circulatory patterns of the Earth's atmosphere are the rotation of the Earth, evaporation of water vapor from the massive oceans, and clouds in the skies that lead to uneven heating and cooling of the surface and atmosphere. Venus and Mars span the range of radiation and convection of the Earth's atmosphere, but don't have all the Earth's complexities. Study of the "simpler" atmospheric systems on Mars and Venus contributes to providing the urgently needed insight into the basic causes which control our atmospheric circulation and generate the major weather systems on Earth.

Once we grasp these causes, we can then hope to understand the long-range effects of pollution, to make reliable long-term weather forecasts, to moderate severe weather systems, and possibly to modify climate. Thus, reaching out to the planets is reaching out for understanding that could help provide solutions to tomorrow's problems here on Earth. Our current energy crisis is in part due to having lived too much for the present, while selling short the future. However, that future is now upon us.

In this section we report the progress made in 1973 toward learning more about our solar system.

Exploration of Jupiter.—The most exciting planetary exploration of 1973 was the Pioneer 10 flyby of the gigantic planet Jupiter in an effort to begin to unravel its major mysteries: why Jupiter radiates 2½ times the heat it receives from the Sun, what is its moving giant red spot that is larger than the Earth, the character of its powerful magnetic field, and the nature of its brilliantly hued atmosphere.

Exploration of the outer region of the solar system was initiated with the launch of Pioneer 10 in March 1972 and continued with Pioneer 11, launched in April 1973. Both spacecraft carry scientific instruments to investigate Jupiter's magnetic fields, radiation belts, and the characteristics of its massive, turbulent atmosphere. Both are also studying for the first time the nature of the asteroid belt and the dynamics of the solar wind in the regions out beyond the orbit of Mars. Both Pioneer 10 and Pioneer 11 have thus far functioned satisfactorily. They have already extended the knowledge of the interplanetary environment obtained from earlier Pioneer and Mariner spacecraft, with Pioneer 11 adding to the data from Pioneer 10 on the nature of the smaller particles in the asteroid belt. The data indicate a lesser number of particles than anticipated. The information has improved our operational capability for future long-duration flights to the outer planets.

Pioneer 10 flew by Jupiter on December 3 at a distance of 131,400 kilometers (81,000 miles) above the clouds, a distance chosen to provide the best overall initial data on Jupiter. The Pioneer 10 data are expected to greatly improve the understanding of the Jovian environment, and have provided the basis for selection of the targeting point for the Pioneer 11 flyby in December 1974.

Outer Planets Mission.—The Mariner Jupiter/Saturn 1977 (MJS '77) Project, approved in 1973 as part of the outer planets exploration program, will conduct comparative studies of the Jupiter and Saturn planetary systems and investigate the interplanetary medium between Earth and Saturn.

The mission calls for two launches in 1977, within a span of 30 days, of identical spacecraft on flyby trajectories that will use the gravity assist swingby technique at Jupiter to reach Saturn. The spacecraft will encounter Jupiter about 1½ years after launch and Saturn about 3½ to 4 years after launch.

During 1973 the science experiments were defined in detail, their interfaces with the mission and spacecraft were identified, and a major review and confirmation of the mission scope and science payload was completed. Mission analysis and minor spacecraft sys-

tem design modifications were carried out to insure compatibility of the mission and the spacecraft with the science experiments and objectives. The preliminary mission and systems design review was completed on schedule. In addition, procurement was started for Viking Orbiter subsystems which can be used on MJS and for those new spacecraft subsystems and science instruments requiring long lead times for development.

Viking Mars Mission.—The Viking project is designed to begin a new phase of Mars exploration in 1976 when two Viking landers reach its surface and begin their detailed scientific investigations. Emphasis will be placed on obtaining data relevant to the search for life on Mars and information that will help us understand the evolution of Mars and the solar system.

During 1973, work on the Orbiter and Lander Systems progressed with completion of critical design reviews; full scale spacecraft thermal and structural tests; integrated functional test of the Lander subsystems; initiation of Proof Test Lander assembly; and start of flight subsystem fabrication.

Launch and Flight Operations System progress included organization and member selection for the flight operations team; development of configuration for the flight operations facilities; start of computer programs; and near completion of the KSC spacecraft assembly, test, and launch facilities. Plans were made for the January 1974 launch of a structural model of the Viking spacecraft from KSC on a Titan/Centaur launch vehicle.

At year end, the Viking program continued essentially on schedule with only two revisions: a 2 month delay in the start of the Lander Proof Test due to late subsystem deliveries and a change in the training of personnel for planetary operations. Training was rescheduled to early 1976 to more effectively utilize the scientists and operations team during the period when the spacecraft is in transit to Mars. The project continues to display high competence in overcoming technical problems in order to maintain schedule.

Mariner Venus/Mercury 1973.—The MVM 1973 spacecraft was launched from Cape Kennedy on November 3 using an Atlas-Centaur D1A launch vehicle. It constitutes the first mission to Mercury. The short trip time of 5 months to Mercury is in sharp contrast to the 2 year Jupiter missions.

The mission plan calls for a 94-day transit time to Venus with arrival at closest approach on February 5, 1974. The fly-by of Venus, at an altitude of about 5,300 km (3,300 miles), provides a gravity assist to the spacecraft, changing its speed and deflecting its trajectory to produce a Mercury fly-by, at an encounter distance of about 1,000 km (621 miles), on March 29, 1974.

Although the primary objective of the MVM 1973 program is the exploration of Venus and Mercury, several other scientific excursions are planned while the spacecraft is enroute. The science mission includes a series of televised Earth-Moon mosaics, an ultraviolet spectrometer experiment to map the outer regions of the Earth's geocorona, two magnetometers continuously monitoring the structure and discontinuities of the interplanetary medium, a charged particle telescope gathering solar and galactic cosmic ray spectra, and a plasma science experiment investigating solar plasma properties between 1.0 and 0.4 Earth-Sun distances.

Making Planetary Exploration More Economical.—Studies to define the options available for the exploration of the solar system emphasized commonality of spacecraft design from mission to mission and a meaningful evolution of technology as mission objectives increase in complexity and performance. The thrust of these studies is to define the extent to which spacecraft components, such as electrical power and guidance and communications systems, developed for earlier missions can be utilized on subsequent (or future) interplanetary spacecraft.

Conceptual design studies for low cost multiple probes and orbiter missions to Venus were completed in June. Work continued on the supporting technology for critical subsystems for these and subsequent planetary missions.

Other work, based on the technology developed for the Venus atmospheric probes, was concerned with development of technology for future missions to the outer planets.

To improve understanding of the cost impact of future advanced mission technology requirements, the common cost drivers in past programs and ways of projecting them for future missions are being studied.

Support Studies for Future Missions.—In support of exploring the inner planets, studies were made of the Pioneer Venus probe and orbiter missions and a Venus orbiting imaging radar mission. Preliminary studies were conducted for post-Viking 1975 missions to Mars, a mission to return a Mars surface sample to Earth, cometary missions to Grigg-Skjellerup and Encke, and for the outer planets a mission to orbit Jupiter and atmospheric entry probe missions to Saturn and Uranus.

Launch vehicle options available for future planetary missions, including the Shuttle, were analyzed, and work is continuing to define the spacecraft interfaces with the Shuttle and to determine how the Shuttle payload and volume capability may be used for future planetary missions.

Astronomy.—Looking into the heavens, we see billions of stars in every stage of birth, evolution, and demise. These observations enable us to develop theories of evolution for the stars and explanations for their physical phenomena. The advent of the space age which

makes possible the use of instrumentation in space for making unique and better observations will increase our understanding and may also provide new physical concepts that are useful to us on Earth from both a scientific and a practical viewpoint.

It is with these thoughts in mind that the following goals have been established for investigating and understanding the universe:

> To understand the origin and continuing evolution of the cosmic environment, by observing and intepreting the basic physical processes in our solar system, the stars, the galaxies, and the universe.
>
> To increase our knowledge of the fundamental laws and principles of physics, particularly energy, that govern observed cosmic phenomena.
>
> To utilize the understanding of the universe and the phenomena occurring in it for the benefit of mankind.

The difficult problems in astronomy have acted to stimulate human thought and progress. Questions about the properties and nature of light, and about space and its relation to time sparked the development of spectroscopy, quantum mechanics, and relativity. Questions regarding the source of solar energy led to the development of theories on nuclear reactions. Many aspects of these theories have been summarized by the now famous Einstein equation $E=mc^2$. This basic understanding about the nature of matter had eminently practical results—nuclear power. Spectroscopic analysis as a tool has been used to improve almost all the substances we use. Even an instrument as practical as the laser is, to a large extent, based on theories and expermients done in support and as part of astronomical research.

To help answer the questions posed, optical telescopes on Earth have long been used to scan the heavens. However, they are limited to receiving radiation that has been filtered by our atmosphere. To obtain "clean" radiation data in a broader spectrum, it is necessary to rise above the Earth's atmosphere. One of the most obvious and effective ways to gather the necessary information is to put an observatory into orbit above the Earth's atmosphere. As explained below, several already have been launched and others are being planned.

Orbiting Astronomical Observatories.—OAO–3 Copernicus, launched in August 1972, continued to obtain scientific data. In its first year, OAO–3 made more than 4,700 observations of 141 unique celestial objects with the Princeton University experiment, and more than 550 observations of 193 celestial objects with the University College London X-ray experiment.

Princeton astronomers indirectly determined the density of the universe to be lower in value than proposed by some cosmologists. The finding, which implies that there is little undiscovered matter in the universe, is based on a measurement of the relative abundance of deuterium in interstellar gas and assumes the validity of the "big bang" origin of the universe.

The University College London experiment observed extended X-ray sources identified with the cluster of galaxies within the Constellation Perseus. The nature of the X-ray emission is still unknown but a soft source was identified within the exploding Seyfert galaxy, NGC 1275. It is probable that some enormous upheavals are taking place in its nucleus, and this may be affecting the whole Perseus cluster of galaxies.

OAO–2 operation was terminated in February 1972 when the experiment failed after 50 months. It produced over 14,000 observations with the University of Wisconsin experiment and over 3,500 with the Smithsonian Astrophysical Observatory experiment. Scientific results reported this year include: detection of a hydrogen cloud a million miles in diameter around a comet; observations that may clarify knowledge of a group of stars with apparently anomalous elements and enormous magnetic fields; and new insights into the structure and composition of the Earth's upper atmosphere.

High Energy Astronomy Observatory (HEAO).—The development of HEAO missions to investigate celectial X-ray, gamma-ray and cosmic-ray phenomena continued. Subsystems for these missions would use about 80 percent of flight proven hardware design from other programs. Early launches will be made by an unmanned expendable Atlas-Centaur vehicle. These payloads are designed to be retrievable by the Space Shuttle. Ultimately, larger payloads will be launched and retrieved by the Space Shuttle.

The Small Astronomical Satellite.—SAS–A, Explorer 42 (launched in 1970) continued to provide data on selected binary star system X-ray sources which it discovered. Since that discovery, scientists have focused attention on this area and are evaluating previously obtained data in more detail.

The initial scientific results from SAS–B, Explorer 48 (launched in November 1972) were presented this year. One of the major results from SAS–B was the observation of a diffuse cosmic gamma radiation background, which, when combined with lower energy gamma ray observations taken on Apollo 15, suggests that the gamma rays were produced continuously over the history of our universe, and, therefore, are a major factor in establishing the energy mechanisms responsible for the creation of the universe. Explorer 48 functioned successfully until June 1973, when the failure of a power supply ended its useful life.

The International Ultraviolet Explorer (IUE).—A joint NASA-ESRO project was initiated this year. It will place a 45-cm astronomical telescope into geosynchronous orbit and operate it as an international observing facility. The satellite, planned for launch in 1977, will be equipped with TV cameras capable of recording ultraviolet spectra from 1200 to 3200Å. Astronomers will operate the orbiting telescope from ground control centers in the United States and Europe. An international group of astronomers was formed to guide the development and postlaunch operations. Eighty proposals for experiments were received and reviewed under NASA auspices; 60 were accepted for the first 6 months of operation. A similar number were received and reviewed by ESRO and the United Kingdom Science Research Council.

Large Space Telescopes (LST).—The concept of the LST calls for a three-meter (approximately 10′ diameter) telescope orbiting the Earth and operating at very near the diffraction limit; it would make possible astronomical observations deeper into space and with more detail than has ever been possible. In 1973, NASA announced an opportunity for participation in the definition of instruments for the LST. One hundred and twenty proposals were received and evaluated, and 36 were accepted. Six teams were formed and started work to define astronomical instrument requirements in the following areas: high and low resolution spectrographs, imaging optics, infrared devices, astrometry, data handling, and operations.

The LST will be designed like ground-based telescopes to use a number of different scientific instruments at its focal plane. This general purpose characteristic will permit the LST to be used effectively as a national facility, capable of supporting worldwide astronomical needs of an international user community.

Two prime contractors and their subcontractors started the definition phase of the optical telescope assembly. Work on the conceptual design of the spacecraft portion of the LST was under way as an in-house effort at MSFC.

Radio Astronomy Explorer (RAE–B).—Explorer 49 was launched in June and placed into lunar orbit. The RAE series is designed to obtain low frequency radio data from solar, planetary, and galactic sources otherwise unobtainable from ground-based radio astronomy telescopes. Due to its lunar orbit, Explorer 49 is providing better data than its predecessor, Explorer 38, since the Moon shields it from terrestrial radio interference. It observed solar bursts and galactic radio sources near the galactic plane and the Orion-Gum nebulae complex region.

Other Astronomy Satellites.—In the international area, work also continued on the Netherlands ultraviolet and X-ray astronomy satellite and on UK–5, a scientific UK/U.S. satellite to make stellar X-ray observations (see below).

Sun-Earth Relationships.—Virtually all the energy received by the Earth or existing on the Earth, including petroleum, had its origin in the Sun. The Sun controls the behavior of our atmosphere and provides all the energy and light necessary to support life on Earth.

In addition to being the ultimate source of our energy the Sun has other extremely important short-term effects on our environment. The Earth's magnetic field is under continuous bombardment by a steady stream of supersonic charged particles from the Sun—the solar wind—which cause our Earth to be engulfed in a giant plasma bubble in space, called the magnetosphere. Through two special direct access paths in this bubble, the solar wind particles are normally able to strike the Earth's upper atmosphere and produce the two brilliant northern and southern auroral ovals. However, major changes in solar wind intensity and frequently-occurring solar flares also can often produce major communications blackouts, and occasional major breakdowns in electric power plants. Thus, the interaction of the solar wind on the ionosphere has very important fundamental effects on our environment.

There have been some recent major advances in our understanding of the mechanisms by which solar storms and flares affect our own climate. For example, it has been found that low pressure troughs over the North Pacific are normally produced immediately after geomagnetic disturbances caused by solar flares. Rainfall in Los Angeles has been shown to correlate directly with the 27-day solar rotation period. Continuation of these and other studies are necessary for the science of meteorology to be wedded ultimately to the science of magnetospheric and solar physics.

Study of the Sun, its interaction with the Earth's atmosphere, and its direct effect on our own lives, is therefore one of the most important endeavors of mankind. In this section, we discuss the 1973 space effort in this vital area.

Apollo Telescope Mount (ATM).—The ATM deployed aboard Skylab in May 1973, is the first of a new "second generation" of space observatories, where the skill of an on-board manned observer is added to the largest observatory ever placed in orbit. The great volume of high-quality solar observations obtained with ATM exceeded the most optimistic predictions of the experimenters. They have already acquired new insights into the structure of the Sun's atmosphere and seen possible implications for atmospheric heating of the Sun by mechanical waves. Several flares were observed in a large number of different wavelengths, and at least one very spectacular eruptive prominence (a huge burst of solar material) was recorded in progress.

ATM also permitted for the first time a study of the nature of coronal holes discovered with OSO's 6 and 7. The solar wind, previously thought to constitute a continuous expansion of the hot outermost layer of the solar atmosphere into space, now appears to be originating primarily—perhaps exclusively—in coronal holes. The magnetic field associated with the solar wind appears to have a significant effect on the Earth's weather.

The activities of the scientist-astronauts support the belief that many important scientific tasks in space can best be accomplished when a carefully trained observer is *at* the instrument itself.

Orbiting Solar Observatories.—OSO–7, launched in September 1971, added observations supporting ATM experiments on solar active and quiet regions during 1973. It also observed surges of gas ejected from the inner corona with speeds approaching 1000 km/sec. In quiet Sun regions, OSO–7 observed oscillations of a 5-minute periodicity, formerly observed only at lower heights. OSO–7 detected these in the upper transition region and low corona. This could be evidence of the long sought "heating mode" which is responsible for the high temperatures in the corona.

Development of the last spacecraft in the series, OSO–I, continued. This spacecraft will offer the best combination of high spectral, angular and time resolution in many important UV and EUV lines.

Explorers and International Satellites.—The final spacecraft in the Interplanetary Monitoring Platform series, IMP–J or Explorer 50, was launched on October 25, 1973. This spacecraft, like its companion IMP–H—Explorer 47, which was launched the previous year, is designed to investigate the solar wind, the Earth's magnetic tail, and solar and galactic cosmic rays near the Earth, but outside the Earth's magnetic field. Both spacecraft are in similar orbits—wide circular arcs that never come closer to the earth than 30 Earth radii, nor farther away than 40. Initially they were placed nearly 180° apart, so that one would always be in the solar wind while the other would usually be in the geomagnetic tail. However, as they fall out of this synchronism and one begins to overlap the other, there will be times when they will be very close together in space and thus will be able to perform detailed studies separating time variations from space variations in the local plasma and fields. Thus, they will act as a prelude to the International Magnetosphere Explorer (IME) program, which is a cooperative venture between NASA and the European Space Research Organization (ESRO). The IME will consist of three spacecraft: a mother/daughter pair to be launched in 1977 into a highly-elliptical orbit about the Earth to study detailed time-space variations; and a heliocentric spacecraft, to be launched in 1978, to one of the libration points between the Sun and the Earth, to study the solar wind input to the magnetosphere.

Helios, a program to send spacecraft in 1974 and 1975 closer to the Sun than ever before, is a cooperative United States-Federal Republic of Germany endeavor. Its purpose is to investigate the properties and processes in interplanetary space near the Sun (the region to within about 0.3 of the distance from the Sun to the Earth) so as to provide a better understanding of how the Sun affects the Earth. The United States will launch the spacecraft, and provide three scientific experiments, tracking and data acquisition facilities and personnel, and technical assistance in testing the spacecraft, and in reviewing the spacecraft design and the spacecraft test program. Germany will design, develop, and fabricate the spacecraft and provide seven experiments.

This year, a substantial test phase was completed on the spacecraft engineering model; subsystem qualification, assembly, and testing of the prototype spacecraft were underway, and integration was underway on the first flight spacecraft.

Exploring Earth's Upper Atmosphere.—A good deal of progress has been made in exploring and surveying the region above about 250 kilometers (150 miles) with the Atmosphere Explorer and Air Density Explorer spacecraft. However, an important gap exists in the 125 to 250 kilometer (75 to 150 mile) region, where most of the solar ultra-violet energy is absorbed and where, consequently, most of the chemical and energy conversion processes occur that govern the structure of the upper atmosphere and may affect weather processes. Three Atmosphere Explorer spacecraft (AE C, D & E) are currently being constructed to investigate systematically this lower region. This program is NASA's primary effort to investigate the largely unexplored region of the lower thermosphere. This year the integration and test phase of the AE–C mission was completed, and the spacecraft was succesfully launched in December.

Study of the Moon.—Study of the Moon provides insight into the evolution of the Earth and therefore its structure and its mineral composition. If one looks at the 4.6 billion years of lunar history, one discovers that nearly everything of major interest happened in the first billion-and-a-half years. By contrast, we know that many major events have occurred on Earth since that time. The changing of the surface of the Earth has done much to obscure its past. The Moon's surface lies open to reveal its antiquity. Apollo has contributed substantially toward unraveling its mysteries.

As a result of the Apollo lunar studies, scientists learned that the Moon is asymmetrical in chemical composition, as well as in shape, surface topography, and mass distribution; and it is also much more com-

plex than most scientists had expected before Apollo 11. When the complexity is understood, the results should greatly extend our comprehension of the processes that have formed the Moon, the Earth, and the solar system. Results to date indicate the following:

The Moon was formed 4.6 billion years ago at the same time as the Earth and the rest of the solar system. Chemical discrepancies between Earth and lunar rocks indicate the improbability of the Moon's ever having been a part of the Earth. While it could have been formed elsewhere in space and then captured by the Earth, the most logical supposition is that the Earth and Moon formed as near neighbors in space out of related clouds of gases and solid matter.

For the first half billion years after its formation the Moon was subjected to intense massive impacts that formed the major mare basins. From 3 to 4 billion years ago, on the near side, these huge scooped-out basins were filled with a series of laval flows resulting in the extensive, dark, flat, and relatively smooth lava surfaces visible today from Earth even with the naked eye.

This flooding stage did not occur on the far side except in several isolated locations; in this area we have large, rough scooped out basins with no filling at all. The last major episode of lunar volcanism apparently ceased 3 billion years ago, although meteoroid impacts continued with decreasing severity in size and number. As a result the lunar surface has remained relatively unchanged up to the present time and records 3 billion years of solar and galactic history.

Data from the Apollo Lunar Surface Experiment Packages (ALSEPs) and lunar orbital instruments suggest that the Moon has a front-side major compositional discontinuity at 55 to 65 km (35 to 40 miles) depth, corresponding to the Earth's crust. Below this, extending to a depth of approximately 1,000 km (620 miles), there appears to be a relatively uniform zone of solid rock that corresponds to the Earth's mantle. Below this may be a core of about 700 km (430 miles) radius. Data from the ALSEP seismometers and magnetometers suggest that this material is near the melting point and may be molten or, at least, semiplastic. However, the overall lighter density of the Moon (3.3 gm/cc) compared to that of the Earth (5.5 gm/cc), and the absence of a significant lunar magnetic field, appears to rule out, for the Moon, a large molten nickel-iron core of the type thought to exist in the Earth. The periodic moonquakes that correspond to the monthly nearest and furthest Earth-Moon distances originate at depths from 800 to 1,100 km (500 to 680 over a semimolten core in response to tidal stresses.
miles) and may be generated by a solid crust slipping

During the next decade, the lunar program will exploit the data from Apollo and automated lunar flights and add to it information from Earth-based telescopes carrying on continued studies of the lunar near side. Major advances in our understanding of the origin and history of the Moon and the solar system are expected to result from these scientific efforts involving second and third generation analysis of individual experiments and returned lunar material and the broad synthesizing of the data from the many related experiments.

Lunar Program.—In mid-1973, following the successful conclusion of the Apollo program, responsibility for the scientific study and exploration of the Moon was assumed by the Office of Space Science. This responsibility includes: collecting and reducing data from the scientific stations still operating on the lunar surface; curating, distributing, analyzing, and carrying out varied research on lunar samples; operating the ground-based laser observations ranging on the lunar laser retroreflectors; preparing cartographic products to meet scientific requirements; conducting an active program in lunar data analysis and synthesis, and in supporting research and technology (SR&T); interfacing with the U.S.S.R. to augment cooperative agreements regarding lunar sciences studies and exploration; and conducting advanced studies to determine the priorities for lunar science problems and to specify the optimum flight systems for resolving them.

During the Apollo program, lunar scientists generally limited their efforts to reduction and analyses of data produced by their individual specific experiments. The current lunar program calls for continued detailed analysis of individual experiments and the synthesizing of results to increase knowledge of the origin and history of the Moon. A concurrent major goal is to use lunar results to further our understanding of the origin and history of the entire solar system. Data on hand will be augmented by new data being received from the five still-operating ALSEPs and an active SR&T program. In response to a NASA request, scientists submitted nearly 100 proposals to initiate the synthesis effort. The prosposals were evaluated, and the most meritorious will receive support.

Apollo Lunar Surface Experiment Package (ALSEP).—The ALSEPs placed on the lunar surface by Apollos 12, 14, 15, 16, and 17 continued to operate and most of the individual instruments were still collecting valid scientific data.

The seismometers in all the ALSEPs are capable of detecting moonquakes and meteoroid impacts on the lunar surface. They have collected data showing that the Moon is seismically relatively quiet compared to the Earth, and that moonquakes are of much smaller amplitudes than earthquakes. Many of the moonquakes that do occur are cyclic in nature, being synchronous with the bimonthly closest approach and furthest separation of the Moon from the Earth. Moonquakes occur at much greater depth in the Moon (800–1,000

km) (500 to 620 miles) than earthquakes do on Earth, indicating a stronger, thicker crust for the Moon. Data from a large meteorite impact on the farside of the Moon suggested the presence of a small semimolten core below 1,000 km (620 miles). Data from magnetometers on the Apollo 12, 15, and 16 ALSEPs, corroborated that conclusion by indicating that the Moon at that depth may have a temperature of 1,200 to 1,500°K (depending on composition) or close to the melting point.

Another important investigation was the heat flow experiment on the Apollo 15 and 17 ALSEPs which indicated that the Moon loses heat at a significantly higher rate than estimated before Apollo. The source of this heat is believed to be a high concentration of radioactive elements within a relatively thin surface layer, about 300 km (200 miles); if the level of radioacivity was distributed uniformly throughout the Moon (rather than within a thin surface layer) the entire body would be molten. Rocks with the necessary high radioactivity were found at the Apollo 12 and 14 sites and appear to represent a period of early lunar melting.

Such rocks were also mapped from orbit by the gamma-ray experiment on Apollo 15 and 16, and the radioactivity found to be variable, with the lunar farside being relatively low in radioactivity. Thus, the orbital gamma ray survey, which covered 20 percent of the lunar surface, apparently measured important variations in near surface radioactivity and may be the best available indicator of heat flow variations over the lunar surface. Its results agreed with data from other orbital sensors, confirming the value of "ground truth" data accumulated at each Apollo landing site in interpreting the broad coverage of the remote sensing instruments.

Laser Ranging.—The three laser ranging retroflectors placed at the Apollo 11, 14, and 15 landing sites show no signs of degradation. The laser telescope at the McDonald Observatory in Texas continued routine ranging on the reflectors with an accuracy of 15 cm. During a short period, the telescope also acquired the French laser reflector mounted on the Lunokhod vehicle delivered to the lunar surface by the U.S.S.R.'s Luna 21 flight. The data obtained were used to refine the lunar orbit and to increase knowledge of the angular motions of the Moon around its center of mass.

A second laser observatory was being constructed on Mt. Haleakala in Hawaii, and systems testing was scheduled to begin in 1974. It should achieve an accuracy of 2 to 3 cm because of improvements in laser technology. As part of its effort to establish an international laser ranging observation program, NASA loaned laser equipment to Australia which is being used in that country's first observatory, now under construction. The United States also increased cooperation with France and Japan, both of which are building laser ranging facilities.

Long-term data from this project will be applicable to studies of such earthly problems as polar motion changes, fluctuation in the rotation rate, and motions of the tectonic plates, all of which may be related to earthquakes.

Lunar Sample Studies.—In this program, more than 130 domestic principal investigators, 55 foreign investigators, and 700 coinvestigators received samples from the Apollo flights. The distributed samples were held to a very small fraction (about 5 percent) of the returned lunar material, so as to assure adequate sample material for later studies and future researches by new or improved techniques. A second storage site for some of the materials is being established at White Sands, New Mexico, to make sure that representative samples would be preserved in the event that those at the Johnson Space Center were lost or destroyed.

Launch Vehicle Programs.—During 1973, the Scout launch vehicle system was used to successfully launch a DOD navigation satellite. In addition, launch vehicles were processed to support four missions planned for the first half of 1974: three international cooperative Explorer class satellites and a Small Explorer Satellite developed by the University of Iowa.

The Delta continued to be the most used NASA launch vehicle. Total Delta launches reached 99 with the launch of TELESAT–B, Radio Astronomy Explorer–B, ITOS–E, ITOS–F, IMP–H, and Atmospheric Explorer–C. During the ITOS–E mission, the second stage hydraulic system failed, causing the loss of the mission. A NASA Board investigated the failure and recommended a number of corrective actions to preclude its recurrence.

This year, the Delta program office completed arrangements with non-NASA users for Delta launches on a reimbursable basis. Such agreements were made with the USAF for the Skynet II program, with the French-German consortium for the Symphonie Program, with the European Space Research Organization for the COS–B mission, with TELESAT Canada for an additional launching of the ANIK satellite, and with several U.S. firms (Western Union, Comsat, the American Satellite Corp., RCA, and the CML Satellite Corp.) for domestic communications satellites. These arrangements mean that the Delta vehicle will remain the most active U.S. space booster.

The Atlas-Centaur launch vehicle successfully launched three missions this year: Pioneer 11, an interplanetary exploratory spacecraft; INTELSAT IV communications satellite, fifth in a series of eight launches which began in 1971 and will be completed in 1974; and the Mariner Venus/Mercury 1973 spacecraft.

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A new launch system, consisting of the NASA-developed high energy fueled Centaur upper stage and the USAF-developed Titan III booster, was being prepared for an early 1974 launch. This Titan III Centaur vehicle will be used to launch the Viking mission and other heavy payloads beyond the lifting capability of Atlas Centaur.

Sounding Rockets, Balloons, and Aircraft.—A variety of means in addition to spacecraft are utilized, as appropriate and economical, to obtain needed space science data. The NASA Airborne Science Program, which uses aircraft to make scientific measurements not possible from Earth, made major progress in 1973 with the installation of a 91 cm (36-inch) infrared telescope in a C–141 aircraft. Preliminary data from the flight tests indicated that the operational characteristics of the telescope will be within design requirements.

The NASA Sounding Rocket Program launched a total of 71 rockets from Wallops Station, VA; White Sands Missile Range, NM; Alaska; Ft. Churchill, Canada; Sweden, Australia and Norway. About 55 research teams from universities, private industry, NASA centers, other U.S. Federal Government agencies, and foreign governments were supported. Rockets played a major role in relation to the Skylab missions during 1973. Four calibration rockets were flown from the White Sands Missile Range to measure any instrumental changes that might have occurred within the solar UV and XUV experiments aboard the Skylab since launch. Two more support rockets flew during the Skylab 2 and 3 missions to provide high resolution solar X-ray spectral data in conjunction with Skylab's high spatial resolution X-ray photographs of the Sun. Three other White Sands Missile Range rockets carrying solar physics payloads obtained information on the Sun's UV and X-ray emission for correlation with observations of solar phenomena made by Skylab, OSO, and ground-based observatories.

Another project under the sounding rocket program is a rocket probe experiment, Gravity Probe-A. This experiment involves an extremely accurate hydrogen maser clock designed to measure more accurately the relativistic effects predicted by Einstein. During 1973, the design of Gravity Probe-A was completed, and development of the hardware began.

In the NASA Ballon Program, 49 balloons were launched from Palestine, Texas; Ft. Churchill, Canada and Australia. The balloons ranged from 0.1 million cubic feet to 36 MCF; the most common size was 11 MCF. A balloon launched from Ft. Churchill on July 15 landed in Siberia early in August. The scientific payload was successfully recovered and returned to the United States by the U.S.S.R.—an example of international cooperation. The scientific data acquired during the flight is being analyzed. Another significant development was the successful testing of "super pressure" balloons from the Australian launch site. These balloons provide the capability of long-duration Earth orbital missions, opening new horizons for astronomy and high energy astrophysics missions.

Shuttle/Spacelab Mission Planning.—Conceptual planning of specific Shuttle missions using the Spacelab was carried out this year. Core instrumentation and its gross requirements were identified. In addition, the National Academy of Sciences held a NASA-sponsored Summer Study at Woods Hole, MA, to assess the usefulness of the various modes of the Shuttle for scientific research, to identify Shuttle and Spacelab characteristics desirable for the various disciplines, and to outline some typical Shuttle/Spacelab payloads and missions.

International Satellites and Probes.—The importance of space science to satisfying man's innate curiosity and providing solutions to his long-term needs and problems has caused other nations to both build their own satellites and to enter into cooperative space projects with NASA. Thus, an agreement was reached with Italy to fly another cooperative satellite, San Marco C–2 in 1974, and negotiations were underway with West Germany for an additional cooperative aeronomy satellite, AEROS–B, to be launched in 1974. Work also continued on several major cooperative projects, including Helios; a Netherlands ultraviolet and X-ray astronomy satellite; INTASAT, a Spanish ionospheric beacon satellite; and UK–5, the fifth in a series of UK/US scientific satellites. The last mentioned will conduct stellar X-ray observations.

Aeronautics and Space Technology

The NASA Aeronautics and Space Technology programs are designed to serve national needs through activities in three areas: building a research and technology base, conducting systems and design studies, and carrying out systems and experimental programs.

Within these three areas, wide-ranging research efforts push forward the frontiers of knowledge in aeronautics, space and nuclear technologies, and nonaerospace civil applications. The resulting benefits are already affecting the daily activities of people in this country, and their impact will be felt to an even greater extent in the future.

Activities within these areas usually take the form of many small programs, but they all fall into one of the following categories: air transportation system improvement, spacecraft subsystems improvement, providing technical support to the military, and applications of technology to nonaerospace systems.

For example, one of the restrictions on the growth of civil aviation is noise, another is congestion at airports, a third is the environmental impact of aircraft. This year, NASA research efforts were directed to reducing aircraft noise by modifying engines and installing sound deadening materials, by changing flight procedures, and by developing very quiet engines for potential application to current and future aircraft. Work was also done on clean combustors to reduce the environmental impact of jet engine emissions, and studies were made of the effect of jet engine exhaust emissions at high altitudes.

Congestion in the air and on the ground at major airports has become a major deterrent to efficient use of air transportation. NASA has engaged in a variety of research projects aimed at resolving this problem. Solutions under consideration include improved ways of controlling terminal air traffic, using STOL and VTOL aircraft that could land at alternate smaller airports.

Another aspect of NASA research was to investigate ways of increasing the efficiency of aircraft. Approaches being studied include reducing drag, increasing aerodynamic efficiency, and reducing weight through the use of advanced materials.

Aircraft safety continued to be an important part of NASA research. Studies were made of the role of human error in aircraft accidents, of runway visibility, of fire retardant materials and paints for use in aircraft structures, and of the hazards of the vortices trailing behind large jets.

A large number of other projects from improving the ride quality of passenger aircraft to developing more efficient, more economical power and propulsion sources were under investigation. Research on spacecraft subsystems included work on new spacecraft propulsion systems, advances in solar and other space power systems, support of the Space Shuttle, study of atmospheric entry, and flight research of lifting bodies.

Reducing Aircraft Noise and Environmental Impact.—One of the chief recommendations of the 1971 Joint DOT–NASA Civil Aviation R. & D. (CARD) Policy Study was that, "Aircraft noise is the largest single impediment to the orderly growth of air commerce, and should be minimized by a vigorous industry/government noise-reduction program." The CARD Policy Study also concluded that though jet aircraft create only about one-seventh the pollution per passenger-mile when compared with automobiles, nevertheless due to anticipated air traffic growth, "Pollution from aircraft engine exhaust emissions will require continued attention." In response to these recommendations, NASA has vigorously pursued the following noise and pollution abatement programs.

Reducing Engine Noise From Existing Transport Aircraft.—The JT8D refan program will demonstrate the technology necessary to reduce the noise footprint area of 727,737, and DC–9 aircraft by 75 percent. These aircraft, all powered by JT8D engines, account for over 60 percent of the operations of the domestic fleet.

The refan program was started in August 1972 with contracts to engine and airframe companies from Lewis Research Center, Cleveland. The changes required in the current JT8D engines to reduce the jet noise on takeoff and the fan noise on approach were determined, and the acoustic nacelles for the modified engines and the air-frame interfaces to accommodate them were studied. Construction was started of the modified engines which will be ground-tested in acoustic nacelles designed for 727 and DC–9 aircraft.

Actual flight tests of a DC–9 aircraft with the modified engines and acoustic nacelles will be made early in 1975 to demonstrate the noise levels achievable by the engine refan approach. The resulting technology will be applicable to both existing and new production JT8D-powered aircraft.

Human Acceptability of Quieter Engines.—A study was completed at Columbia University to evaluate the acceptability of quieter engines. The study was a combined field survey/laboratory investigation of three aircraft noise levels: (1) baseline (2) –6EPNdB, and (3) –12EPNdB. The field survey established the attitudes and opinions people had about aircraft operations and noise; subjects for the laboratory investigation were selected from those surveyed. In the laboratory, subjects were exposed to noise stimuli at the three different levels and at exposure rates comparable to those actually encountered under flight paths around John F. Kennedy International Airport. The findings of the study were that: the subjects were able to perceive the noise reduction; the subjects reported a mean annoyance reduction of -0.7 per –6EPNdB of noise reduction on an annoyance scale of 0 to 4. Work continued at Columbia University in an effort to understand the relative difference between takeoff and landing sounds on annoyance judgments.

Noise Reduction Flight Procedures.—A B–727–200 aircraft equipped with special avionics to assist the pilot in making two-segment noise abatement approaches was flown in scheduled airline passenger service. It was routed to cities with airport guidance capabilities for two-segment approaches. In the 6-month evaluation with over 500 two-segment approaches made by 38 different flight crews the procedure was demonstrated to be safe, to be capable of interfacing with the ATC environment, to cause no significant increase in pilot workload, and to have no effect on passenger comfort. Evaluation of another

aircraft model will occur in 1974. The two-segment approach reduced the 90 EPNdB approach noise footprint area of the B–727 by about 65 percent.

Clean Combustor Program.—Contracts for the first phase of the clean combustor program for jet engines were awarded to two companies. During this phase, analytical and experimental research will be conducted on a variety of low emission combustor design concepts. The most promising concepts will be selected for further research at larger scale during the second phase of the program in 1974. The final phase in 1975 will include the demonstration of a clean combustor in a modern full-scale high pressure ratio engine. The clean combustor program is expected to demonstrate that a practical combustor can be developed to meet the very low pollution emission levels established by the Environmental Protection Agency Emission Standards for 1979.

Quiet, Clean Short-Haul Experimental Engine (QCSEE).—A powered lift propulsion research program was initiated. The program objective is to design, build, and test experimental engines to demonstrate the technology needed for very quiet, very clean and efficient propulsion systems to be used in economically viable and environmentally acceptable powered lift short haul aircraft. Program goals include: 95 EPNdB noise footprint area of less than 0.5 square mile; emission levels of the experimental clean combustor program; thrust to weight ratio of 6 to 1 or better; high bypass ratio engine technology for under the wing and over the wing systems; composite, variable pitch, thrust reversing, low pressure ratio fans with gear reduction drive for low tip speed.

Global Air Sampling Program.—NASA is conducting a research program to determine the contribution of high altitude jet aircraft engine exhaust emissions to atmospheric pollution. One part of the program calls for installation of air sampling systems in commercial Boeing 747 airplanes to routinely measure global air quality in the world airlanes. NASA and the National Oceanic and Atmospheric Administration will examine the data to characterize the natural atmosphere and identify any trends in pollutant concentrations. The resulting information will be used to help establish exhaust emission criteria for future jet engines.

Stratospheric Jet Wake Measurements.—NASA initiated a program to help predict the effects of aircraft operations on stratospheric air chemistry. It will seek to determine the nature and distribution of effluent emissions into the turbulent wake of an aircraft and the subsequent distribution and chemical reactions as the wake begins to diffuse and mix in the normally quiescent stratosphere. Techniques to be employed include altitude chamber measurement of emissions from a J–58 engine for correlation of data from flight measurements of YF12 aircraft emissions, construction of analytical models for jet/wake mixing studies, stratospheric chemistry studies, and flight experiment definition and data analysis.

Relieving Airport Congestion and Reducing Dependence on Conventional Airports.—One of the real problems in fulfilling the promise of air transportation has been the air and ground congestion around principal airports due to facility overloads. The result has been lengthy delays, excessive energy consumption, and needless pollution. Suggested solutions have been to improve terminal air traffic control and to use short takeoff and landing (STOL) and vertical takeoff and landing (VTOL) aircraft that could use alternate smaller airports to relieve the overload. The following programs are designed to help achieve these aims.

Joint DOT/NASA STOL Operating Systems Program.—The program continued to pursue its objective of providing navigation, guidance, control, and flight management information for use in establishing system concepts, design criteria, and operational procedures for the STOL short haul aircraft.

A STOLAND avionics system, devised for use in STOL ground simulations and flight evaluations of advanced concepts for terminal area navigation, guidance, control, and flight procedures, was installed in the C–8 augmentor-wing STOL research airplane. Initial flight checkouts were conducted late this year, and another STOLAND system was being prepared for flight experiments in a DHC–6 turboprop STOL airplane next year.

Short and Reduced Take-Off and Landing Aircraft (STOL/RTOL).—Flight tests of the C–8 augmentor-wing research airplane continued. Purpose of the tests is to verify by early 1974 the increase in aerodynamic lift found in previous wind-tunnel model tests of the jet augmentor concept, and to determine the operational characteristics and limitations of the aircraft. The aircraft was modified this year to incorporate a powered elevator and an advanced terminal area guidance, navigation, and control system. The new equipment will enable the aircraft to accommodate broader, more representative experiments relating to STOL/RTOL handling qualities and operating systems.

Powered-lift systems research in the wind tunnel concentrated on models of the jet augmentor-wing and upper-surface blown flap concepts. Large-scale tests of a swept jet augmentor wing model having lobe nozzles for reduced noise were carried out in the 40-by-80-foot tunnel. Upper surface blown flap studies were initiated with small and large-scale tests on two- and four-engined configurations. Ground-based simulation studies

were continued jointly with the FAA. Purpose of this work is to help develop criteria on which to base requirements for handling qualities of powered-lift aircraft. The deflected slipstream and jet augmentor wing were the first concepts investigated.

Terminal Configured Vehicle Operating Experiments.—This is a joint NASA–FAA program to evaluate and demonstrate advanced aircraft and equipment technology for digital automatic flight control and guidance systems which will make CTOL and RTOL aircraft environmentally more acceptable, safer, and compatible with advanced air traffic control systems for the terminal area. Included for study are electronic displays, flight procedures, and airplane modifications. NASA acquired a B–737 aircraft equipped with advanced electronic equipment including displays and began flight experiments.

STOL Crosswind Landing Research.—A flight investigation to extend the operational limitations imposed by crosswinds on low-speed STOL and RTOL aircraft was initiated at the Langley Research Center. The research program covers piloting techniques and aircraft modifications such as a special crosswind landing gear which can be adjusted for research purposes. Candidate crosswind landing gear configurations were model tested to provide data helpful in design of the full-scale hardware. Conceptual design of a full-scale adjustable cross-wind landing gear will be initiated in 1974.

Vertical Takeoff and Landing Aircraft (VTOL).—Several lift-fan transport studies applicable to commercial short-haul aircraft were conducted. An investigation of hovering ground-effect was completed on a remote-fan transport configuration. Another more advanced remote-fan model was designed and was under construction; wind-tunnel tests were planned for 1974 in the V/STOL tunnel. Small- and large-scale tests were begun on small, light lift-cruise fan nacelles and vectoring-control systems for such aircraft. Contracts for conceptual design studies of advanced lift-fan civil transports were extended, studies of the application of lift-fan technology to military transports were initiated, and contractor oral reviews of the studies were held in November. The studies will be used to guide future technology programs.

Wind tunnel tests were completed on a jet VTOL fighter configuration having one lift engine and two lift/cruise engines. Design and construction of a model of a fighter configuration utilizing the ejector-augmentor concept was completed. Free flight tests will be carried out in the full-scale tunnel next year.

Fixed base simulator studies were initiated to develop control, stabilization, and guidance systems for zero visibility VTOL landings. Flight tests were begun with the X–14B variable-stability aircraft to verify hover control systems developed in analytical and simulation studies.

Rotorcraft research studies included full-scale tests on the whirl tower of a rotor having an ogee tip shape intended to reduce the tip vortex strength and therefore rotor vibration and noise. In-house and contracted investigations of other rotor concepts indicated that the variable geometry and bearingless rotors are particularly promising; larger-scale model tests are planned.

Flight tests were completed using the variable stability CH–46 helicopter to document vertical-velocity-command concepts in steep approaches—both piloted and automatic. Studies of other landing approaches with a concave downward flight path (to avoid obstacles or reduce noise) were started, and another program was initiated to equip a CH–53 helicopter with an acoustically insulated passenger cabin for studies beginning in 1974, of noise, vibration, and motion qualities acceptable to civil transport passengers.

VTOL Operating Systems Experiments.—The objective of this program is to establish a technology base leading to improved VTOL operating efficiency and safety, especially in low visibility conditions, and decreased environmental impact. Simulation and flight experiments were conducted using rotary wing VTOL aircraft (helicopters) at Langley Research Center, Va. Nonrotary wing aircraft were evaluated through simulation at the Ames Research Center. An adaptation of the STOLAND flight research system (called V/STOLAND) developed for STOL flight research was being readied for use in ground simulations at Ames and later flight research with the Tilt Rotor Research Aircraft.

VTOL Autoland System.—Research continued at Langley Research Center to establish design guidelines for practical, cost effective VTOL automatic landing systems for civil applications. This year flight tests were conducted on a three-axis velocity sensor. A strap-down laser gyro attitude measurement system, designed and built at the Marshall Space Flight Center, was delivered to Langley for flight testing. The newly developed systems and sensors appear to offer a cost effective way of meeting the performance requirements for VTOL automatic landing systems.

Rotor Systems Research Aircraft.—NASA and the Army awarded a contract in November for the design, fabrication, and test of two Rotor Systems Research Aircraft (RSRA). Project management was placed in a NASA/Army Project Office at the Langley Research Center.

The RSRA will obtain better data on the rotor concepts through actual flight test, it will achieve cost savings through repeated use of the vehicle by both organizations, and it will assure timely completion of re-

search programs. The RSRA is expected to make its first flight in May 1976 and begin its service as an advanced research tool shortly thereafter.

Tilt Rotor Research Aircraft.—As the result of a competitive preliminary design effort, a contractor was selected in July to design, fabricate, and flight test two Tilt Rotor Research Aircraft (TRRA). It is to be used to demonstrate that the dynamic stability problems of previous models have been solved and that technology is ready for application to military and civil aircraft. The project is being managed by a joint NASA/Army Project Office located at the Ames Research Center.

A tilt rotor aircraft retains the hovering capability of the helicopter, and in addition, enjoys the speed and ride qualities of a turboprop when its rotors are "tilted" forward for cruise flight. The first flight is expected in May 1976. It will initiate a thorough flight test program.

Aircraft Ride Quality.—The Flight and Langley Research Centers conducted a research program to determine the fundamental relationships between the physical environment (vibration, noise, etc.) of a transportation system's passenger compartment and the psychological response (comfort related) of the passengers. Passenger response was studied under actual airline operating conditions and preliminary relationships were established for the effect of lateral and normal accelerations on passenger acceptance. For controlled flight conditions, the Flight Research Center at Edwards, CA conducted studies in the General Purpose Airborne Simulator (GPAS) to define the boundaries of passenger acceptance criteria. The flight research results, both airline and GPAS, are used as guides for the Langley simulation studies, in which a number of simulators study passenger response under controlled conditions. Work continued to define acceptable vibratory motions representative of enroute flight phases and to define acceptable motion relationships representative of those encountered during maneuvering in the airport terminal area. Data from this program will be used to establish passenger acceptance/ride quality criteria for future short-haul transportation systems.

Increasing Aircraft Efficiency.—Generally, for transport aircraft, the weight of the fuel is much greater than the weight of the payload. Therefore, relatively small reductions in fuel requirements due to reduced drag or higher propulsive efficiency, can not only reduce critical fuel consumption, but can have a large effect on the overall efficiency of the aircraft. Similar efficiency increases can be obtained through reduced structural weight. In an effort to achieve these gains, NASA is pursuing the following programs.

Advanced Transport Technology.—This program continued its research efforts to provide a technology base for future, more efficient, long haul subsonic and near-sonic transport aircraft. High-subsonic speed flight tests of a TF–8A airplane with a supercritical wing design were completed. Test results confirmed the predictions for reduced drag and optimized performance and demonstrated the importance of supercritical wing technology as a key technical advance toward improved transport aircraft.

Two major trunk airlines were asked to conduct a critical review of the advanced technology recommendations resulting from earlier system design studies. In their reviews, the airlines were concerned with reliability and maintenance costs as major factors influencing their assessment of the advantages of advanced technology. Knowing the areas of concern, NASA researchers are able to consider them during technology demonstration efforts.

Earlier system design studies were extended to determine what technology was needed to make future transports more compatible with terminal area air traffic control systems. Better compatibility would reduce air system delays from congestion and lessen community noise impact. Results indicated that advanced technology can improve maneuverability in the terminal area, allow steeper approach paths, lessen approach and landing speeds, and significantly reduce noise footprint area at a cost of about 3 percent increase in gross weight. Plans were made to study engine nacelle designs for even greater reduction in the noise footprint area. This would be accomplished by applying interwoven acoustic absorbent and composite structural materials without increasing gross weight or operating cost.

Other studies examined the relationship between new technology and fuel conservation. Results indicated that a future large long-range transport aircraft similar to the present Boeing 747 can achieve a 22-percent saving in fuel requirements through the application of advanced transport technology.

As a consequence of national concern over potential costs and shortages of petroleum-based fuels, a system design study was begun to identify the aircraft technology needs for alternate aircraft fuels. Liquid hydrogen was selected for consideration because of its high energy per pound, and because its low density and large volume requirement may be most applicable to large aircraft. The study was designed to provide: an assessment of the feasibility and advantages of hydrogen fuel for long-range subsonic transport aircraft to be introduced in the years 1990–95; an assessment of the problems and technology requirements peculiar to hydrogen-fueled subsonic aircraft; and an identification of actions required (theory, laboratory studies, flight re-

search) to accelerate development of the new aircraft technology.

Filamentary Composite Materials in Structural Applications.—These materials consist of strong nonmetallic fibers embedded in a plastic matrix. They have strength, stiffness properties, and resistance to fatigue that are superior to metals in many applications. Their use in aircraft construction could reduce weight by 25 to 30 percent over a metallic structure.

Several NASA programs were conducted to obtain design and manufacturing experience and to evaluate reliability and maintenance of composite components in service operations. An Army CH–54 helicopter with a composite reinforced tail cone began flight tests, and the center wing boxes of two USAF C–130 aircraft were being fabricated for flight testing in 1974.

Composite external fairings were installed at six locations on three wide-body commercial jet aircraft in regular passenger service. In addition, the aluminum spoilers on 27 other commercial jet airliners were replaced with graphite-epoxy composite spoilers. They will accumulate flight experience for 5 years. Plans were made for applications of composites to rudder and aileron components of commercial airliners.

Skin Friction Drag Reduction.—The boundary layer flow over subsonic and supersonic aircraft accounts for approximately 50 and 40 percent, respectively, of the total drag resistance encountered in a normal mission. The Langley Research Center investigated methods for reducing boundary layer "skin friction" drag. Such a reduction would increase aerodynamic efficiency and reduce fuel consumption. Fuel savings could be a significant contribution to resolving the energy crisis facing the Nation. The compliant or flexible wall, gaseous injection through slots, or combined gas/particle injection were concepts under consideration. Each of these concepts was tested and appeared promising, but additional analyses and experimental studies are required to verify their economic application on aircraft.

Efficient Low Speed Wing.—Significant progress was made in the analytical and wind tunnel development of a new airfoil section optimized for the lower speed general aviation performance range. Wind tunnel data predicted a 30 percent increase in maximum lift and a 50 percent improvement in lift-to-drag ratio over the present airfoils. The greater thickness (17 percent) permits lighter construction through optimum location of internal structure; at the same time, the larger internal volume makes it possible to use larger fuel tanks thereby increasing range. A twin engine aircraft was being modified to provide flight validation of the wind tunnel predictions. First flight of the modified airplane was scheduled for July 1974.

Digital Fly-By-Wire Experimental Program.—The first phase of the program, completed in November, demonstrated the feasibility of digital fly-by-wire flight control of an aircraft utilizing equipment derived from the Apollo program. Over 40 flights were made in an F–8 aircraft which had been modified by replacing its conventional mechanical control linkages with electrical wires which carried signals from the Apollo computer to move the control surfaces.

During the second phase of the program, which was started this year, the Apollo equipment will be replaced by conventional state-of-the-art aircraft equipment. Eventually, the system will become all-digital. Future aircraft designs will profit from the increased flexibility, improved performance, and lower cost offered by all-digital systems.

Transonic Aircraft Technology Program (TACT).—In this joint NASA/USAF program, a supercritical wing set was delivered by the manufacturer, static-tested by the Air Force, and installed on the F–111 aircraft by NASA. Under the technical direction of the Flight Research Center, flight tests were begun in October to evaluate the benefits of supercritical technology for application to high performance aircraft. The design criteria derived from the tests will be applicable to both military and commercial aircraft.

Panel Displays.—NASA scientists developed a two-color monolithic array of light emitting diodes for the displaying of alphanumeric information on board aircraft and spacecraft. Green/red emission is obtained by careful control of the properties of gallium phosphide and by varying the current-frequency characteristics. These solid-state array modules applied to a flat-panel display device offer advantages over the cathode ray tube: low volume, light weight, and reduced power consumption.

Aircraft Safety.—Not only must aircraft be made more efficient, but air travel must be made safer as well. To help achieve this, NASA has been investigating factors causing human errors, working on fire-retardant techniques, and studying hazards due to swirling vortices trailing behind large jet transports.

Human Error in Aircraft Accidents.—The Lovelace Foundation, under a NASA Flight Research Center contract, completed an analysis of human error-related jet transport accidents for the period 1958–1970. Some 74 accidents were examined using National Transportation Safety Board records as the data source. Approximately 70 variables per accident were used in the analysis in an attempt to discover the enabling factors or conditions that lead to a human error aircraft accident. Examples of enabling conditions are crew duty times, airport weather, runway conditions, night time operations, and crew decision making. The preliminary

finding was that if a number of enabling conditions occur simultaneously accidents seem to occur more often. Work was initiated to determine the quantitative significance of the findings.

Runway Visibility Tests.—The first complete theoretical model of the light-scattering process in the Earth's atmosphere was developed at Wallops Station. After validation in actual fog conditions early in 1974, the model will be used in constructing accurate instrumentation for measuring runway visibility conditions as the pilot really sees them. It will also have another use. These conditions are now measured by estimating visibility as seen from the tower, or by a photocell which measures the output of a light a short distance away, and such methods may bear little relation to what the pilot actually sees. The validated scatter model can be used to evaluate present techniques.

Fire-Retardant Polymers for Aircraft.—NASA has conducted extensive research on aircraft crash fires, developing fire-retardant foams used between the cabin shell and the interior of the aircraft and fire-retardant paints for use in engine nacelles and other similar areas. This year, a new fire-retardant phenophthalein-polycarbonate polymeric window material was synthesized as a potential replacement for the flammable acrylic windows currently used in aircraft. The materials were applied to military aircraft to demonstrate their effectiveness. Tests were also made of fire retardant fabrics, coatings, and other aircraft interior materials to determine their safety and effectiveness.

Fire Safety Technology.—Full-scale fuselage fire tests were conducted in the course of preliminary assessments of the nonflammable properties of new materials under consideration for aircraft interiors. These materials showed good fire-resistance performance and lower smoke production than current aircraft interior materials, but still produced significant amounts of toxic gaseous byproducts. The Ames Research Center continued investigating the mechanisms and types of toxic gases involved in the combination of various materials and the responses of the human organism.

Tests of polycarbonate aircraft windows conducted at Ames demonstrated that the windows charred when exposed to flame, thus protecting the fuselage interior from infrared radiation produced by an outside fire. Combined with fuselage insulative foams developed earlier, the polycarbonate windows contributed to a six-fold increase in the time available for passengers to escape before the temperature inside an intact fuselage would be raised high enough by an outside fire to exceed human limitations.

Additional research was conducted on a family of nonflammable, nontoxic inorganic polymers which are extremely expensive, but may become economically practical with further investigation.

Aircraft Wake Vortex Hazard.—NASA intensified its efforts to eliminate the hazard of the swirling vortices trailing behind large jet transports. Numerous wind tunnel, water tank, and preliminary flight tests were conducted by the Ames, Langley, and Flight Research Centers to identify mechanical devices or design changes which can accelerate vortex breakup. Several schemes were proposed for early vortex dissipation, and these and other techniques will be selected by June 1974 for actual flight test evaluation with transport-type aircraft.

Wake Turbulence Flight Tests.—To define the magnitude and extent of the safety hazard created by trailing vortices from large jet aircraft, NASA, the FAA, and industry conducted a joint flight investigation of the wake generated by several wide-body civil jet transports. Instrumented probe aircraft ranging in size from a Lear Jet to a DC–10 were flown through the wake of the wide-body aircraft. Measurements were made of critical parameters which define the vortex intensity, size, position, dissipation, and upset hazard to the probe aircraft. The FAA is using this data to establish standards for safe operational separation of aircraft.

Advanced Supersonic Technology.—Though much of NASA's research is concerned with improving subsonic flight, research is continuing to make supersonic flight efficient, with low noise and environmental impact.

Thus during 1973, research took place on propulsion, structures and materials, aerodynamics, and stability and controls applicable to military and civil supersonic cruise aircraft.

The first phase of a contract study to determine the feasibility of developing an advanced supersonic transport configuration with low sonic boom was completed. The results indicated that a Mach 2.7 configuration, producing a sonic boom of 1 psf, was feasible but additional design studies would be required to overcome the unacceptably high sideline noise and takeoff distance.

The aerodynamic data base was expanded with the completion of low-speed unpowered wind tunnel tests of advanced variable sweep and blended wing/fuselage arrow-wing configuration concepts. Low-speed powered tests were scheduled to be completed early next year.

As part of the structures and materials effort, a high temperature titanium panel with conventional skin/stringer construction but using a weld braze technique was built and will be flown on a YF–12 airplane. Flight evaluation will continue into 1974 on other titanium structures. The NASA/JPL high speed interferometer was installed on the French and British Concorde aircraft and flights were conducted in June and October to obtain stratospheric natural background data. These data are expected to assist the Department of Trans-

portation's Climatic Impact Assessment Program (CIAP) to evaluate the potential climatic impact of high altitude aircraft.

Thirty flights were completed by YF–12 aircraft in the NASA/USAF propulsion and aerodynamics research programs. One series obtained basic flight information on steady-state inlet performance using a YF–12 aircraft with an extensively instrumented propulsion system. Similar test data were obtained in a wind tunnel on a one-third-scale inlet. Another series of research flights collected information on aerodynamic boundary layer characteristics. The results were analyzed and compared with ground facility and flight test results to evaluate the methods used to extrapolate full scale flight.

Preparations were made for a YF–12 flight loads symposium early in 1974. All results of the loads and structural analysis research accomplished during the 1971–73 period will be reported and discussed.

Military Support Programs.—NASA continued to provide support for the military. NASA engineers are assigned to and colocated in the USAF F–15 Systems Program Office and the Aeronautical Propulsion Laboratory at Wright-Patterson Air Force Base, and in the B–1 system program office at the contractor's plant. NASA capabilities are made more readily available by the system of colocating personnel at program offices.

Application of Aerospace Technology to Civil Systems.—Though aerospace technology has been applied to numerous civil applications, from air cushion vehicles to computerized metropolitan traffic control systems, the following two particularly important application programs are included in this section.

Low Pollution/Low Fuel Consumption Automotive Engines.—NASA is cooperating with the EPA and the DOT to develop the technology for reducing the fuel consumption and polluting exhaust emissions of automotive engines. Two alternatives were studied: One approach is concerned with hydrogen injection for internal combustion engines. This work, at the Jet Propulsion Laboratory, Pasadena, CA, is based on a recent discovery that relatively small quantities of hydrogen rich gas introduced into the internal combustion engine along with the normal gasoline/air mixture permits it to be operated with increased efficiency and greatly reduced pollutant emissions. The initial phase demonstrated its potential for application to aircraft and automobile engines.

The second possibility is under study in a joint EPA/NASA/industry automotive gas turbine program. Here work was started on the application of aircraft gas turbine and combustor technology to automotive gas turbine design. The purpose of the program is to demonstrate by late 1975 that a gas turbine powered automobile can meet Federal exhaust emission standards, improve fuel economy, and possibly reduce costs to the consumer.

NASTRAN Computer Program for Structural Analysis.—This program, initially released in 1970, is currently being used in the design and analysis of various types of aeronautical and space vehicle structures, and in the design of railroad roadbeds and tracks, nuclear reactors, large skyscrapers, automobiles, ships, turbines, heavy machinery, astrodome type sports stadia, and many other structures. A recent application was in the analysis of a long-span, cable-stayed freeway bridge being designed for the city of Seattle.

NASTRAN was expanded this year with the addition of the capability for complete thermal analysis and complete aircraft analysis. Work was begun to give NASTRAN the ability to predict aircraft flutter. By the end of the year, the number of engineers using NASTRAN exceeded 2,000, and the number continued to increase by about 50 percent per year. The program was used by over 180 non-aerospace companies in addition to widespread use in the aerospace industry.

Space Communications and Navigation.—Space programs have pushed the limits of present day technology harder than virtually any other of man's activities. In trying to improve communication and navigation for space activities, new developments in electronics and computer technology have emerged. The following describes some of NASA's current programs in these areas.

Optical Mass Memory Technology.—In this program an organic molecular system that exists in two different spatial orientations was synthesized for use in high speed, high capacity holographic computer memories. The conversion of one form of the molecule into the other is caused by the interaction with light irradiation and is the basis of writing binary information into the system. Readout is effected by the reconversion of the molecule to its original form by a different light source. The system offers ease of conversion, high storage density, and low cost of material, advantages which make it a likely choice for the laser read-write optical mass memory.

Laser Communication Tests.—A laser data transfer system was tested at Marshall Space Flight Center using a high altitude aircraft at 60,000 feet altitude with a laser ground station atop a nearby mountain. The two laser systems were able to acquire and track one another successfully, but were not able to transfer data at the highest planned rate because boresight of the aircraft equipment was adversely affected by temperature variations.

High Temperature Antenna Technology.—The Langley Research Center completed development of the necessary background data and techniques for the design of the Shuttle antenna systems. Part of the development was devoted to determining which materials would protect the antenna against thermal and structural stresses and at the same time maintain good electromagnetic transmission characteristics. The research produced six protective antenna "window" materials, including composites of silica, boron nitride, and mullite fiber. A second element of the task was to develop a computer prediction program to analyze the electromagnetic radiation characteristics of antennas mounted on large complex-shaped vehicles. This program was verified by fabricating and testing scale models, and will obviate the need for costly and extensive full scale tests. As a final part of the development, an analysis was completed to determine the feasibility of structurally integrating the antenna with the vehicle.

High Data Rate Antennas.—The Jet Propulsion Laboratory designed and tested a furlable conical antenna with a line feed for deep space missions requiring high data rates at extremely long distances. The size of antennas has been limited by the diameter of the shroud on the launch vehicle since they could not be folded and yet work efficiently when deployed. The new antenna has a surface accuracy when deployed which is so good that it can be used at the new X-band wavelength, and the line feed matches the conical antenna so well that an overall efficiency of 73 percent has been achieved at X-band. With the addition of an S-band capability the antenna will be suitable for most foreseeable missions to the outer planets.

Spaceborne Microwave Amplifier.—Langley Research Center completed the development of a medium-power microwave traveling wave tube amplifier (TWTA) suitable for use on Space Shuttle and other space vehicles requiring several tens of watts for information transfer. The TWTA has an output power level of 100 watts at C-band and an overall efficiency greater than 42 percent. The design included the first use of heat pipe thermal cooling in space-type microwave amplifiers and will serve as the basis for its application to future higher power levels.

S–X Band Experiment.—The Jet Propulsion Laboratory completed fabrication of dual frequency equipment called the S–X Band Experiment, which was installed on the Mariner Venus/Mercury spacecraft. The experiment adds an X-band radio link to the standard S-band link and provides for simultaneous transmission of the two signals to improve radio navigation for planetary exploration. In radio navigation, a delay of unknown length in the time it takes for the spacecraft radio signal to reach the Earth results from the perturbation of the radio signal by electrically charged particles in space. The simultaneous use of both S and X band signals permits the differential delay effect to be measured and compensated for to improve navigational accuracies. The use of the higher frequency X-band link also permits the transmission of more data under clear weather conditions. Plans were made to include the dual frequency system on future planetary missions.

Spacecraft Propulsion.—NASA is in constant search for more efficient ways to power spacecraft. Hydrogen combustion technology, which has evolved from space propulsion programs, is now being explored for civilian use in such areas as electric power generation and aircraft propulsion to help alleviate the world-wide petroleum shortage.

Electric Propulsion.—This form of propulsion, with its high specific impulse (over 1,000 seconds), is being considered because of its potential for increasing payload and/or reducing cost of future space missions. This program emphasizes the development of the technology for both primary and auxiliary applications.

In auxiliary propulsion work, final flight acceptance tests were completed on a one millipound (150-watt) ion engine. This engine is to be flown as an experiment on the ATS–F to demonstrate north-south station keeping. A ground test was started to demonstrate a 5-year cycle of the same engine system. Endurance testing (13 million pulses) of a pulsed plasma thruster unit was completed. Such units are ideally suited for precise precession control of spinning type satellites.

In the area of primary propulsion, a 6,000-hour endurance test was begun on a 30 cm (2.75 kw) ion thruster, which will be a standard module for future use and a companion power conditioner with a thermal self-radiating feature was tested to determine its performance capability. The power conditioner provides the proper voltages and currents to the thruster.

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. Atomic hydrogen is being evaluated for this objective, since it can release more than 10 times the energy available from the best rocket propellants now in use. The major problem to be solved is the method for stabilizing the very reactive atom until the energy release is needed in a rocket motor. The Lewis Research Center designed and conducted experiments in a laboratory apparatus which showed that the storability of a highly energetic material (such as atomic hydrogen) can be influenced by a powerful magnetic field. Further experiments were planned to investigate the maximum storage life of the energetic material.

Small thrusters used to control the position and attitude of satellites and spacecraft emit materials which can cause deposits on the lenses, windows, and other critical surfaces of the spacecraft. In research on this problem, the amount of gas that can flow "backward" from the exit plane of a nozzle toward spacecraft surfaces was measured directly. The tests showed that, contrary to present flow theory, a relatively large amount of gas flows rearward from the nozzles. The research provided increased knowledge of spacecraft contamination. The data will be used to design nozzles that will reduce or eliminate backflow.

Long Life Propulsion.—This program has been carried on for several years in an effort to define the best propellants, materials, and designs for long-life propulsion systems required on planetary missions with flight times up to 10 years. This year a propulsion system (thruster, tanks, valves) which uses space storable propellants (fluorinated oxidizer with hydrazine-type fuel) was tested in static firings at simulated space pressure. The propellants, which also give 30 percent higher specific impulse than present propellants, were tested at thrust levels of 1,000 pounds for 30, 400, and 420 seconds. The results were satisfactory and indicated that space storable propulsion can be developed for future space missions.

Solid Propulsion Technology.—An advanced solid propellant motor for spacecraft propulsion was successfully tested at simulated altitude. It gives low thrust during a relatively long burn time in order to provide shockless ignition and low acceleration forces on spacecraft which carry delicate instruments and extended flexible beams and antennas. The motors burned for 125 seconds at an average thrust of 7,886 N (1,773 lb.) which would give a typical planetary orbiting spacecraft a low acceleration of .042 m/sec^2 (0.14g). The advanced features included a low-shock igniter, a low-burn-rate propellant, and an all carbon nozzle, weighing only 40 percent of a comparable ablative nozzle.

A second type of new solid propellant motor, designed for upper stages of launch vehicles, was also successfully fired. It demonstrated a new capability for solid rockets—thrust termination on command, followed by reignition on command. Thus, it gives the two controlled thrust periods needed to place satellites in orbit. The rocket contained 1,450 kg (3,200 lb.) of high performance propellant; it delivered 97,800 N (22,000 lb.) of peak thrust in two pulses, of 36 seconds and 15 seconds, with specific impulse of 303 seconds.

Reusable Oxygen-Hydrogen Propulsion.—In the Lewis Research Center propulsion technology program, engine preliminary design studies defining component and engine performance and operation requirements were completed. Contracts were awarded to demonstrate 10-hour life turbomachinery high speed bearings and seals, and small high pressure liquid oxygen and liquid hydrogen pump performance. Studies were continued of low cycle thermal fatigue problems and advanced fabrication techniques.

Termination of Nuclear Propulsion Activity.— As a result of decisions announced early this year, the joint NASA/AEC Space Nuclear Systems Office was abolished and its activities terminated by July 1973. Development of solid-core nuclear rocket engines ceased and nuclear reactor power technology efforts were brought to an orderly conclusion. The decisions were made in recognition of the advanced technical development of such systems and the fact that there were no plans for their use in the space program in the next 10 to 15 years.

Solar and Other Spacecraft Power Advances.—Solar power, pioneered for spacecraft use, is now being considered, in somewhat different forms, for home heating. As indicated in the following, NASA is continuing to push forward the frontiers of solar and other power sources.

Energy Systems.—Continued improvements were made in performance, reliability, and life of power components and systems and at the same time costs were reduced. In solar cell research, wrap-around contacts were perfected to permit simultaneous contacting of many cells and making replacement of damaged cells easier. Growing of solar cell ribbons progressed. This technique will avoid wasting over three-quarters of the solar cell material in dicing, slicing, and polishing of wafers by the traditional method. High-efficiency, thin solar cells were demonstrated; they will make it possible to obtain more than a 50-percent increase in the power density of solar arrays. Plastic covers, to replace more expensive glass covers for such arrays, were prepared for flight testing. And the Solar Cell Radiation Handbook was issued.

A number of nongassing nickel-cadmium cells were evaluated. The tests indicated that the new cell construction permits use of a plastic cell seal which has several advantages over the ceramic seal: It is cheaper, more reliable when no high pressures are developed, and allows more electrolyte to be added to each cell before sealing, as gas recombination is not critical anymore. In addition, eliminating semidry operation means less migration of cadmium metal and longer life for the separator and the cell. In preliminary tests on pulse charging, the new cells also showed better charge acceptance and lower end-of-charge voltages, another sign of longer life capability.

In another area, the third electrode completed almost 5 years of service on the OAO, proving its reliability and durability. A book on accelerated testing of space batteries was issued. It details the test approaches

being put into effect to reduce time and cost of cell and battery testing.

An improved method for controlling power converters was developed and installed for evaluation at a remote FAA microwave repeater station. Another development was a solid-state electronic switch for use in higher-performing power processing protective circuits.

Energetics and Lasers.—Basic research on a closed loop magnetohydrodynamic (MHD) power generator for the direct generation of electricity from rapidly flowing inert gases neared completion. Scientific data were obtained, and the next step will be to determine feasibility on the basis of physics principles. MHD generators do not employ moving parts and can be operated at much higher temperatures than turbines. They should therefore offer greater reliability and efficiency in space as well as the potential for power applications on Earth.

In research on controlled thermonuclear fusion (CTF), a "Bumpy Torus" apparatus with superconducting magnets was built at the Lewis Research Center and put into operation for producing fusion-like plasmas for research purposes. The Bumpy Torus differs from most other fusion research machines in that it is capable of continuous operation. This permits research on fusion plasma applications to be carried out under realistic conditions with somewhat greater ease than in pulsed CTF research machines. The purpose of this program is to develop the know-how for using fusion energy in space. Progress was made in research on fissioning uranium plasma when the first samples of such plasmas for laboratory research were produced in the Langley Research Center plasma focus apparatus. During this work, powerful nonequilibrium radiation in the ultraviolet and soft X-ray spectrum was observed. The observation is significant because knowledge of the spectral distribution of radiant power is essential to determining the feasibility of fissioning plasma applications.

Primary goals of the NASA laser research program are a broader spectrum of frequencies, higher power, and greater efficiency. One project investigated the use of metal vapors as lasants, but the vaporization of metals presented additional problems. Jet Propulsion Laboratory researchers substituted copper chloride for copper as a lasant with promising results.

Other work was directed toward the use of laser beams as superconductors for power transmission in space. A principal problem is the conversion of laser power to other useful forms of energy such as mechanical motion or electricity. New concepts for direct laser power conversion developed in this research program included the reversible photon engine and the near-infrared, point-contact diode electromagnetic receiver. This work could revolutionize space power technology, and by developing the technology for piping almost unlimited amounts of laser power through evacuated tubes, it could help solve major problems of power distribution on Earth.

Radioisotope Power Systems.—The AEC continued development of radioisotope power systems for space missions in support of NASA (Viking and Mariner) and DOD missions. NASA continued to support technology projects on thermodynamic power conversion systems to provide lower cost radioisotope power systems for space.

Space Shuttle Support.—A supporting wind tunnel program was undertaken to evaluate the aerothermodynamic and flight performance characteristics of the Space Shuttle vehicle. A synthesis computer program, ODIN (Optimal Design Integration), was also developed to evaluate the effects of small design changes on performance, weight, and other parameters. Arc-jet tests of candidate heat shield materials were conducted to aid in the selection of the reusable Thermal Protection System (TPS). Progress was also made in acquiring knowledge of the effects on heat transfer of gaps and joints in the TPS. Data from this study will be used by designers in selecting the best method of applying the heat protection system to the Shuttle.

Advanced Atmospheric Entry Technology.—Progress was made in understanding the complex entry problems caused by the very high heating expected during probe entry into Venus, Uranus, Saturn, and Jupiter. As part of this work, a comprehensive computational program was developed. The program uses very high-speed computers to provide design data for entry probes with minimum heat shield weight and maximum payload. The experimental and analytical work make it possible to compute accurately the heat transfer and heat shield ablation rate for Venus entry; better estimates of planetary entry probe performance for other planets were also made possible.

Research on graphite heat shields indicated that previously unexplained high mass loss rates were attributable to compressive thermal stress; accordingly, plans were made to carry on work during the coming year to improve the high temperature strength of graphite. Studies of reflecting type heat shields, which can significantly reduce weight, continued, and an extensive screening program has identified silica as a high performance reflecting heat shield material.

Lifting Body Flight Research.—This is a joint NASA/Air Force program to develop a technology base for advanced spacecraft and military fighter type aircraft. The M–2, HL–10, and X–24A lifting body vehicles used in the program were previously retired from flight status after completing a total of 108 research flights. This year, the X–24A underwent external modifications to increase its performance. Flight tests on the

X–24B were begun to assess performance and handling qualities and to determine the control characteristics from low supersonic speeds through landing.

Tracking and Data Acquisition

The tracking and data acquisition program continued to support NASA flight missions, including Skylab and some 40 other flight projects. For Skylab, the networks provided the vital communications link between the astronauts and the ground-based flight controllers. The 1973 launches included such major missions as Pioneer 11, the Atmosphere Explorer, and the Mariner Venus/Mercury Mission.

The networks increased their capability significantly as two 64-meter (210 feet) diameter antennas became operational. The new antennas are updated versions of the highly successful 64-meter antenna at Goldstone, California. One is in Spain, 40 miles from Madrid, the other in Australia, near Canberra.

Spaceflight Tracking and Data Network (STDN).—The STDN provided tracking and data acquisition services to over 40 individual space flight projects. The network supported all NASA Earth orbital missions and a variety of space projects conducted by other government agencies and foreign countries.

Skylab.—Network activities were highlighted by the support rendered to the Skylab program. Shortly after the 80-ton Skylab was launched on May 14, the network stations began receiving data that indicated the orbiting laboratory was in serious difficulty. The solar panels which provide the electrical power needed to operate the on-board systems had not deployed, and the interior of the spacecraft was overheating.

Ground-based engineers analyzed data received by the network stations and were able to determine the status of the solar panels and assemble a "tool kit" for its repair by the astronauts. Also, by transmitting commands via the network, the flight controllers were able to maneuver the spacecraft to minimize the heat generated by the Sun.

When the Skylab 2 astronauts went to work on the damaged Skylab, the network relayed real-time television of the men successfully accomplishing the first major repair job in space. The network supported this and the two subsequent manned Skylab missions.

Lunar.—The network also continued its support of a number of lunar missions. Data was continuously recorded from five separate Apollo Lunar Surface Experiment Packages (ALSEP) left on the Moon by Apollo astronauts and from the Radio Astronomy Explorer (Explorer 49), launched in June. The Explorer spacecraft was placed in lunar orbit to make measurements of galactic and solar radio noise.

Support of Canadian Satellite.—The STDN also rendered launch and early post launch support to the second of a series of Canadian domestic communications satellites, ANIK–2. NASA services were furnished on a reimbursable basis.

Tracking and Data Relay Satellite System.—Work was essentially completed on studies and technology development for the TDRSS. The TDRSS system is designed to employ specially designed communications satellites in synchronous orbit to relay data between low altitude mission spacecraft and a single ground station located in the United States. It is expected to replace several existing ground stations, particularly those overseas, and, more important, provide nearly continuous access to future manned and unmanned spacecraft, such as the Space Shuttle. The system definition studies were completed and indicate that TDRSS service could be available in the late 1970's, in time for the Space Shuttle era.

Deep Space Network (DSN).—The DSN continued its support of NASA's planetary and interplanetary space flight missions. Limited support was given to the extended mission phase of the Pioneer 6, 7, 8, and 9 spacecraft in orbit around the Sun. Heavy demands were placed on the network by the Pioneer 10 and 11 and the Mariner Venus/Mercury missions.

Jupiter Mission.—The Pioneer 10 mission required near continuous support as it sped through the asteroid belt on the way to Jupiter. When the spacecraft encountered Jupiter on December 3, the network began acquiring new data on the planet from the three large 64-meter (210 feet) antenna stations evenly spaced around the world. The Madrid, Spain, and Canberra, Australia, stations, which became operational earlier this year, with the station at Goldstone, CA, are providing the capability needed to obtain data from the planet. The distance to Jupiter from Earth, about 900 million kilometers (560,000,000 miles), far exceeds the range of the standard 26-meter (80 feet) antennas of the network.

The network also provided near-continuous coverage to a twin spacecraft, Pioneer 11, launched April 6. The Pioneer 11 spacecraft will encounter Jupiter late next year. Based on analysis of data obtained from the Pioneer 10 mission, a decision will be made in the near future on a possible change in the trajectory of Pioneer 11.

Venus/Mercury Mission.—The launch of the Mariner Venus/Mercury mission on November 3, significantly increased the workload on the network. Several critical flight phases occur before the spacecraft's initial encounter with Venus (February 1974) which require 64-meter (210 feet) antenna support. For the first time in planetary missions it will be necessary to

recover numerous TV images of Earth and the Moon immediately following the launch phase and while the spacecraft is still close to the Earth in order to calibrate the science system; also, critical multiple mid-course trajectory changes will be required to achieve the precise flyby of the planet Venus and the use of the planet's gravity to assist in achieving the follow-on trajectory needed to fly by Mercury.

The entire sequence will require complex scheduling of the facilities, and possibly in the event of a spacecraft emergency, real-time sharing of the antennas.

Saturn.—This year, the 64-meter (210 feet) antenna at Goldstone was also used to conduct the first successful radar probe of Saturn. The results of the probe were very significant: from them it appears that the planet's distinctive rings may be composed of large chunks of solid material in orbit like a swarm of tiny moons. Scientists had previously thought that the rings of Saturn were made of gas, ice or dust, or some combination of these.

International Affairs

The highlights of 1973 were the conclusion of an agreement with the European Space Research Organization (ESRO) for the development in Europe of a manned orbital laboratory (Spacelab) for use with the U.S. Space Shuttle, and a marked increase in cooperative activity with the U.S.S.R. in fulfillment of the 1972 Summit Agreement on the joint Apollo/Soyuz Test Project.

Spacelab.—On September 24, culminating almost 4 years of discussions and negotiations, NASA signed a Memorandum of Understanding with the European Space Research Organization (ESRO) providing for development by Europe of a laboratory (Spacelab) for use in manned sortie missions with the Space Shuttle. ESRO will design, develop, manufacture and deliver to NASA a Spacelab flight unit on behalf of Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Switzerland, and the United Kingdom, the European countries funding the $400 million effort.

Spacelab represents a major contribution by the European community to the United States Space Transportation System. It will also provide opportunities for U.S. and foreign scientists and engineers to accompany their experiments into space for the first time.

After delivery of the first Spacelab, NASA will manage all operational activities, including crew training and flight operations. Additional Spacelab units of the same basic design needed for U.S. programs will be procured from Europe.

US/USSR Cooperation.—Joint NASA/Soviet Academy of Sciences Working Groups continued to implement the May 24, 1972 U.S./U.S.S.R. 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 science and applications.

Apollo/Soyuz Test Project.—At a joint midterm review of this project in October, all independent activities were reported to be on schedule. Senior representatives of NASA and the Soviet Academy agreed that all joint working group activities were also on schedule, that the conduct and future planning of the project was satisfactory, and that the test mission could be expected to proceed as planned. Major progress included naming of flight crews and flight directors, familiarization of United States and Soviet crews with each other's spacecraft, selection of joint experiments, exchange of safety assessment reports, dynamic testing of both United States and Soviet docking system development units, arrangements for participation by specialists of both sides in critical testing and fit checking, and detailed development of such operational aspects of the joint mission as crew activities, control center operation, and trajectories.

Space Science.—In space science, the principal developments were data exchanges designed to assist both sides in assuring the success of their future missions to Mars and Venus, continuing exchange of physiological data from Soviet and U.S. manned space flight and ground-based programs, and work on common pre- and post-flight medical examination procedures. In addition, a NASA lunar scientist visited the Vernadsky Institute in Moscow, a joint working seminar was held on collisionless shock waves in the magnetosphere, and a meeting of lunar cartographic experts in Moscow considered basic principles for compiling lunar maps, a common system of selenodetic coordinates, and a joint project to compile a map of the Moon on a scale of 1:5,000,000.

Space Applications.—In space applications, operational and scientific weather data from sounding rocket networks were exchanged, coordinated oceanological studies were carried out to compare radiation measurements by U.S. satellites with surface data acquired by Soviet ships in the Atlantic, a successful joint experiment was conducted in coordinated microwave measurements in the Bering Sea area, and further efforts were made to define projects in the study of the natural environment.

Under a NASA/Soviet Academy agreement of October 1965, a joint U.S./U.S.S.R. editorial board continued work on a joint review of space biology and medicine planned for publication in 1974.

International Satellite and Probe Launchings.—The second Canadian operational telecommunications satellite (ANIK–2) was launched April 20 from KSC. Plans were completed with Italy for a cooperative mission in 1974 using a second San Marco C spacecraft to acquire equatorial density measurements, and with Germany for the reimbursable launching in 1974 of a second AEROS satellite for aeronomy studies. These two satellites will be coordinated with the NASA Atmosphere Explorer spacecraft launched in December of this year to conduct the first such concerted and systematic study of atmospheric measurements using spacecraft and instrumentation of three countries.

In addition, work continued on four other cooperative satellite missions: the CTS experimental communications satellite with Canada, the HELIOS solar probe with West Germany, the INTASAT ionospheric beacon with Spain, and the UK–5 stellar X-ray satellite; and two other reimbursable projects—Canada's ANIK C operational telecommunications satellite and UK's X4 technology spacecraft. All but CTS are scheduled for launching in 1974.

Discussions were undertaken with France/Germany and ESRO on several reimbursable launch missions: Symphonie, a French/German experimental communications satellite; and five ESRO spacecraft: COS–B for the study of cosmic rays, GEOS to investigate the outer magnetosphere, OTS for experimental communications technology, MAROTS for experimental maritime communications, and Meteosat to complement two American and one Japanese geostationary meteorological satellites for the Global Atmospheric Research Program (GARP).

Foreign Participation in Approved NASA Missions.—Skylab: Four foreign experiments were flown aboard Skylab during 1973: a French ultraviolet panorama experiment, a Swiss solar wind composition experiment, a Belgian space processing experiment to study silver grids melted in space, and a Japanese study of whisker-reinforced composites, the latter two experiments both using the multipurpose electric furnace facility. A UK scientist acted as a consultant in a NASA welding experiment, and physicians from Germany and the United Kingdom joined the Skylab biomedical team to evaluate effects of long duration space flight on crews. Agreement was reached for 40 data analysis investigations, involving scientists in 19 countries and the U.N. Food and Agricultural Organization (FAO) for the study of Earth resources data from the Earth Resources Experiment Package (EREP). Correlated astronomical sounding rocket programs were conducted with Germany and the United Kingdom, and foreign guest investigators were selected from France, Japan, and the United Kingdom to participate in the Skylab ATM solar telescope program.

German and Australian scientists participated as coinvestigators on experiments aboard the Pioneer 11 mission, and French and UK scientists acted as coinvestigators on the television science team for the Mariner Venus/Mercury project.

In response to NASA announcements of flight opportunity, a UK scientist was chosen to serve on the Imaging Science Team for the Mariner Jupiter/Saturn spacecraft and German and French coinvestigators were selected for the same mission. French and German instrumentation was chosen for flight on the 1978 Pioneer Venus Probe mission, and Canadian, French and UK scientists were selected to participate in the instrument definition for the large space telescope planned for launch on the Space Shuttle. Seven foreign experiments using data from the Tropical Wind, Energy Conversion, and Reference Level Experiment (TWERLE) to be flown on the Nimbus F spacecraft in 1974 were tentatively approved. Agreements were also concluded with Australia and France for lunar laser ranging programs.

Earth Resources.—One hundred and forty foreign investigations using the Earth Resources Technology Satellite (ERTS) and Skylab EREP data were underway during 1973; they involved scientists from 37 countries and the U.N. FAO and the U.N. Economic Commission for Asia and the Far East. In addition, Brazil joined Canada in establishing its own ERTS data acquisition and processing facilities, and additional countries expressed interest in doing the same. Significant results of these projects to date include the utilization of ERTS data in the study of the long drought in Sahelian Africa (subsurface water has been located close to usable soils), a marked improvement in charting the Amazon and its tributaries, drastic revision of the forestry map of Thailand (with important economic implications), and the location of locust-breeding areas in Saudi Arabia.

Satellite Instructional Television Experiment (SITE).—During 1973, work continued on this NASA/Indian experiment. SITE, a 1-year experiment to be initiated in mid-1975, will involve TV signals transmitted from an Indian ground station via the NASA ATS–F spacecraft directly to some 2,000 village ground receivers. India is producing all the ground equipment and instructional programing.

Sounding Rockets.—New agreements for cooperative or NASA sounding rocket programs were signed with Australia, Brazil, Germany, the Netherlands, Norway, and Sweden. Cooperative launchings occurred from ranges in Australia, Brazil, Canada, Sweden, and the United States.

Lunar Sample Program.—Fifty foreign Principal Investigators were selected to participate in the NASA Apollo 17 Lunar Sample Program. They represent institutions in Australia, Belgium, Canada, Finland, France, Germany, India, Italy, Japan, Norway, South Africa, Switzerland, the United Kingdom, and the European Space Research Organization (ESRO).

Tracking and Data Acquisition Cooperation.—Agreements for use of tracking stations abroad were renewed with Canada. NASA Advanced Range Instrumented Aircraft (ARIA), to support launches, were accommodated by countries on four continents. An agreement for use of the airfield in Mauritius was terminated, and plans were announced for the closing of South African facilities. In October–December, NASA provided tracking support for the French EOLE satellite while France supported NASA's Small Astronomy Satellite–2 during the first part of the year.

Disseminating Technology and Benefits

Technology Utilization Office.—This Office has prime responsibility for promoting the secondary use in the industrial and public sectors of research and development resulting from NASA's aeronautical and space programs.

Publications issued by this office include Tech Briefs—single-page technical summaries of useful new materials, devices, methods; Technical Support Packages—in-depth technical descriptions to support Tech Briefs; Compilations—sets of descriptive briefs on techniques or processes relating to a single field of use; and other NASA Special Publications.

The inventory of NASA Tech Briefs increased again in 1973, reaching a total of 5,679. Tech Briefs were distributed to approximately 15,000 regular subscribers at industrial organizations and research groups, and copies were sent to about 85,000 others upon specific request. In addition, more than 25 Compilations, Technology Surveys, and general program materials were distributed in response to requests.

Dissemination is achieved by means of six NASA-sponsored Regional Dissemination Centers (RDC), in Connecticut, Indiana, North Carolina, Pennsylvania, New Mexico, and California. The centers added 150 new subscribers. Their income from sales increased from $580,600 in 1972 to an estimated $685,000 in 1973. The Computer Software and Management Information Center (COSMIC) in Athens, GA, increased its inventory of computer software packages.

During 1973, NASA's licensing regulations were reissued; the regulations now make it possible to obtain exclusive rights to NASA inventions more expeditiously following the disclosure of new technology. To spread information about applications procedures and patents NASA has to offer, the Technology Utilization Program sponsored patent licensing conferences on the West coast and in the Northeast sections of the country. In addition, plans were made to conduct meetings in other geographical regions.

Technology Application Projects.—The Technology Utilization Office continued its efforts to apply NASA technology to problems at Federal, State, and local levels. Working closely with other government agencies, the Office developed a number of technology applications projects involving State and local governments in the effort to transfer "hard" and "soft" technology to the public sector. Although it is still in the developmental stage, the effort showed that State and local governments may be able to strengthen and improve their programs in environmental quality, health care, law enforcement, transportation, and public safety by participating in the NASA technology transfer program. Projects that appear to be applicable at this level include the lead paint detector, the fireman's life support system, the application of ferrofluids to solid waste separation, the drug detector, the low cost fire detection system, the characterization of atmospheric aerosols with laser radar (LIDAR), and the detection of structural deterioration in bridges.

In another effort to expedite the transfer of space technology to public use, the Technology Utilization Office began a program of consultation with the venture capital community. The purpose of this activity is to identify organizations willing to invest capital in promoting commercial applications of technology.

University Affairs

NASA funded 1,456 research grants and contracts totaling $114,900,000 in support of research and space flight experiments at 228 universities. A special program was conducted to assure opportunities to minority schools to participate in the Nation's aeronautics and space efforts. This program provided 51 research grants totaling $1,303,000 to 25 minority institutions.

IV Department of Defense

Introduction

Over the past year, satellite communications have played a significant role in DOD space activities. The Defense Satellite Communication Systems continued to provide secure communications in support of critical command, control, intelligence, and warning needs. Last year the 13 remaining Phase I satellites provided essential service to priority users while corrective modifications were completed on the remaining 4 Phase II satellites. Phase II service was terminated in June 1973 with the failure of the second Phase II satellite. Launch of the third and fourth satellites in late 1973 will allow Phase II service to be resumed with new earth and shipboard terminals, new modulation devices, and existing earth terminals that have been significantly improved over the past year. Progress was excellent during the year on the future Fleet Satellite Communications System in support of tactical communications requirements of the Navy and Air Force. The satellite design has been simplified, the Engineering Model is in design and fabrication, and a production contract was awarded for the Fleet Broadcast Receivers. Terminal segment development was begun in January 1973 on the Air Force Satellite Communications System which will meet strategic command and control needs. The Air Force Satellite Communications System space segment uses the Navy Fleet Satellite Communications System, the Air Force Satellite Data System, and global backup capability on other DOD satellites. Under a 1970 United Kingdom agreement for a follow-on to their Skynet II program, two satellites are being built by the United Kingdom, with United States manufactured communication subsystems, for launch by the United States in 1974. A new agreement was prepared for Skynet III communication satellites. A contract was awarded for the United States to develop, procure, and launch two satellites in support of the NATO Phase III communications satellite program. In support of United States and U.S.S.R. Direct Communications Link policy discussions, an earth station for the Molniya system is presently being installed in the United States. Both the Molniya II and INTELSAT satellite systems will be used when the Direct Communications Link is operational in 1974. During 1973, high quality visual and infrared weather data collected by DOD satellites for the military forces, were made available to the civil/scientific community through the National Oceanic and Atmospheric Administration. Extensive studies, analyses, and experiments have confirmed the feasibility of the satellite NAVSTAR Global Positioning System.

Important events have occurred in major DOD aeronautics programs. A decision was made for full-scale development of the A–10 aircraft to provide close air support for ground combatants. The B–1 strategic bomber for the 1980's is midway in its development phase with first flight now scheduled for mid-1974. The F/FB–111 development was completed, and combat operations have shown our all-weather capability to attack targets is enhanced. The Navy F–14 carrier-based tactical fighter in flight tests, and in the fleet environment, is meeting and, in some cases exceeding, stringent design requirements. The Air Force F–15 advanced tactical fighter is on schedule and 11 aircraft delivered to the Air Force are in flight test. Weapons delivery accuracy continues to be the hallmark of the A–7D attack airplane. Two contractors are each building two Advanced Medium STOL Transport prototypes for flight test to provide a future STOL transport development option.

Also, two contractors have completed the design and are in final fabrication stages of two Light Weight Fighter prototypes which are to explore new technology leading to a low cost, high performance, austere fighter. All S–3A carrier-based, antisubmarine warfare aircraft milestones have been met; the development program has been very successful; and a contract option for 45 additional aircraft has been executed. Full scale development of the E–3A Airborne Warning and Control System (AWACS) avionics subsystem was initiated in January 1973 with system integration demonstration scheduled to start early next year. Three 747 aircraft procured during 1973 will be configured as interim National Emergency Airborne Command Posts and a fourth 747 procured in 1973 will serve as a test-bed aircraft supporting Advanced

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Airborne Command Post equipment development. The approved procurement of 81 C–5A Heavy Logistics Transport Aircraft has been completed and 77 of these have been performing strategic airlift missions on a worldwide basis. Development of advanced technology components continued for the austere Heavy Lift Helicopter prototype. The Utility Tactical Transport Aircraft System development continued on schedule directed toward a competitive fly off. Under the Advanced Attack Helicopter development program two contractors were selected for a competitive fly off program. This development will significantly improve the combat effectiveness of our land forces at an affordable price.

Space Activities

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

Phase I, the Initial Defense Satellite Communications System (IDSCS), was acquired primarily as a research and development system with the additional objective to provide an emergency capability to supplement the Defense Communications System. Twenty-six small, near-synchronous, low power IDSCS satellites were launched in the period 1966 to 1968. They had an expected maximum life of 3 years; however, 13 are still operational, 3 having failed during 1973. Although the failures further reduced the system capability, it continued to provide essential service to priority users.

Development and acquisition of Phase II DSCS, the follow-on operational system, was approved in 1968. The objectives of this phase are to establish an operational military satellite communications system that will satisfy unique and vital communications requirements of the United States and other authorized users that cannot be fulfilled by other communications means. These objectives are being met through the development and acquisition of six new, high-power, geostationary satellites, new earth and shipboard terminals, new modulation devices, and the modification and improvement of earth terminals acquired for the IDSCS.

The first two of the six satellites were dual launched on November 2, 1971, utilizing a Titan IIIC booster. Technical problems with the satellite, positioned to serve the Pacific area, occurred during September 1972. Similar problems developed in June 1973 with the satellite positioned for Atlantic users. Both cases resulted in termination of Phase II satellite services and reversion of users to the IDSCS. To preclude a recurrence of these problems with the remaining four satellites, corrective modifications were accomplished. A dual launch of the third and fourth satellites in December 1973 will enable the resumption of service via the Phase II satellites in early 1974.

Continuing progress was made toward modification of the earth terminals, acquired in the IDSCS phase, to significantly improve their reliability and capability during Phase II. The Army received relivery of an engineering development model of a new heavy earth terminal and will separately procure 38 foot diameter antennas for medium earth terminals. The Army continued the development of new modulation and error correction coding equipment for the future conversion of the DSCS to a digital system. The Navy awarded an engineering development contract for an improved shipboard satellite terminal. Pending the availability of production models of this terminal, the Navy installed interim shipboard satellite terminals on two major command ships and is planning to install two additional terminals.

Extensive studies and hardware design changes were accomplished to insure interoperability among DSCS users under various operational conditions. Preliminary planning was accomplished for the procurement of replenishment satellites, new earth terminals, and modulation equipment to maintain the DSCS as a viable system.

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. The contract for the design and development of the FLTSATCOM spacecraft Engineering Model was awarded in late 1972. As a result of a preliminary design review completed in July 1973, a decision was made to simplify the design to reduce complexity and provide better launch-weight margin. Design fabrication, and testing of the spacecraft Engineering Model was initiated. Coordination for the procurement of the Fleet Broadcast Earth Station was completed, and the procurement cycle initiated with a production contract awarded for the Fleet Broadcast Receivers. Test and evaluation of the ship/submarine radio was completed and development of computer controlled information exchange subsystem continued.

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 AF SATCOM space segment is comprised of Air Force ultra high frequency (UHF) communications capability on the Navy Fleet Satellite Communications (FLT SATCOM) System and the Air Force Satellite Data System (SDS), and global backup capability on other

DOD satellites. The AFSATCOM terminal segment will consist of airborne, mobile, and fixed terminals. The terminal development was begun in January 1973, and initial operational testing is scheduled to begin in mid-1974.

International Cooperation.—The United States has developed, procured, and launched several advanced communications satellites for the United Kingdom and NATO. The United Kingdom's initial communication satellite system, known as Skynet, achieved operational status in 1971. By early 1972, the Skynet satellites had failed, making the United Kingdom dependent on NATO and United States satellite resources. Under a 1970 United Kingdom agreement for a follow-on Skynet II program, two satellites are being built by the United Kingdom with United States manufactured communication subsystems. They will be launched by the United States in 1974. A new agreement was prepared for Skynet III communications satellites.

The NATO Phase II communications satellite system became operational in 1972, with the orbit of two satellites similar to the United Kingdom Skynet I. One of these satellites failed in April 1972. A total of 12 earth terminals was operational in 1973. Pursuant to a June 1972 agreement, a contract was awarded for the United States to develop, procure, and launch two satellites in support of the NATO Phase III communications satellite program. Agreements were completed with NATO and the United Kingdom to cover use of NATO and United Kingdom earth terminals by the United States in return for NATO and United Kingdom use of United States military communication satellites to provide more effective use of the assets of both systems and as a contingency against the failure of the remaining satellite.

Policy discussions having been concluded between the United States and U.S.S.R. Government representatives concerning the implementation of the improved Direct Communications Link between the two governments, discussions were held regarding technical matters and operating procedures. Both the Soviet Molniya II and the INTELSAT satellite systems will be used. Contracts were awarded in 1972 for the construction and operation of the U.S. earth terminal for use via the Soviet Molniya system and for the telegraph coders to meet both United States and U.S.S.R. requirements. The earth station and terminal equipment for the Molniya system are presently being installed in the United States. The improved Direct Communications Link is scheduled to become operational in 1974.

Defense Systems Application Program (DSAP).—This space program provides timely, high-quality visual and infrared weather data to DOD military forces. The satellites operate in two modes, stored and direct. In the stored mode, data are recorded worldwide, then transmitted from the satellite to the Air Force Global Weather Central in Nebraska for processing and use. In the direct mode, the satellite transmits real-time images of the local surface clouds to mobile terminals at key locations throughout the world. The terminal at Hawaii, for example, provided daily support to the Skylab mission to insure splashdown occurred in an area of clear weather. In December of 1972, the data from this program were declassified and made available to the civil/scientific community through the National Oceanic and Atmospheric Administration (NOAA).

Navigation Satellite Activity.—There are no existing navigation systems which can provide precise all-weather, worldwide, three-dimensional position and velocity data in a common reference grid for military users. Space technology provides the potential to achieve such a capability with a single navigation and positioning system.

The NAVSTAR Global Positioning System (GPS) is a major triservice development effort for such a space-based system. It is planned to be fully operational in the 1980's. To date, extensive studies, analyses, and experiments using prototype equipment have confirmed the feasibility of attaining extremely accurate positioning and navigation with such a system. Under Air Force lead this program will emphasize design of equipment for minimum life cycle costs and early full demonstration of operational utility. During 1973, the Navy completed fabrication of the first of several technology satellites. The first launch will be in 1974 and be part of the joint service effort to validate the concepts of GPS. The Army conducted exploratory receiver development and tests in a navigation satellite ground-based simulation environment at White Sands Missile Range. Participation by civil agencies in the development program is being encouraged.

The Navy continued to investigate near term improvements to the existing space-based navigation aid, the Navy Navigation Satellite System (TRANSIT). Three improvement flight tests have been planned. The first satellite, launched in September 1972, included testing of a Disturbance Compensation System (DISCOS) to detect orbit disturbances caused by solar radiation pressure and atmospheric drag and to compensate for these disturbances in order to improve system accuracy. Conceptual and circuit design of a second improved experimental satellite has been completed. Engineering, analysis, design, and construction of this new experimental satellite continued during 1973. The third configuration is still under study.

Titan III.—The Titan III family of launch vehicles continues to serve for the bulk of DOD satellite launches. There has been a total of 72 Titan III launches, and an additional 28 launch vehicles are on order to meet firm mission requirements. The first launch of a Titan III modified to launch a NASA Centaur upper stage is scheduled for January 1974.

Space Ground Support

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

Eastern Test Range (ETR).—In 1973 the Air Force ETR provided continuing support for DOD space and missile operations, NASA space programs, and commercial satellites launched from the Cape Canaveral, Fla., area. This support included range safety, launch, and data acquisition functions. Improvement and modernization of the range instrumentation complex are in progress to achieve more efficient operation and provide required capability to satisfy user test requirements.

White Sands Missile Range (WSMR).—The Army WSMR continued to provide ground support to DOD and NASA aeronautics and space programs. A full spectrum of ground support was provided including technical data from instrumentation such as telemetry, radar, optical systems, real-time trajectory, and digital computers for the analyses of tests and flight safety. NASA program support included the Skylab calibration rocket program, an upper atmospheric rocket sounding program using the Aerobee rocket vehicle, numerous smaller rocket systems, and a variety of astronomical test programs.

Satellite Control Facility (SCF).—During 1973, the workload remained relatively stable for the SCF. Preparatory efforts were underway for improved communication and data system capabilities. The completion of these efforts will result in a more responsive network with greater reliabilty. The last of the three new 46-feet antennas was completed at the Vandenberg Tracking Station completing the update of the three dual stations.

Western Test Range.—The Space and Missile Test Center (SAMTEC) continued to operate the WTR in support of space and ballistic missile launches from Vandenberg Air Force Base, Calif. The last WTR Range Instrumentation Ship, the USNS *Huntsville,* has been placed in wet storage. This ship will be deactivated in 1974. The WTR has continued to selectively improve range instrumentation in order to meet range user requirements. The new midcourse radar at Kaena Point, Oahu, Hawaii, is operational. SAMTEC has entered into a joint procurement with the Navy and Army for three new Digital Instrumentation Radars. These small, highly reliable, transportable radars will be used to provide precise tracking information in order to enhance range safety.

Aeronautical Activities

A–10 Close Air Support Aircraft.—The Air Force completed its competitive prototype evaluation of the A–X candidates, the A–9 and A–10, for the close air support mission for which design requirements stressed responsiveness, maneuverability, survivability, and simplicity along with low cost. Early in 1973 full scale development of the winning A–X prototype, the A–10, was initiated.

Development testing of the A–10 prototypes (two) has been continued with over 400 flight hours accumulated by mid-October 1973. One A–10 is going through a series of aerodynamic tests, while the other is being instrumented for airload tests. The A–10 "most probable" unit flyaway cost estimate is $1.7 million (1970 dollars). However, the design-to-cost target is $1.5 million.

B–1 Bomber Program.—The B–1 bomber is being developed in anticipation of the need for a more capable strategic aircraft for the 1980's and beyond. In July 1973, an assessment of progress schedule, cost, and risk factors resulted in a revision to the development schedule. The program is midway in its development phase with first flight of the B–1 now scheduled for midyear 1974.

The first of the three prototype aircraft is in final assembly with all major systems installed. The prototype engines have accumulated over 2,400 test hours. The planned first increment of the flight test program will consist of a three-vehicle, 22 calendar month period of engineering development testing necessary to expand the flight envelop and permit evaluation of key development and operational issues.

F/FB–111 Aircraft.—Development of the F/FB–111 is complete and the production deliveries remain on schedule with 14 of the currently authorized F–111's remaining to be delivered as of November 1, 1973. Forty-eight F–111's were deployed to Southeast Asia to conduct single aircraft, night, adverse weather bombing strikes. The operation and tactics employed were satisfactory and demonstrated an enhanced capability to attack targets around the clock in near all weather conditions.

F–14 Carrier-Based Tactical Fighter.—Based on results to date the airplane is meeting and in some cases is exceeding the stringent requirements carefully detailed for the F–14 by the Navy in 1968. In flight tests, as well as in the fleet training environment, the F–14A is proving to be a highly maneuverable and agile fighter, and it has clearly demonstrated its air superiority capability against all versions of current fleet fighter aircraft. Additionally, the F–14A has successfully demonstrated the capability to fulfill the Fleet Air Defense role by virtue of its multitrack, multishot Phoenix air-to-air missile firings, achieving an unprecedented 92 percent hit success ratio. By October 1973, 36 F–14 aircraft had accumulated 5,900 flight hours.

F–15 Advanced Tactical Fighter.—The F–15 program is proceeding on schedule. Eleven aircraft have been delivered to the Air Force. These aircraft are being used in flight test to investigate flight characteristics and to demonstrate flight performance of the aircraft/engine and associated subsystems such as avionics and armament. Over 12,000 test flights had been conducted by the end of 1973.

A–7D Attack Airplane.—Production deliveries of the A–7D airplane continued. The modernization program for the reserve forces was highlighted by the delivery of a new-production airplane to the Air National Guard on September 19, 1973. Weapons delivery accuracy continues to be the hallmark of A–7D operational effectiveness.

Advanced Medium STOL Transport (AMST) Prototypes.—The objective of the AMST prototype program is to design, fabricate, and evaluate turbofan powered, advanced technology, prototype aircraft in order to provide a STOL transport development option for the modernization of the tactical airlift force. Two contractors began building two aircraft each in January 1973. Engines were selected, preliminary design completed, extensive wind tunnel tests conducted, some engineering drawings released and initial parts manufactured. Flight testing for the YC–14 and YC–15 prototypes is scheduled to begin in the summer and fall of 1975.

Lightweight Fighter Prototype Program.—This Air Force program will explore the advantages of promising new technology. Two contractors each have completed the design and are in final fabrication stages of two prototype lightweight fighter aircraft. A joint Air Force-contractor flight test evaluation will commence in early 1974 to determine the feasibility and operational practicality of potentially lower cost, high performance, relatively austere fighter aircraft that incorporate new aerodynamic concepts and design ideas.

S3–A Carrier-Based Antisubmarine Warfare Aircraft.—In October 1973, the Navy procured the third production lot of 45 S–3A aircraft after the prime contractor met the long standing milestone of delivering the first four production aircraft to the Navy for use in Board of Inspection and Survey Trials. This milestone was met ahead of schedule, as have been all previous milestones with the S–3A program. This also marks the near completion of an extensive development effort in which over 3,600 flight hours were flown, including over 120 hours operating with a submarine target in a real-world environment. The S–3A development program is considered as having been very successful.

E–3A Airborne Warning and Control System (AWACS).—Full scale development of the AWACS mission avionics subsystems (data processor, communication, navigation, display, and identification), was initiated in January 1973. NATO interest in AWACS has been stimulated through an April 1973 evaluation in Europe of the AWACS radar development system and subsequent discussions with NATO officials. Modification of the radar development system in preparation for a system integration demonstration commenced in September 1973. Long lead procurement for production aircraft started in November 1973. Fabrication of three development test evaluation systems was started in January 1973 and system integration demonstration will be conducted between March and October of 1974.

E–4A/B Advanced Airborne Command Post (AABNCP).—The AANBCP 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^3) center that will operate during all phases of general war. These aircraft will accommodate larger battle staffs and improved C^3 equipment, and will enable the NCA and SAC to more effectively and flexibly control our general war forces throughout international crisis situations.

Four 747 aircraft were procured during 1973. The first three aircraft will be configured as interim National Emergency Airborne Command Posts (NEACP) by transferring the equipment from present NEACP EC–135's. The fourth 747 will be used as a test bed aircraft to support development and test of the advanced C^3 equipment.

C–5A Heavy Logistics Transport Aircraft.—The mission of the C–5A is to provide a fast reaction capability to airlift combat or support units worldwide under general war, limited war, and peacetime conditions. It is capable of air dropping troops and equipment. The aircraft is designed to match material with man-

power mobility. The approved procurement of 81 aircraft has been completed. Seventy-seven of these are assigned to the Military Airlift Command (MAC) and have been performing strategic airlift missions on a worldwide basis. Two aircraft are in test and refurbishment programs, and two have been lost in ground accidents. Operational aircraft have achieved over 100,000 flying hours. C–5's flew approximately 150 missions from October 15 to November 15 to resupply Israeli forces. They delivered about 11,000 tons of supplies, almost half the total tonnage delivered by MAC aircraft. The remaining tonnage was carried by C–141 aircraft in 420 missions.

Fatigue life of the C–5 continued to be a subject of concern. Flight and fuel management techniques and an active lift distribution control system to reduce stress on critical wing areas have been implemented as measures to increase fatigue life. Service life is expected to increase from 6,500 to between 11,000 and 17,000 hours. Instruments are being added to all C–5 aircraft to record wing stress. Design work on possible modified wing sections has been initiated. The decision to modify the wing will depend on operational experience factors.

Heavy Lift Helicopter (HLH).—The basic HLH program goal is 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 underway 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 June 1974. A single austere prototype aircraft will be built to test these advanced technology components, verify the HLH technology and assure that mission requirements can be met. First flight of this prototype is planned for August 1975.

Utility Tactical Transport Aircraft System (UTTAS).—The Utility Tactical Transport Aircraft System (UTTAS) will be the Army's first true assault lift helicopter capable of carrying an infantry squad. It is designed to lift 11 combat-equipped 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. As a result, cost effectiveness will be the primary state-of-the-art advancement achieved by the UTTAS. The UTTAS will have an increased payload over the UH–1 helicopter which will reduce the number of troop carrying helicopters that are required. The UTTAS will exhibit substantially improved maintainability, reliability, survivability, and performance. The Army awarded airframe contracts in August 1972 for a competitive fly-off. In March 1972, a contract was signed for the development and procurement of the UTTAS engine. The UTTAS development is proceeding on schedule with no major problems. The engine has accumulated over 700 hours of test cell operation.

Advanced Attack Helicopter.—Proposals in response to the Army's solicitation for bids were received from five companies. Contracts were awarded on June 22, 1973, to two companies to develop prototypes for a competitive flyoff. A stringent design to cost goal of $1.6 million (1972 dollars) average unit flyaway recurring cost in production has been established. The objective of the program is to acquire a weapon system that will significantly improve the combat effectiveness of our land forces at an affordable price.

Supporting Research and Development

Arnold Engineering Development Center (AEDC).—AEDC provides environmental simulation testing for all major aeronautical, missile, and space programs under development as well as existing operational systems problems as they evolve. DOD programs supported by AEDC include Minuteman, F–15, B–1, A–10, Trident (ULMS), Safeguard, AWACS, SRAM, SCAD, Advanced Ballistic Re-Entry System (ABRES), Lightweight Fighter, advanced transport, Poseidon, and advanced technology programs. AEDC has provided significant environmental test support for NASA on the Apollo progam and is presently planning to support the Space Shuttle program.

ARPA MAUI Optical Station (AMOS).—The objectives of AMOS are to provide radiation signatures of ballistic missiles and space objects, and to serve as a test bed for the development of optical techniques to characterize exoatmospheric objects. The Defense Advanced Research Project Agency (DARPA) Maui Observation Station has continued its optical research program using two 48-inch and one 60-inch telescopes. A variety of target measurements were made on missile targets launched at the Western Test Range and on orbiting space objects. The station provided measurements support to the early phases of the NASA Skylab program. Two new sensor systems became operational in 1973, a multicolor infrared tracking radiometer with spectral coverage from 3 to 22 microns and a high brightness ruby laser illumination system. A new computer tracking system has improved the capability of precision pointing of the large telescopes.

DARPA–501 Space Experiment.—This experiment, launched into orbit in October 1972, was designed to accomplish a survey of the radiation background in space from a 400-nautical-mile polar orbit. One of

the spectrometers continued to provide gamma ray spectra for its orbital environment through May 1973, and all five of the charged particle detectors are still operational. The experiment has successfully characterized the radiation background caused by interaction of charged particles with the satellite itself and by the processes taking place in the atmosphere under a variety of conditions.

Solar Radiation (SOLRAD) Monitoring Satellite Program.—The planned space environment monitoring and forecasting system consists of a two-satellite constellation, deployed in a 70,000 NM circular orbit, and existing ground facilities for telemetry acquisition, command, data processing, and dissemination. Each satellite, designated SOLRAD–HI (Solar Radiation-High Altitude), will be equipped with detectors sensitive to changes of solar electromagnetic (X-ray, UV) and particle (protons, solar wind) emissions. Component and subsystem design and fabrication continued, leading to a planned 1975 launch.

Environmental Remote Sensing.—The Navy has a continuing need for global environmental information to support fleet air, surface, and subsurface operations. Weather information is required for aircraft carrier operations, ship navigation, and storm evasion. Oceanographic information is needed for submarine warfare operations and for safe routing of ships. Since traditional environmental measurements from the vast ocean areas of the world are extremely sparse, airborne and satellite remote sensing techniques provide a unique means of acquiring these measurements.

The need for real-time weather data aboard ship is being met through the development of the satellite readout equipment which has been operating successfully in a feasibility status aboard ship for 2 years. The acquisition of environmental satellite data to meet the Navy's global weather and oceanographic forecasting responsibilities is being accomplished through the development of a Satellite Data Processing System co-located with the Fleet Numerical Weather Central at Monterey, Calif. This system utilizes data selectively from existing satellite systems. The hardware specifications for the system were completed in 1973. Satellite sensor technology effort is directed to the attainment of all-weather measurement of sea surface temperature, sea state, and other oceanographic parameters necessary for a complete operational capability. Airborne measurements in conjunction with Skylab as well as cooperation with NASA and NOAA in planning of experiments for GEOS C, NIMBUS–G, SEASAT–A, and GOES have complemented this development.

Composite Materials for Military Aircraft.—The Air Force program in composites continues to emphasize the use of boron/epoxy and graphite/epoxy materials. The objective is to demonstrate the advantages of composite materials through the design, fabrication, and performance evaluation of specific major structural components. Static tests of a graphite/epoxy full-scale mid and aft fuselage portion of an F–5 aircraft demonstrated weight savings of 15 percent. Satisfactory progress is being achieved in another program to demonstrate the advantages of advanced composites in a fighter-wing application. Other projects with composites are focused on reducing the costs of the basic materials and developing low cost fabrication techniques to yield a composite structure at a price per pound equivalent to metallic structures.

An Army program to fabricate and test main rotor blades for an AH–1G (COBRA) helicopter, constructed of multiple tubular spars, is underway. These blades are made of composite materials and offer a significant reduction in radar reflectivity and improved resistance to ballistic damage. Programs to fabricate such items as rotor hubs, transmission housings, and other drive train components from composite materials are in progress. Progress has permitted the design of a monocoque/sandwich aft fuselage for future tactical and utility helicopters. Preliminary conceptual designs of composite modular panels for large heavy lift helicopters indicate that advanced-composite helicopter airframe structures can provide significant system cost advantages in the 1980's. Progress has also been made in the development of composite materials for aircraft windshields.

Advanced Aircraft Propulsion.—Engineering development of the 1,500 shp Utility Tactical Transport Aircraft System (UTTAS) engine is proceeding on schedule to achieve design power. 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 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. STAGG technology will support future Army aircraft and auxiliary powerplants in the 200–1,000 shp range.

A major success of the Army's aeronautical propulsion 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 (99%) and demonstrated compliance with 1975 proposed EPA

regulations for this class of aircraft propulsion engine 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 at 74 percent thermodynamic efficiency for the 3–5 lbs/sec class of compressors. The demonstrated increase in compression results in a 20 percent or better reduction in specific fuel consumption for future small gas turbines and translates into increased range or higher payload for a specific fuel load.

Helicopter Rotor Dynamics.—Improvements in the responsiveness, efficiency, and utility of 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 parametric structural variables.

Fluidic Stabilization System for Helicopters.—Flight tests of a three-axis advanced hydrofluidic stabilization system (autopilot) were initiated in August 1973. The system is being tested on a UH–1M helicopter. Hydrofluidic controls promise improved reliability, lower cost, reduced maintenance requirements, and decreased system vulnerability over the electromechanical stabilization systems currently in use.

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 emphasized quantification of aircraft performance, weight, and far-field rotor acoustic signature for their dependency on selected design parameters. This is the first step leading to an assessment of the performance and weight trade-offs that are required to achieve noise reduction by the most promising design. The Army will be able to establish the price in performance and/or dollars of further reducing the noise of the proposed tilt-rotor aircraft. A unique test facility is well on the way to completion, and once acoustic modifications are complete, it will be available for research on basic mechanisms of rotary wing aerodynamic sound generation and their correlation with performance parameters.

Remotely Piloted Vehicles (RPV's).—The objective of the program is to produce a family of vehicles that will complement manned aircraft by performing a variety of missions where crew attrition would be high or where RPV's show cost savings without loss in effectiveness. RPV's will be developed to demonstrate a capability to perform high altitude, long endurance, relay missions, and low and medium altitude tactical missions, such as reconnaissance, target acquisition, and electronic warfare. Specific prototype developments underway on subsystems include command and control, data transmission, advanced navigation, airframes, launch, and recovery and the integration of various sensor payloads with the RPV's. Mission concepts are being refined to insure employment of RPV's in the most effective manner.

Relationship With NASA

Aeronautics and Astronautics Coordinating Board (AACB).—The AACB serves as the principal formal coordinating body between the DOD and NASA. The Board met four times over the past year concentrating on providing broad policy guidance on major problems of concern to both agencies in the field of space and aeronautics. The Board continued to support the High Reynolds Number Tunnel (HIRT), the Aeropropulsion System Test Facility (ASTF), and the Full Scale Subsonic Wind Tunnel as vital to our future national aeronautical needs. The AACB will continue to develop a total advocacy package, covering these new national facilities. The Board agreed that HIRT has the highest national priority and NASA supports the DOD in acquiring this facility for acquisition with a 1978 availability date as the first of the jointly advocated new national facilities. The NASA intermediate High Reynolds Number research facility may be included, after further AACB review, in the total national program plan on an appropriate priority basis. In the space area, the AACB undertook a review of DOD/NASA planning leading to a decision on the kind of a Shuttle upper stage that is needed and which agency should develop the upper stage. The Board cochairmen agreed that the planners of both agencies should emphasize modest upper stage approaches offering the least risk which will meet established needs. A tentative agreement was reached that the DOD will develop the initial upper stage for the Space Shuttle. This initial stage will be a modification of an existing expendable upper stage.

Space Shuttle.—Over the past year, the DOD and NASA have worked closely in their respective roles—NASA as the Shuttle developer and the DOD as an important future user of the Space Shuttle. The DOD continued to strongly support this development. Coordination and planning goals are: (1) to insure that NASA knows and understands DOD needs so that the Space Shuttle, as developed, will be of maximum

utility for military payloads; (2) to provide data essential to planning and to support decisions leading to future use of the Shuttle; (3) to fully explore ways DOD can benefit most from the Shuttle's unique capabilities; and, (4) to coordinate with NASA our Shuttle related activities with a view to the best possible use of resources available to both agencies. For planning purposes DOD has considered December 1982 as a target date for initial Shuttle launches from Vandenburg Air Force Base. In accord with the tentative agreement, the Air Force is now planning to provide the initial upper stage for use with the Space Shuttle.

Rotor Systems Research Aircraft (RSRA).—The joint Army/NASA program to develop two RSRA made significant progress in 1973. Two detailed proposals were evaluated, a winner was selected, and a contract was awarded in November for the design, fabrication, and flight test of the two RSRA. Delivery is expected in 1976. The RSRA will provide a much needed and unique capability for research on new rotor concepts, rotorcraft components and subsystems, and composite material structures on a common, fully instrumented test bed.

Tilt Rotor Research Aircraft.—The Army and NASA are jointly developing and testing a tilt-rotor research aircraft to advance the state-of-the-art of the tilt rotor concept and verify the technology base heretofore established by DOD, NASA, and the industry. The preliminary design of the research aircraft was completed in March 1972, and a contract for the fabrication and flight testing of two tilt rotor aircraft was signed in July 1973. The first flight of the aircraft is scheduled for June 1976.

Medical Projects.—Biomedical support and studies rerelated to aeronautics and space flight have been provided by the Naval Aerospace Medical Research Laboratory, Pensacola, Fla. Vectorcardiograms obtained under weightless conditions aboard Skylab are undergoing evaluation. Assessment of the nuclear emulsions used to monitor radiation exposure of Apollo and Skylab astronauts continued. Studies on the effects of very strong magnetic field and of magnetic field free environments on man and animals were completed. Improved techniques for measuring changes in electrooculogram and electroencephalogram signals as a function of motion sickness severity levels are being derived.

V Atomic Energy Commission

Introduction

The AEC's space nuclear systems program during 1973 had four major objectives; i.e., (1) to develop and provide radioisotope thermoelectric generators (RTG's) for scheduled DOD and NASA flight missions, (2) to evaluate and develop the improved and lower cost technologies required to meet the demands of projected requirements in the future, (3) to extend space technology to potential terrestrial energy applications, and (4) to continue with NASA the joint development of isotopic heat for spacecraft thermal functions. The former program emphasis which included a major effort on nuclear propulsion and reactor power systems was modified early in 1973 with the decision to discontinue the space orientation of the propulsion and reactor power programs. A small effort directed toward basic technology improvements and toward applying these space technologies to terrestrial energy related applications was continued.

Nuclear space power systems offer some unique technical characteristics which make them mandatory in some space missions and advantageous in many others. They are not dependent upon the sun as a source of energy; are relatively resistant to external radiation; and are relatively unaffected by harsh or hostile environments. Thus, outer planetary missions, where sunlight is scarce or where hostile environments will be encountered, will require nuclear systems. In addition, those earth-oriented missions which have a strong requirement for radiation resistance, environmental independence or freedom from orbital constraints can best be satisfied through the use of nuclear energy. Over the past decade, 16-isotopic-powered RTG systems have been launched and 6 more are scheduled during the next 4 years.

Space Electric Power

SNAP-27/ALSEP.—The five SNAP-27 radioisotope thermoelectric generators (RTG's) placed on the lunar surface by the Apollo astronauts continued to operate in excess of design requirements throughout the year. The first unit has now been in continuous operation for over 4 years. The design goal was a minimum of 63 watts after 1 year and all five generators have now surpassed that goal.

Transit RTG.—The RTG used in the Navy Transit Navigation Satellite, launched in September 1972, continued operating throughout the year. The design power is 30 watts after 5 years and, based on indirect measurements, the RTG power level appears to be in accordance with design expectations.

Jupiter Spacecraft.—On April 5, 1973, the Pioneer 11 spacecraft was launched on its long journey to fly by the planet Jupiter. Like its predecessor, Pioneer 10, it is powered by four Pu–238 isotopically fueled thermoelectric generators. Each generator is designed to provide a minimum of 30 watts or a total of 120 watts of electrical power during the spacecraft's nearly 2-year, 500-million-mile journey and flyby of the big planet.

Pioneer 10 fulfilled its basic mission objectives when it passed by Jupiter in early December of this year. It provided the power by which man's first close-range scientific observations of this important planet were made and has contributed significantly to the understanding of our solar system. As of the end of 1973, the spacecraft was 25 million miles beyond Jupiter and still functioning. The long life capability of the generators should allow the spacecraft to continue transmitting information back to Earth on the nature of the heliosphere for several years as it proceeds on its journey through the solar system and eventually on out into interstellar space.

Pioneer 11 has completed approximately one half of its journey and is scheduled to reach Jupiter in late 1974. The generators are currently operating within design expectations and should continue to operate well past Jupiter. If appropriate, the mission trajectory may be altered to extend its mission course to fly by the planet Saturn.

Viking Mars Lander.—The two Viking Mars Lander missions scheduled for launch during the summer of 1975 are also scheduled to use Pioneer-type isotopic generators. Two generators will be required for each of the lander missions. Final modifications were made

during 1973 to adapt the generator design to the Martian environment and to meet the slightly higher power requirements of the lander missions, i.e., a minimum of 35 watts per generator or a total of 70 watts after 2 years. Two electrically heated engineering generators were fabricated and delivered to NASA in mid-1973 for integration testing. A prototype set of isotopically fueled generators was also fabricated, tested, and delivered.

Multihundred Watt (MHW) Flight Missions—LES 8/9 and MJS.—For several years, the AEC has been developing a higher powered, multihundred watt (MHW) isotopically fueled thermoelectric generator. This system will be flown for the first time in early 1975 as the sole power supply for the DOD's Lincoln Experimental Satellite (LES 8/9). Then, in 1977 this same system, adapted to outer planetary environments, will be used as the power supply for the two Mariner Jupiter/Saturn (MJS) spacecrafts scheduled for launch in that year.

During 1973, the program was concentrated on the LES 8/9 mission. The design of the basic generator system was completed and qualification testing of the generator and isotopic heat source was initiated. Fabrication of the flight units for the LES program began during the latter part of the year. The basic generator is a modular unit designed to provide a minimum of 125 watts of electrical power after 5 years of continuous operation. Higher power levels are achieved by using multiple units. The LES program will use two generators for 250 watts and the MJS program will require three for nearly 400 watts. A separate contract is currently being negotiated for the efforts associated with the Mariner Jupiter/Saturn mission.

Low-Cost, High-Performance Generator Technology.—Future mission projections show a continuing need for radioisotope systems through the 1970's and on into the 1980's. Currently, the two major mission categories are the DOD's SURVSATCOM satellite network and NASA's continuing outer planetary exporation program. Both categories could require many systems for multiple launches. However, performance and cost requirements for the nuclear power system are significantly more stringent than those imposed on current systems. The SURVSATCOM goals are a reduction in costs by a factor of 4 to 5 and a significant reduction in weight. Decreased cost and significant reduction in weight are also important in the outer planetary missions where mission viability will become increasingly cost oriented and where total spacecraft weight is restricted by the overall booster capability.

To meet these increased performance criteria, effort was initiated in 1973 on a low-cost, high-performance generator technology. The goal will be selection of a reference system design by mid-1976 with development completed by the late 1970's. Studies were conducted during 1973, under DOD funding, to identify the performance potential of various technologies and to provide a basis for selection of those heat source and converter technologies which should receive emphasis in 1974.

Reactor Program Termination.—Early in 1973, the decision was made to discontinue the space-oriented reactor power system development efforts. The programs affected were the thermionic reactor development effort for high-power space systems and the Zirconium-Hydride/Compact Converter reactor thermoelectric efforts for medium power systems. Both programs were joint AEC/NASA sponsored efforts.

The thermionic reactor development efforts were phased out by the middle of the year except for a low level of effort on basic thermionic conversion technology. This effort is directed toward applying the principles of thermionic conversion which has good potential for application to terrestrial energy related uses such as topping cycles for electric generating plants or remote location power supplies. Laboratory type experiments were carried out during the year to verify the feasibility of the theoretical performance improvements which are required if such a technology is to have any real terrestrial application potential.

The Zirconium-Hydride/Compact Converter reactor thermoelectric efforts were reduced to a minimum level pending an evaluation of the potential future DOD needs for nuclear power systems. A skeleton technical capability was maintained. This would allow the program to be restarted at a minimal cost should such a need be identified. The joint DOD/AEC study to assess the future DOD needs began in the middle of the year and is scheduled for completion early in 1974.

Nuclear Propulsion Program Termination

With the termination of the NERVA program in 1972, the continuing nuclear propulsion efforts had been centered at the AEC's Los Alamos Scientific Laboratory in New Mexico and the Nuclear Rocket Development Station in Nevada. Early in 1973, the decision was made to discontinue all space-oriented nuclear propulsion development efforts and the programs at these two locations were phased out by the middle of the year. Facilities were deactivated and any usable equipment was transferred to other Federal programs. The essential technology accomplishments were preserved through appropriate documentation and/or storage of reports and records in Federal record centers.

A low level of effort was authorized late in the year to evaluate the potential of applying nuclear rocket reactor technology to terrestrial energy related applications; e.g., thermochemical hydrogen production or

process heat applications such as coal gasification or liquefaction. The effort includes both basic technical and systems feasibility studies.

Isotopic Heat for Spacecraft Thermal Functions

The Atomic Energy Commission and the National Aeronautics and Space Administration have been involved in a joint effort for the past several years utilizing isotopic heat for spacecraft operations. The following joint effort projects were underway during 1973:

Pioneer 11 Jupiter Spacecraft.—Twelve, one-watt heaters were utilized on the Pioneer 11 spacecraft, launched in 1973, to heat the guidance system, sun sensor and magnetometer from the outer space extreme cold.

Waste Management Water Recovery Life Support System for Spacecraft.—This four-man system was tested for 180 days utilizing isotopic heat for the thermal input to the process. This system provides drinking water recovery from urine condensate and wash water. It also disposes of all nonmetal trash and human waste.

Trace Contaminate Removal Catalytic Oxidizer.—Isotopic heat is used in this system to remove trace contaminate gases from spacecraft cabin atmosphere. This system would be used by manned spacecraft in longer duration missions.

VI Department of State

Introduction

Growth of international space cooperation in support of foreign policy objectives and the National Aeronautics and Space Act was a matter of high priority to the Department of State during 1973. Attention continued to be focused both on expanded cooperation with individual countries and on space endeavors with multilateral and international organizations.

Major achievements of the year were the finalization and conclusion of an agreement with nine European countries for the development in Europe of a laboratory module to be used in conjunction with the U.S. Space Shuttle System, and the increased cooperative activity with the U.S.S.R. pursuant to the Summit Agreement of May 24, 1972, in space science and applications, and the Joint Apollo/Soyuz Test Project. Other areas of interest were international cooperation in communications satellite systems, ratification of the Outer Space Liability Convention, and an expansion of interest and activities in Earth resources satellite programs.

Activities Within the United Nations

The United States continued to play a leading role in the United Nations Committee on the Peaceful Uses of Outer Space and its subsidiary organs, giving substantial support to the U.N. program of information and promotion concerning space technology applications and participating actively in the further development of international law applicable to outer space. In this connection, with the deposit of instruments of ratification by the United States, United Kingdom, and U.S.S.R. on October 9, the Outer Space Liability Convention entered into force for the three countries.

Working Group on Remote Sensing.—The achievements of ERTS–1, the experimental satellite designed to survey Earth resources and the environment launched in July 1972, have been warmly applauded by the international community. Nevertheless, the very success of ERTS–1 stimulated concerns among some countries that this new technology may become a threat to national control over natural resources. Growing demands for an international review of the legal aspects of remote sensing from space of Earth resources are a reflection of these concerns. The U.S.S.R. and France have both drafted legal principles that might apply to this new technology.

At its first substantive session (January 29–February 10, 1973) the Working Group on Remote Sensing of the Earth by Satellites pursued its assigned examination of various international aspects of the developing remote sensing technology. In so doing, the Group took into account the initial results of the mission of ERTS–1. The group expressed appreciation for the broad international participation in the ERTS–1 and, prospectively, the EREP (Skylab) and ERTS–B programs. Contributing to a realistic appraisal of current state of the art, senior NASA officials presented an extensive technical briefing. The Working Group session was highlighted by the United States offer to provide a master copy of all data derived from our experimental satellite remote sensing program to a U.N. international distribution facility should one be established. A central element in the Group's subsequent work is to be a study of possible alternative modes of international remote sensing data dissemination, taking account of the United States offer.

Scientific and Technical Subcommittee.—The United States played a major role in the proceedings of the subcommittee which were focused on the U.N. space applications program and the report of the Working Group on Remote Sensing. The American position remained in favor of the broadest possible international cooperation in the peaceful uses of outer space. This position manifested itself, inter alia, in our support for continuation of the program of panels and regional seminars carried on by the U.S. Experts on Space Applications, as well as our posture on further work of the Remote Sensing Working Group.

Working Group on Direct Broadcast Satellites (DBS).—The DBS Working Group was convened for the first time in 3 years to consider new developments, both technical and political-legal, in the broadcast satellite field since its last session in 1970. Considering

that the Working Group could not perform its mandate without up-to-date information on the current and the prospective state of the art, the United States provided the Group with a detailed technical briefing early in the session. Many members of the Working Group, nevertheless, proved more concerned with political-legal implications of developing DBS technology. Following up on its initiative at the 1972 U.N. General Assembly, the U.S.S.R. asserted the necessity of internationally binding rules governing DBS. Other countries, led by Sweden and Canada, advocated consideration of agreed principles. The United States maintained that endorsement of the need for either a treaty or principles would be premature in light of the developmental stage of direct broadcast technology, cautioning that in any future consideration of the issue, concerns over protecting against possible unwelcome transmissions must be very carefully weighed against the importance of maintaining the free exchange of information and ideas. The Working Group took no action in this area, but recommended reconvening in spring 1974, primarily to reconsider political-legal aspects of DBS while continuing to take technical and economic factors into account. This recommendation ultimately was approved by the General Assembly.

Legal Subcommittee.—Legal Subcommittee negotiators failed to reach agreement on pending treaties on exploration and use of the Moon and registration of objects launched into outer space. However, major progress was achieved on the latter. The United States made an important contribution by submitting its own draft registration treaty. Noting previous U.S. reservations toward a registration treaty, Canada, together with France a cosponsor of the earlier draft, called the U.S. move "an act of international enlightenment." The U.S. draft, along with a modified French-Canadian text, became the basis for negotiation. Efforts at accommodation of remaining differences in the parent Outer Space Committee came very near to success. However, disagreement persisted over a provision requiring external marking of space objects by the launching state. We maintained that such a provision could not be justified on technical and economic grounds and would not contribute to the identification of an object which might return to Earth and cause damage.

In contrast to registration, less progress was achieved on a Moon treaty. The three major outstanding issues—expansion of treaty scope to cover the other bodies of the Solar System, provision for advance notification of missions, and provisions concerning possible future exploitation of natural resources of celestial bodies—remained unresolved. The resources question proved the most intractable. The United States demanded a provision against a moratorium on resource exploitation pending establishment of an international regime governing such exploitation. A group of developing countries, apparently fearing possible implications for resource exploitation in other environments, especially the deep seabeds, insisted on an explicit moratorium provision. Despite intensive negotiations in the Outer Space Committee, the question remained at an impasse.

Outer Space Committee.—Besides carrying on the negotiations mentioned above, the Outer Space Committee considered and approved the reports of its subsidiary bodies, including recommendations regarding their future work, and endorsed these to the General Assembly for final approval. One element of contention arose concerning priorities for the Legal Subcommittee—the United States prevailed in its support to giving highest priority to efforts at completing the registration and Moon treaties. The U.S.S.R. attempted to gain higher or equal priority for legal implications of direct broadcast satellites, but eventually settled for a priority lower than that for the unfinished treaties. The Subcommittee was also to reserve some time for considering the legal aspects of remote sensing.

General Assembly.—The General Assembly had on its agenda the Outer Space Committee report and the question of a convention to govern international direct television broadcasting by satellites (a carryover from a 1972 Soviet initiative). Inasmuch as the Outer Space Committee's report contained a recommendation for its future work affecting the latter question, a single resolution, cosponsored by the U.S., was tabled covering both topics and approving the recommendation. The resolution was adopted by a wide margin. The U.S.S.R. and its allies abstained, principally because the resolution also called for expanding the Outer Space Committee in a manner reflecting the changes in UN membership since the Committee's establishment in 1961, particularly the need for greater developing country representation. The U.S.S.R. maintained that the question of Committee enlargement had not been studied adequately. In our view, the relatively modest expansion from 28 to 37 members entailed in the resolution would permit the Committee to continue its previous effective operation on the basis of consensus.

International Cooperation

Cooperation With Europe.—In August and September 1973, after 4 years of discussion, the United States and nine members of the European Space Research Organization (ESRO)—Belgium, Denmark, France, Germany, Italy, The Netherlands, Spain, Switzerland, and the United Kingdom—signed an agreement providing for European development of a space laboratory to be used in conjunction with the U.S. Space Shuttle System. The space laboratory will consist of a pres-

surized module, in which scientists can perform experiments in a shirt sleeve environment and an unpressurized instrument pallet or platform. The lab will remain attached to the Shuttle during orbital missions and like the Shuttle, will be reusable. The space laboratory will cost between $300 and $400 million, making it one of the most important cooperative programs in which the United States has been involved. Agreement among the European participants to develop the space laboratory as joint endeavor was made possible by a decision taken in the European Space Conference (ESC) to undertake two other operational projects; the L3S launcher, and a maritime satellite (MAROTS), and to form a single European Space Agency.

On September 24, a joint State Department/European Space Conference communique was signed marking the completion of arrangements to bring the agreement into force. At the same time NASA and ESRO signed a Memorandum of Understanding between the two implementing agencies. In remarks delivered at the signing ceremony the United States cited agreement as a "major cooperative understanding between the United States of America and Europe," and said it would "add a new dimension to Atlantic partnership."

On January 17, 1973, the United States and the United Kingdom concluded an agreement providing for United Kingdom access to United States space launch capabilities on a reimursable basis. Under the agreement, the United Kingdom Department of Trade and Industry (DTI) will purchase appropriate boosters and launching services from NASA for satellite projects undertaken by DTI. This was the first agreement concluded pursuant to the U.S. Launch Assistance Policy of October 9, 1972.

During 1973, NASA signed a cooperative agreement with Italy for a 1974 launch from the San Marco launch facility in Kenya and a reimbursable agreement with Germany for a launch of a second AEROS satellite in 1974.

NASA discussions were held with France, Germany, and ESRO on a variety of reimbursable missions for which launch contracts are expected early next year.

Cooperative sounding rocket campaigns with European countries continued in 1973. The Department provided assistance as NASA concluded agreements with Germany, The Netherlands, Norway, and Sweden for sounding rocket projects.

Cooperation with Japan.—Space cooperation between the United States and Japan during 1973 was dominated by an increased 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 launch starting in 1975.

Cooperation with the Soviet Union.—Joint NASA/Soviet Academy of Sciences Working Groups continued to implement the 1972 U.S./U.S.S.R. Space Cooperation Agreement, which provides for a joint experimental flight in 1975 to test compatible rendezvous and docking systems, and for cooperation in space science and applications.

At the midterm review of the Apollo/Soyuz test project, held in October, both parties reported that all independent and joint working group activities were on schedule.

In the space science and applications areas there has been a continuing exchange of operational and scientific weather data, coordinated oceanological studies, a joint experiment in coordinated microwave measurements in the Bering Sea, efforts to define projects in the study of the natural environment, interplanetary data exchanges, physiological data obtained from manned space flight exchanges, lunar sample scientist visits, and a joint meeting of lunar cartographic experts to consider basic principles for compiling lunar maps.

Technology Transfer.—In 1973 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. They consist of an Intergovernmental Agreement and an Operating Agreement. The U.S. Government is a party to the former, and designated the Communications Satellite Corp. (ComSat), a U.S. company, to be its signatory to the latter. Under the definitive agreements, INTELSAT has a structure consisting of an Assembly of Parties, a Meeting of Signatories, a Board of Governors and an Executive Organ responsible to the Board of Governors. The first meeting of the Assembly of Parties will be held in February 1974. ComSat participated in the first meeting of the Meeting of Signatories in November 1973, and represented the United States at the bimonthly meetings of the Board of Governors.

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The Board of Governors selected a Chilean national to be Secretary General with responsibility for 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. INTELSAT's capital is divided among the 84 signatories according to their percentage use of the INTELSAT system. ComSat held about 40 percent of the capitalization as of December 31, 1973.

On December 31, 1973, there were 68 INTELSAT Earth stations operating in 52 countries. In August 1973, the fifth satellite in the INTELSAT IV series was launched thus adding substantial capacity to the global communications converge. 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 1974 of at least two more satellites in the INTELSAT IV series, and during 1975 by the launch of the first of two or three planned 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 1973 initial system design work was undertaken for the introduction in 1978 of the even larger INTELSAT V satellites.

On April 20, NASA launched ANIK–2, the second Canadian operational domestic communications satellite.

Earth Resources Survey Program.—ERTS–1, the first satellite dedicated entirely to the survey of Earth resources from space, was launched on July 23, 1972. The initial results from the ERTS experiment are encouraging, and the reports on its performance before various U.N. committees have been well received.

Experiments from 38 foreign nations and two international organizations are included in ERTS–1. Our remote sensing agreement with Brazil was extended on April 6, 1973, until April 1, 1976. Brazil is constructing their own ERTS receiving station under arrangements covered by a Memorandum of Understanding between NASA and the Brazilian Space Research Institute. NASA also accepted a large number of foreign Earth resources experiment proposals for Skylab, the manned space laboratory which had three manned missions in 1973.

Aeronautical Satellites.—Since the late 1960's the United States has been negotiating with the European Space Research Organization and Canada on a proposed experimental aeronautical communications satellite system (AEROSAT) to test the use of this communications mode of international aviation purposes. These negotiations reached a final stage in 1973, which may result in the launching of two satellites over the Atlantic Ocean in the late 1970's. It is thought that an operational system, which could be particularly useful for air traffic control and company communications over the North Atlantic, 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 1973 in the efforts of the Inter-Governmental Maritime Consultative Organization (IMCO) to consider how a maritime communications satellite capability might be developed and implemented. Further discussions will be held in 1974.

Support to Federal Agencies

NASA Spaceflight Support.—The Department and its posts overseas continued in 1973 to support NASA-manned space flight missions, by arranging for the basing of recovery, tracking and other mobile support forces at foreign installations for Skylab missions I–IV.

NASA tracking station agreements were renewed with Canada, the Malagasy Republic and Spain (for use of the Canary Islands). An agreement for use of an airfield in Mauritius was terminated and plans were announced for the closure of the South Africa stations.

Facilities of the Department continued to support NASA's lunar sample investigation program by transporting and handling lunar samples consigned to foreign scientists.

Cooperation with the Department of Defense.—During 1973 the Department of State continued to work closely with the Department of Defense on various military space issues having international implications.

VII Department of Transportation

Introduction

The Department of Transportation (DOT) is charged to assure the coordinated and effective administration of the transportation programs of the Federal Government that are designed to encourage the provision of fast, safe, efficient, and convenient transportation by private enterprise to the maximum extent feasible. DOT must identify transportation problems and assist with their solution; one technique that it uses is to stimulate and sponsor technological advances in transportation. Recognizing that aerospace research and development have contributed to solution of transportation problems and can continue to assist in the solution of urban and interurban transportation problems, the Department has encouraged and supported the use of applicable aerospace technology in the design of personal rapid transit systems, high speed ground vehicles, computer-controlled urban traffic systems, and other new and promising applications.

The Federal Aviation Administration (FAA) conducts the majority of the DOT programs related to aerospace. Its functions relate only to aviation, including promotion of aviation safety and of civil aviation, development and operation of a system of air traffic control, certification of pilots and equipment, a nationwide system of airports, and similar activities.

One of FAA's chief concerns is the modernization of the airspace system, including both air traffic control facilities and the flight service stations. During the last year, installation was completed of 60 automated radar terminal systems at the Nation's busiest terminal areas. Twenty air route traffic control centers have also been automated, supplying computerized flight data processing capability over the entire country.

A study recommended the modernization of flight service stations, proposing a system of about 25–50 manned stations, operating in conjunction with about 3,500 pilot briefing terminals to supply weather information and other data to pilots.

Aernoautical satellites have great potential for use in air traffic control as well as for keeping track of ships at sea. Complex international arrangements are being made to facilitate operation and use of such systems when they become available.

Other concepts and systems to facilitate air traffic and its control include microwave landing systems, intermittent positive control to assure adequate separation between aircraft, and the area naviation system.

Aviation safety is the most conspicuous and perhaps the most significant of FAA's responsibilities. Two devices to avoid midair collisions are being investigated—the proximity warning indicator and the collision avoidance system, a more sophisticated proximity warning system—but FAA will continue its ground-based air traffic control system. The phenomenon of wake vortexes is a very serious threat to aviation; intensive studies are being made to eliminate or control the threat. Aircraft, like other forms of transportation, can also be sources of pollution. Both noise pollution and air pollution result from operation of aircraft, and particularly of aircraft engines. FAA's programs are developing techniques to avoid both kinds of pollution; when they are available, FAA will require their use by appropriate regulation. Both types of control require coordination of studies—intragovernmental coordination for noise suppression programs and international coordination for evaluation of impacts upon climate resulting from the operation of fleets of high-flying jets.

Air Traffic Control and Navigation

The major DOT aeronautical activity has been the development and operation of the National Airspace System (NAS) by means of which the Federal Aviation Administration (FAA) provides air traffic control services and flight services to both military and civilian aircraft throughout the United States to help achieve the efficient use of airspace, and to prevent collisions.

National Airspace System Modernization.—Because the number of aircraft, flights, and passengers has continued to increase, it has been necessary for FAA to modify and improve its air traffic control system almost continuously to prevent or minimize the ill effects of system overload: Congestion at the major terminals, delays in landings, fuel wastage when planes

are required to delay in traffic patterns before landing, and additional pollution from planes circling airports in holding patterns.

In recent years the primary thrust of this modernization effort has been implementation of two-semiautomatic air traffic control systems which had been in the planning and implementation stages almost since 1961 when the President authorized implementation of the two systems:

- Automated Radar Terminal System (ARTS) III, for introduction at 61 of the Nation's busiest terminal areas.
- National Airspace System (NAS) En Route Stage A, for introduction at 20 air-route traffic control centers (ARTCC's) in the contiguous 48 States.

Calendar year 1973 saw FAA's terminal area automation program reach a significant milestone. By year's end, 60 ARTS III systems had been delivered to designated terminal locations. The 61st and last system, planned for the San Francisco-Oakland area, was placed in storage; 55 were in full operational use at the end of the reporting period; the remaining 5 were undergoing final operational shakedown testing.

Unlike ARTS III, which is going operational as a complete system at each designated site, NAS En Route Stage A is being installed and implemented in two phases. The first phase, which is essentially complete, provides automatic flight data processing and interfacility data transfer. The second phase provides digital radar displays and radar data processing. At the end of the calendar year, all 20 ARTCC's had a computerized flight data processing capability. The computer updating equipment used at these centers facilitates communication between the controller and the automated system.

As to software, 17 centers were operating under a version of the NAS En Route Stage A program. The Miami and Salt Lake City centers were using an interim software program designed for a single computer. The Jacksonville center was operating under another and earlier interim software program.

In addition to these two major automation programs, FAA continued to test a prototype ARTS II system for terminal areas that do not have the traffic density to qualify for ARTS III. During the calendar year, a prototype ARTS II system was evaluated at the Wilkes-Barre, Pa., terminal radar approach control cab. The results of this evaluation enabled FAA to determine the final specifications for the ARTS II production model.

Flight Service Station Modernization.—Unlike the air traffic control system, which is reaping the benefits of automation and computer technology, FAA's flight service station (FSS) system has not taken advantage of the latest technological developments. In consequence, the FSS system is not as efficient as it might be.

During the calendar year, a team composed of FAA and Office of the Secretary personnel, which had been formed to study and recommend ways of modernizing the FSS system, proposed that the current system of 250 manned flight service stations be replaced by:

- A hard core of between 20 and 50 manned, large-hub flight service stations, and
- Approximately 3,500 pilot briefing terminals located at approximately 2,500 airports.

These briefing terminals, each linked to one of the 20 or more hub stations, would utilize a cathode-ray tube display coupled to computer inputs that would permit automatic filing of flight plans and provide individually tailored reports and other data. Pilots would simply punch a few keys to send their flight plans directly to a central computer processing facility, which would store and retrieve information. Almost instantaneously, pilots would receive on the cathode tube display en route weather, Notices to Airmen (NOTAM), and additional information that could affect their flight.

At the large-hub stations, flight service specialists would:

- Handle ground-to-air radio traffic.
- Provide preflight briefings and file flight plans for pilots without access to automated terminals.
- Give emergency flight assistance.
- Monitor navigational aids.

The proposed system would have a number of significant advantages over the current system. Specifically, it would:

- Be considerably cheaper to operate.
- Give pilots a direct link to the information they need.
- Provide pilots greater access to briefing materials.
- Tailor information more to the specific needs of individual pilots.
- Provide more up-to-date weather reporting.
- Do all the recordkeeping by computer, thus eliminating paperwork and clerical chores.
- Free the flight service specialist to concentrate on providing faster and better in-flight assistance.

Testing of the automated Aviation Weather and NOTAM system in an operational environment is scheduled to begin at a single site during calendar 1974. Present plans look to the nationwide implementation of the new system over a 10-year period.

Advanced Air Traffic Management.—The Advanced Air Traffic Management System (AATMS) study is investigating new concepts for air traffic management for application in the post-1985 period that can meet

the air traffic demands of that era. The study builds upon the work of the DOT Air Traffic Control Advisory Committee in 1969. The earlier study described concepts and system definition studies were performed to help identify future research needs. Promising candidate concepts include: Satellites for surveillance, communication, and navigation; greatly expanded use of automation in the ground-based control functions, and utilization of integrated wave form techniques for signal transmission as a means to minimize the complexity and cost of aircraft equipment.

A direct tie-in is being made with FAA work to upgrade the air traffic control system by defining potential means for further extending its capabilities through 1985 and beyond as a part of the AATMS study. The results of these studies are expected to be a basis for FAA Air Traffic Control R. & D. Planning for fiscal year 1975 and later.

Other ATC Developments.—Other FAA research and development activities in air traffic control and navigation included:

Electronic Voice Switching Systems.—This program is designed to provide both air traffic control centers and certain large control tower facilities with the latest in telephone-switching technology. Such electronic switching systems would reduce the cost of communications while increasing air traffic control efficiency. The greater efficiency offered by electronic voice switching would be achieved by: (1) Increasing the speed of establishing communication between controllers, (2) reducing out-of-service time resulting from equipment failures, (3) acquiring increased system flexibility in rearranging existing services and adding new ones, and (4) improving maintenance communications.

Microwave Landing System (MLS).—This system, whose development was recommended by DOT's Air Traffic Control Advisory Committee in March 1970, is regarded as a key element in FAA's Upgraded Third Generation ATC System, which is expected to come into use in the 1980's. The system's development and implementation is proceeding in accordance with the 5-year schedule established by an interagency Governmental committee. The first phase of the MLS program, to provide technique analysis and contract definition, was completed this calendar year. The second phase, scheduled for completion during the first quarter of calendar 1974, is a feasibility demonstration involving four contractors and two competing techniques. At the end of this phase, one of the two techniques will be chosen and carried into prototype development.

Intermittent Positive Control (IPC).—This concept was developed by the Air Traffic Control Advisory Committee to provide automatic safety separation service. The new service would automatically separate Visual Flight Rules (VFR) aircraft flying within radar surveillance coverage whenever a potential for collision exists between them and other VFR or Instrument Flight Rules (IFR) aircraft. During the calendar year, the basic IPC concept-analysis and simulation-development activities were carried out. This resulted in defining the IPC system that will serve as the basis for continued development and testing activities, which will begin in the spring of 1974 in accordance with a plan developed during this reporting period. Simulation studies will also be conducted to assure that IPC logic will not interfere with the operation of the ATC system in high density terminal areas.

Discrete Address Beacon System (DABS).—This is an improved air-traffic control beacon system that will allow ground equipment to interrogate, and discriminate between, responses from specific aircraft of interest. It will also significantly reduce interference and provide a data link that could be used with a ground-based anticollision system. During the reporting period, an experimental facility for DABS was completed and testing begun. Test results are being used to develop specifications for a test-bed DABS model. At year's end, procurement was expected to begin in early 1975.

Area Navigation.—This recently implemented system of aerial navigation has a decided flexibility advantage over the VOR/DME (very high frequency omnidirectional radio range/distance measuring equipment) system in use today, because it permits establishing routes without deploying additional ground-based navigation aids along each route by utilizing the existing VOR/DME stations. Area navigation was officially launched in the United States on April 29, 1971, when FAA established four transcontinental high-altitude area navigation routes between New York City and the west coast. The area navigation capability has been available and evaluated since the late forties using commercially built airborne equipment of varying degrees of sophistication. Problems associated with transitioning from the present route structure to a much more efficient structure, made possible using area navigation, have delayed its implementation. As a result, a joint FAA-aviation industry task force was established to define problem areas and develop solutions. FAA circulated the task force's report to the aviation industry for comments in February 1973. At year's end, a policy statement was being prepared for release. Meanwhile, the FAA was proceeding to validate the task force's concepts, resolve problem areas, define airborne equipment characteristics, and quantify the system's benefits.

Use of Satellites in Air and Water Traffic Control

Aeronautical Satellite (Aerosat).—An aeronautical satellite system would further extend the capability of FAA in Air Traffic Control. Although such a system is not now in existence, extensive plans have been in preparation. An aeronautical satellite system serving aircraft flying transoceanic routes would have significant advantages over the present transoceanic air traffic control and communications system. Such a system would:

- Make new and less-congested communications channels available to overwater traffic. (The high frequency band now used on transoceanic routes is becoming increasingly cluttered by the growing number of international overocean flights and is expected to reach the saturation point by the end of the decade.)
- Improve the reliability of point-to-point communications. (Today's system suffers from fading, static, and other interference, often causing aircraft to lose radio contact with distant ground stations.)
- Reduce aircraft separation standards—and thus increase overocean route capacity—by allowing air traffic controllers to monitor and pinpoint the location of ocean-crossing aircraft. (The lack of reliable point-to-point communication in today's system, which makes ATC surveillance of transoceanic flights impossible, has imposed flight separation requirements over water that far exceed those in use over land and has thus severely limited the capacity of overwater air corridors.)

During the calendar year, Congress approved an administration request for $2.7 million for Aerosat research. At the same time, the United States, the European Space Research Organization (ERSO), and Canada were engaged in working out a final Memorandum of Understanding for launching the international program. While awaiting the signing of this agreement, the Department of Transportation and NASA were readying ground and flight equipment for a joint-test program that will utilize the ATS–F Satellite, scheduled for an April 1974 launching.

Aerosat Program Activities.—Another in the series of international meetings on the Aerosat program was held at Ottawa, Canada, during January 1973. At that meeting general agreement was reached on a Memorandum of Understanding and a technical specification for a joint program. During hearings before Senator Cannon's Aviation Subcommittee (March 1973) and Congressman McFall's Transportation Subcommittee (April 1973), the substance of this joint international program was presented by DOT/FAA. The U.S. air carriers, represented by the Air Transport Association, actively opposed the program. As a result, Congressional approval was withheld pending a resolution of the disagreement between DOT/FAA and the airlines. After extensive negotiations which resulted in some restructuring of the program, formal agreement was reached with the airlines on the revised program; it was documented through an exchange of correspondence in July 1973, and immediately transmitted to Congressman McFall's and Senator Byrd's Subcommittees on Transportation. As a result, congressional approval to release the revised U.S. position to the European and Canadian participants was authorized. This approval was subject to the condition that prior to signing any formal agreement, the Department of Transportation must make a formal presentation to both the Senate and House Appropriation Committees. The resulting U.S. proposal for the Aerosat program was formally transmitted to the European participants and Canada at a meeting in Madrid, Spain, in late July 1973. One portion of a U.S. proposal involved only Canada and the United States and agreement on this aspect was consummated in late August 1973.

In addition to Aerosat activities, extensive planning and development of a program has continued for experimentation with NASA's ATS–F satellite. At NASA's request, DOT agreed to take the lead in developing an integrated test plan for aeronautical and maritime experimentation to be conducted by FAA, USCG, and the Transportation Systems Center (TSC), as well as the Maritime Administration, NASA, Canada, and the ESRO. This integrated test plan was completed and approved by NASA in early November 1973, with the ATS–F scheduled for launch in April 1974 and experimentation planned for May/June 1974.

Maritime Satellite (MARSAT).—Closely related to Aerosat in concept is a similar system using satellites to monitor ships' activity (MARSAT). Two meetings of the Panel of Experts on Maritime Satellites were held in 1973. The activity centered primarily on institutional arrangements and technical parameters. The panel continued to review and up-date a Draft Convention for the Establishment of a Maritime Satellite System, with most of the discussion to date focusing on the creation of a new Intergovernmental Organization to implement the system. An international conference has been scheduled for February–March 1975, under the auspices of the Intergovernmental Maritime Consultive Organization (IMCO), to provide a forum for intergovernmental negotiation of the convention. On the technical side, a summary of parameters for a maritime satellite system has been developed. This concept assumes that satellite dedicated specifically to this purpose will be used. Using this approach, a "first-

cut" cost estimate of the dedicated system was calculated. This will be refined in the later work of the panel of which two additional meetings have been scheduled for 1974, and intensive economic studies will assess the commercial viability of the system. The goal of the panel remains the preparation of a detailed report covering the organizational, technical, economic, and operational aspects of a maritime satellite system, which would be submitted to the 1975 conference to serve as the basis of its discussion.

Aviation Safety Research and Development

Midair-Collision Avoidance.—FAA is firmly committed to the premise that its ground-based air traffic control system is, and will be for the foreseeable future, the primary collision-avoidance system in the United States. FAA recognizes, however, that it has a responsibility to investigate, evaluate, and implement all collision-avoidance techniques—provided they: (1) Enhance the system's overall safety, (2) are compatible with the ground-based ATC system, (3) are in the interest of all airspace users, and (4) can be made economically attractive.

Presently, two air-to-air collision-avoidance systems are at the center of the Government's and the aviation industry's attention:

- Proximity Warning Indicator (PWI). This device helps the pilot visually locate any aircraft posing a threat or a potential threat of collision with his own aircraft, after which the pilot himself must evaluate the situation and determine his proper response.
- Collision-Avoidance System (CAS). This system is technologically more sophisticated than the PWI. It detects all potential dangerous intruders in the airspace, evaluates the degree of danger, and, if necessary, indicates to the pilot in time for safe execution the proper avoidance maneuver.

With no airborne CAS or PWI system presently operational, the main thrust of FAA's air-to-air collision-avoidance program is to consider objectively all feasible alternatives to reducing and/or eliminating the threat of midair collisions. This program has been closely planned and coordinated with the Department of Defense and NASA. Though a number of hard technical, practical, and economic problems remain to be resolved, these joint FAA–DOD–NASA efforts are moving ahead rapidly on a broad front: Competing CAS systems are being tested and evaluated; PWI operational and system requirements are being refined; the compatibility of evolving airborne CAS and PWI systems with the ground-based ATC system is being evaluated.

Meanwhile, the capability of ground-based systems to assure safe separation will be developed and implemented as rapidly as possible through increased use of regulatory measures, the augmentation of ARTS III and NAS En Route Stage A software programs, and the development of intermittent positive control and discrete address beacon systems.

Wake Turbulence.—Vortexes hazardous to smaller aircraft form in the wake of large aircraft. This phenomenon has posed a potential threat to safety. It has also had the effect of restricting airspace capacity. Accordingly, FAA has been vigorously pursuing a full-scale program aimed at reducing both the hazards posed by this phenomenon and its capacity-restrictive effects.

Wake vortex data collection sites have been established at two major airports. At year's end, a third site was expected to be established at Heathrow Airport in the United Kingdom. Concurrent efforts were also underway to define more fully the hazards experienced by aircraft when approaching, or penetrating, the vortex of another aircraft. The aim of these concurrent efforts is to develop a Wake Vortex Avoidance System, which will establish safe airspace spacings as a function of: (1) the life and transport of vortices under various meterological conditions, and (2) the actual hazard they present to encountering aircraft.

Other Safety Programs.—FAA continued to pursue a variety of other aviation safety programs. In the area of aircraft safety, it continued to demonstrate the technical, operational, and economic feasibility of safety improvements and provide the data required for new or improved criteria for aircraft design, operations, maintenance, pilot performance, and weapon- and bomb-detection specifications. The more significant calendar year aircraft safety efforts included:

- A program to define steep takeoff and landing criteria for aircraft. This program involved pilots from the military services, domestic and international airlines, and aircraft manufacturers.
- A program seeking to modify the flammability characteristics of high volatility jet fuel (JP–4), which is used by the U.S. Air Force, so as to approach the flammability characteristics of low volatility jet fuel (kerosene), which is used by civil and naval aviation. A barrel of crude oil can yield nearly three times more JP–4 fuel than kerosene. Should this effort be successful, it would be a boon to jet-fuel users in these times of increasing crude oil shortages.
- Measurements of toxic gases from burning cabin materials. At the end of the reporting period, 60 such materials were expected to be tested by the middle of calendar 1974.
- An investigation seeking to reduce fuel-tank fires due to lightning strikes while in flight or to static discharges while refueling.

- Analysis and testing of general aviation aircraft design and equipment to reduce stall-spin accidents.
- A study of general aviation seat-restraint system design. This study was completed during the reporting period and is expected to lead to the issuance of a new technical-standard order on seat and restraint systems.
- A cooperative study with NASA seeking to improve the design criteria for general aviation aircraft and thus materially improve occupant crash-survivability. This study includes full-scale crash tests.

Environmental Programs

Aircraft Air Pollution.—FAA's efforts in this area are directed toward providing itself with the necessary knowledge to administer the aircraft industry's compliance with the engine-emission standards imposed by the Environmental Protection Agency. Specifically, FAA is seeking to:

- Gain a better understanding of the factors affecting the generation of undesirable emissions.
- Determine the trade-offs between performance and pollution.
- Determine the changes that occur with age and use of both turbine and reciprocating engines.

An investigation was begun during the reporting period to determine the exhaust-emission variability of turbine engines. Testing involved the use of engines on test stands and in aircraft. In addition, the agency continued its efforts to determine what proportion of the total pollution around airports is contributed by aircraft-engine emissions. This study, coupled with other efforts, will ultimately lead to the development of monitoring criteria for use by FAA's enforcement services. On tap for the near future is the exploration of ground operation procedures at one or more airports to determine how emissions may be reduced without affecting safety or appreciably reducing airport traffic capacity.

Aircraft-Engine Noise Abatement.—Aircraft-engine noise continues to be a major inhibiting factor in airport development. It has worked to deter capacity increases for existing airports and the building of new ones.

The recent introduction of three wide-body jets—the Boeing 747, the DC–10, and the Lockheed L–1011—which meet the noise-emission requirements set down by the Federal Air Regulations (part 36) gave the airport communities around large terminal areas some relief. It also gave the public some encouragement that noise reductions were on the way. The effect, however, has not been wholly advantageous nationwide. The introduction of these wide-body jets had relegated the older and noiser aircraft to flying shorter route segments and into and out of medium- to low-activity terminals. Thus, while the noise level at the large transportation hubs has dropped, it has increased at other terminal areas.

In recent regulatory actions, FAA has required all newly manufactured jet aircraft over 75,000 pounds (except DC–8's and Boeing 707's) to meet the noise standards set down by part 36 after December 1, 1973. New DC–8's must meet these standards after December 1, 1974; all new airplanes in the transport category, after December 31, 1974.

Noise Program Coordination and Planning.—The Noise Act of 1972 identifies the EPA as the responsible Government agency for the coordination of the Government's research and technology programs dealing with noise. In view of this assignment of responsibility and after consultation with the EPA, the joint office terminated the Interagency Noise Abatement Program (IANAP) activity that had been directed at interagency air transportation noise program coordination. However, the office continued to perform this function for NASA and DOT/FAA. A 5-year air transportation noise research and technology program was developed of which the purpose is to reduce aircraft noise to the lowest practical levels. Joint efforts are developing the techniques for measuring and predicting the noise of individual aircraft and of fleet operations, and for assessing the impact of this noise on individuals and communities. The plan was reviewed and assessed with respect to the on-going programs within DOT and NASA. Appropriate actions have been taken to modify programs as necessary. This program planning process will continue.

Climatic Impact Determination.—The Climatic Impact Assessment Program (CIAP), established in the Office of Assistant Secretary for Systems Development and Technology, provides management for a program to assess, by mid-1974, the effects upon the climate of high altitude aircraft, including subsonic and supersonic, projected to the time period 1985–1990. The program considers the impact on people, plants, and animals of climatic changes resulting from introducing into the upper atmosphere the propulsion effluents of a world high-altitude fleet. December 1974 is the target date for a report on the climatic changes which will take into account both sociological concerns and the possibility of applying technology to alleviate those concerns.

Program accomplishments in 1973 are:

- Stimulated the support and collaboration of scientists in Britain, France, Belgium, India, Australia, Canada, and Japan. Reached tentative agreements with the U.S.S.R.

- Contracted more than 90 tasks involving participation of over 50 Government laboratories, universities, and private organizations.
- Made measurements in the stratosphere.
- Began data compilation in the stratosphere, troposphere, and biosphere.
- Participated in and encouraged engine improvement programs for zero environmental impact.
- Began international discussions with atmospheric research scientists in the United Kingdom, France, Australia, Japan, Belgium, and the Soviet Union.
- The National Academy of Science/National Academy of Engineering CIAP Program Advisory Committee of the National Research Council reviewed the CIAP program for the third time and made recommendations for initiating additional stratospheric research effort.

Energy

The rapidly worsening energy shortage required the Department during FY 1973 to give increasing emphasis to research on the energy-related aspects of transportation. The Department also established a transportation energy program within the Office of the Secretary to coordinate and review all DOT energy-related efforts, suggests needed changes in the programs, and prepare DOT responses to the conservation efforts of the rest of the nation.

Already in operation was the Transportation Energy R. & D. Goals Panel which had members from many Government agencies and was chaired by the DOT. The panel completed its work and issued its report on "Research and Development Opportunities for Improved Transportation Energy Usage."

The Department continued its program of studies on mass production techniques for advanced engines for automobiles in collaboration with the Environmental Protection Agency, as well as other research on forms of propulsion that tend to conserve energy.

Aerospace Technology Utilization

High Speed Ground Transportation Systems.—Several new forms of transportation have been developed which employ technology and systems that were originally perfected for aerospace application; others are under development. Most promising among these are several types of high speed ground vehicles, such as tracked air-cushion vehicles and tracked levitated vehicles that operate in their own guideways, or suspended from overhead structures. These are clean, efficient, fast, and economical means of transportation which will serve the Nation well and at the same time conserve energy. The high speed program includes three major elements: (1) a 150 mph Prototype Tracked Air Cushion Vehicle (PTACV), which is scheduled to start testing at the High Speed Ground Test Center (HSGTC) near Pueblo, Colo., early in calendar year 1974; (2) a 300 mph Tracked Levitated Research Vehicle (TLRV), which is currently under test at the HSGTC; and, (3) an investigation of magnetic levitation suspension systems, which is still in its early stages.

The application of aerospace technology to high speed ground transportation is illustrated by the 300 mph TLRV program. The two primary contractors are aerospace firms. The aerodynamic design of the vehicle was based on wind tunnel tests conducted in an aerospace facility. The structural design and fabrication use aircraft construction techniques. The instrumentation approach, including the use of a telemetry system, is based on aerospace technology. The vehicle uses an active secondary suspension system, intended to improve ride comfort in high speed turns, which was patterned after the stability augmentation systems used on aircraft.

The TLRV uses three JTF15D–1 turbofan engines—the engine used on the Cessna Citation. The fan air from these engines is used to supply the vehicle's air cushions, for both levitation and lateral guidance. The core thrust is used for the initial low speed testing— up to about 100 mi/h. The thrust for the higher speed range will be provided by two linear induction motors, using wayside power pickup. The TLRV also uses hardware developed for other aircraft programs, including: the windshield, from the Gulfstream II; the seats and restraints, from the B–25; and the air conditioning unit, from commercial aircraft applications.

Simulated Helicopter Training Device.—On August 9, 1973, the Coast Guard accepted and placed in commission its first simulated training device, the Variable Cockpit Training System for rotary wing aircraft. This system simulates the dynamic performance and response of the HH–35F and HH–52A helicopters and their systems and subsystems over the full operational ranges. This is accomplished with full sensation to the student of the parameters of Earth's atmosphere and the flight environment; yet, the device can portray emergency conditions without the actual flight hazards. This advanced simulation training technology will result in overall improved training capability, with substantial cost savings to the Coast Guard.

VIII Arms Control and Disarmament Agency

The Arms Control and Disarmament Agency has three basic categories of interest in space activities. In each of these ACDA participates in the formulation of U.S. policy and in negotiations necessary to reach international agreement.

ACDA's primary interest is in maintaining space as an environment free of competition in military forces and weaponry. This interest is embodied in the Outer Space Treaty, which 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, and a total of 68 countries have ratified it. Of the countries with independent space programs—the United States, U.S.S.R., France, Japan, and the Peoples Republic of China—only the Peoples Republic of China is not presently a signatory.

Of almost equal importance is ACDA's interest in protecting the use of space for purposes related to peace-keeping, crisis management, and treaty monitoring. Utilization of the unique features of space for crisis management and peace-keeping is represented by the agreement negotiated in 1971 providing for the establishment of a secure, spacebased communications "hot line" between the Governments of the United States and the U.S.S.R., utilizing the U.S. Intelsat and the Soviet Molniya systems. ACDA's interest in utilizing space for treaty monitoring is exemplified by the provision of the strategic arms limitation agreements with the U.S.S.R. which specifies that neither country will interfere with the national technical means of verification of the other. This provision would, for example, prohibit interference with a satellite in orbit used for verification of the agreements.

Finally, ACDA seeks to encourage other countries to refrain from utilizing space technology and hardware to develop strategic offensive forces. ACDA participates in the detailed reviews which precede the export of U.S. space technology or hardware, and is active in the formulation of U.S. policy on bilateral and multilateral international programs for the peaceful use of space. ACDA also participates in similar reviews of commercial avionics systems, especially inertial navigation systems, which could be used in strategic weapons. As with space systems, the intent is to encourage legitimate trade and cooperation but to institute any safeguards necessary to prevent illegitimate uses of such technology and hardware.

IX Department of the Interior

Introduction

The Department of the Interior, in meeting its responsibilities for the management, inventory, and conservation of the Nation's resources, employs aircraft on an operational basis. Bureaus and offices within the Department owned or leased 109 aircraft for both mission-oriented flights and general utility. The Earth Resources Observation Systems (EROS) program serves the Department by coordinating research and implementing operational use of the technology of remote sensing from aircraft and spacecraft that is applicable to resource inventory and management. Departmental activities include international cooperation in wildlife regulatory administration, scientific research projects, technical training programs, and technical assistance.

Geological Survey employed aircraft in support of geological and geophysical investigations and in the management and monitoring of Federal Outer Continental Shelf mineral resources as in previous years. Research is continuing to be supported by the Office of Water Resources Research in the use of remote-sensor data acquired by aircraft in hydrologic studies, and by the Bonneville Power Administration in the use of satellite meteorological data for input to water resource programs, especially the operation of hydroelectric systems.

Aeronautics

Operations.—On July 1, 1973, the Office of Aircraft Services was established under the jurisdiction of the Assistant Secretary—Management, for the purpose of raising safety standards, increasing the efficiency, and promoting the economical operation of aircraft activities in the Department. The Office has been given responsibility for Departmentwide functions related to control of aircraft services and facilities. This includes, among others, assuming ownership of and managing all aircraft and aircraft facilities now owned by the Department, its Bureaus and Offices; coordinating aircraft use to obtain the best utilization of existing equipment consistent with various mission requirements; and furnishing technical assistance in areas of specialized aircraft problems.

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

In addition, Bonneville Power Administration contracts for low-level aerial coverage of transmission corridors for use in reconnaissance, tower sitings, design, and selective right-of-way clearing. Construction contracts may also call for use of helicopters in construction and logging where such methods will minimize environmental impacts in sensitive locations.

In order to service the Snettisham Hydroelectric Project, 28 miles south of Juneau, the Alaska Power Administration uses contract float planes to transport personnel once every 10 days to this otherwise inaccessible site. Snow surveys of the Snettisham project watershed are conducted by helicopter on an average of four times per year to obtain planning data for the operation of the project.

The use of aircraft by the Bureau of Land Management for wildland fire control continued to expand during 1973. The Bureau operated its own fleet of aircraft and chartered, leased, and contracted special aircraft to meet the tactical and logistical needs of fire suppression forces, including the aerial application of fire retardant chemicals. Aerial seeding of clouds to reduce lightning ignition of wildfire was operational during 1973, and high-altitude photography and infrared scanning were used to locate and map fires.

The Bureau of Indian Affairs has a formal agreement with NASA to obtain high-altitude photography

of all Indian reservations in the United States to be done on a reimbursable basis. The BIA also has entered into an agreement with USGS for the production of orthophotoquads and orthophoto mosaics from this photography and for technical assistance in photo-interpretation. The orthophotoquads and orthophoto mosaics will be used as base maps for natural resource overlays and together they will be used to develop and implement comprehensive planning.

The Bureau of Mines continued monitoring old strip mine pits turned trash dumps for Hurricane Agnes residue. Periodic flights resulted in the early detection and extinguishment of two fires with high potential for generating fires in coal seams.

The Bureau of Reclamation utilized helicopters and fixed-wing aircraft for transportation of control survey parties and equipment, for investigations and inspections required for project operation and maintenance, and in the collecting of photography and scanner imagery used in planning, development, and management of multipurpose water resource projects. Typical uses included photographic reconnaissance for environmental assessment of reservoir sites, identification of potentially hazardous landslide areas, a survey of recreation development potential on Bureau reservoirs, and observation of Navajo Dam and canal distribution facilities during the initial filling of the reservoir to monitor possible seepage through the dam and canal system.

The Bureau of Sport Fisheries and Wildlife conducted aerial surveys over large portions of the 50 States, Canada, and Mexico, to collect data for research and management purposes. Particularly, Bureau observers aboard the NASA CV–990 aircraft in the Bering Sea experiment (BESEX) were able to verify extensions of previously established marine mammal ranges.

In another aerial survey, the disappearance of a rare and endangered marine mammal was established. Concern for the existence of the Caribbean monk seal was expressed less than 10 years ago; this species is now extinct. The Bureau has found aerial surveillance extremely useful in detection of illegal dredge and fill operations along the Atlantic and Gulf Coasts. This technique is now scheduled as a continuing operation using imagery obtained from fixed-wing aircraft and spacecraft.

The Bureau of Reclamation found color infrared aerial photographs to be an accurate and rapid means of conducting a land-use suitability survey of approximately 300 square miles of land on the Dolores Project in southwestern Colorado. Thermal infrared scanner imagery is being evaluated as a means of identifying predawn cold air pockets that represent a frost damage potential in orchard lands. Photographic and optical mechanical scanner imagery has been used in demonstrating a relationship between crop reflectance or emission and the depth to near-surface ground water in irrigated agriculture. Studies are continuing in the use of aircraft remote sensing for identification and mapping of weeds and phreatophytes in Bureau canals and reservoirs. Contractors' aircraft continue to be used in atmospheric water resources research as cloud-seeding platforms and for collection of meteorological and hydrological data.

The Geological Survey contracted for 275,000 square miles of aerial photography for its national topographic mapping program. Of this total, over 50,000 square miles were photographed at 37,500 feet as quad-centered, high-altitude coverage used for orthophoto image maps. The quad-centered photography is used for analyzing map revision requirements, making interim map products and final photo image maps. Acceptance of color photography for topographic mapping is still minimal although environmental studies have given impetus to the purchase of color infrared photography for wetland and land-use maps.

Research.—The Bonneville Power Administration has contracted for high-altitude color mosaic coverage for many of its facilities. This 1:48,000-scale photography is being used for regional environmental studies and reconnaissance. In addition, high-altitude color photography has been obtained for several select facility study areas as part of an effort to determine the suitability of infrared photography for providing resources and land use data needed for facility location and environmental impact evaluations.

The Bureau of Indian Affairs is coordinating research on the Navajo-Hopi Reservations, Ariz., of applications of remote-sensing techniques to land resource problems. A section within the Navajo-Hopi Reservations is being used as a test site for developing a land-use map to include range and soil data. The map is being prepared at a scale of 1: 24,000 using high-altitude color and color infrared photography flown by NASA. The Bureau of Indian Affairs is also continuing its remote-sensing project on the Salt River Indian Reservation, adjacent to Phoenix, Ariz., for regional comprehensive planning and for monitoring changes in natural conditions on the reservation bordering the Phoenix metropolitan area.

The Geological Survey 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 methods to analyze and display remote-sensor data. High-altitude thermal imagery of the Denver Front Range area reveal subtle topographic features, not seen on topographic maps, which can be related to mineralized areas. Some quartzites can also

be distinguished thermally in the mountains as well as at the north end of the Pikes Peak batholith. Thermal infrared survey flights over Mount Rainier detected 48 previously unrecorded pinpoint radiation anomalies around the main cone and higher flanks in outcrop areas of andesite flows. A new trielement scanner which records two thermal infrared bands and one visible band has been acquired. One of its main functions will be to determine the effectiveness of measurement of energy level in the two thermal bands for discriminating rock types.

Space

Research.—Research by the Department in space applications to Earth resources was coordinated by the Earth Resources Observation Systems (EROS) program. Experiments using the Earth Resources Technology Satellite (ERTS) and Skylab Earth Resources Experimental Package (EREP) data are in progress, and most are achieving meaningful results. Individual bureaus and offices have had substantial success in testing the use of or incorporating some of the evolving techniques and products into operational aspects of their programs.

The EROS Data Center, Sioux Falls, S. Dak., in its second year of operation, continues as the primary public sales outlet for spacecraft- and aircraft-acquired remote-sensing data. Data are available at the Center from NASA aircraft remote-sensing missions and from aerial mapping missions flown for the Geological Survey in addition to satellite data from ERTS–1. Personnel and equipment in Sioux Falls are now located in the new Karl E. Mundt Federal Building, a 107,000 square foot facility located on 320 acres, 18 miles northeast of Sioux Falls. The new facility was dedicated August 7, 1973.

Data sales to other Federal agencies, State and local governments, universities, private industry, and general public totaled $300,000 in fiscal year 1973, and are projected at almost $1 million for fiscal year 1974. ERTS data in the forms of both imagery and magnetic tapes are available from the facility.

The Data Center also operates training and applications assistance facilities with principal emphasis on the transferring of techniques for extraction of information to operational users. Techniques for application of the data to environmental and resource management problems being developed by various research investigators, universities, and NASA, are documented in procedural form and made available to users through the applications assistance staff at the Data Center. Short courses for both U.S. and foreign scientists and resource managers in the use of remote-sensing data are also offered by the EROS Data Center.

The EROS Experiments and Evaluation Office located at the NASA Mississippi Test Facility opened its users' assistance center to the general public. Since January over 700 potential users of remote sensing have visited the center to receive briefings on the EROS program, to search out available data through the computer link with the EROS Data Center in South Dakota, or to use the image enhancement and interpretation equipment. A remote-sensing training program has been instituted as well as a cooperative program with the Bureau of Sports Fisheries and Wildlife to undertake a land and water management study of the Atchafalaya River Basin in Louisiana. In conjunction with the Geological Survey of Alabama (GSA) an ERTS–1 satellite image mosaic of Alabama was prepared by the Experiments and Evaluation Office and published by the GSA.

The EROS program initiated several research projects and supported others, including efforts to develop a conceptual model for utilization of remotely collected areal data to monitor and measure continental water flux. The theoretical work is near completion and the model is now to be tested against aerial- and satellite-acquired data. A study was completed that demonstrates that large-scale unreclaimed stripped land can be easily seen on all MSS bands. The demonstration area was in southeastern Ohio. Revision of existing geology, physiography, and land-use maps at scales of 1: 250,000 and smaller utilizing ERTS–1 imagery as the primary source has been successfully accomplished in several test sites, including the Lake Ontario Basin.

The EROS program mapped the Mississippi River flood using ERTS–1 imagery of the 1,200 mile reach below St. Louis, Mo. The flood data obtained March 31 and May 4 and 5, 1973, were compared with imagery collected by ERTS on October 1 and 2, 1972, when the river was confined to its normal channels. Using additive color techniques, temporal composites of MSS band 7 were created that vividly depict the flooded areas in relation to the normal channel.

The EROS program also supports the ERTS data collection at the Technology Applications Center of the University of New Mexico. The center serves as a data collection point and provides data management and technical assistance to 11 Federal, State, and local agencies investigating, within ongoing programs and projects, the application of ERTS in the State of New Mexico, under the supervision of the Middle Rio Grande Council of Governments.

As part of an ERTS experiment involving Latin America, evaluation of ERTS–1 imagery has led to the conclusion that the data are ideally suited for small-scale geologic mapping and structural analysis of remote inaccessible areas such as the Andes of South America; some compilation of geologic, drainage and cultural maps at 1:1 million scale has been accomplished and maps have been revised with marked improvement in content. Recognition of change in

various hydrologic aspects, in vegetation and snowline, has been possible by analysis of repetitive data.

ERTS imagery acquired over Iceland in support of a multidisciplinary, multinational experiment has been particularly useful in displaying subtle geologic structure and landforms. Results indicate that a reappraisal of some of the geologic history of Iceland may be necessary. Enhancement is due to a combination of low sun angle (7°) and snow cover in this near polar region. Images were also acquired prior, during, and after the eruption of Kirkjufell, providing this experiment team and others with a new tool for studying erupting volcanoes: new deposits, and the direction and areal distribution of the eruption plume.

The Bureau of Indian Affairs is now investigating the use of ERTS imagery and high-altitude photography (1: 80,000 black and white, 1: 40,000 color infrared) to develop resource data for Environmental Impact Statements and overall reservation planning on the Crow-Northern Cheyenne Reservations, Mont. Delineations from ERTS imagery will be controlled to a 1:125,000-scale orthophoto mosaic.

The feasibility of establishing a comprehensive natural resource information system has been demonstrated under a Bureau of Indian Affairs and the Bureau of Land Management contract. The Natural Resources Information System (NRIS) was developed to digitize all types of data, both graphic and tabular, as they pertain to a specific geographic location and which can be useful at multiple management levels. All seven of the resource-oriented bureaus within the Department of the Interior participated in the project. The basic objective of the NRIS development program is to provide the resource managers of the Department with a capability to manipulate and analyze large volumes of relevant map data and thereby to assist them in their planning and managing functions. This computer-based approach can be viewed as a tool to be used in cataloging, inventorying, correlating, and analyzing available data in a uniform, consistent manner, at speeds and complexities not practical by conventional manual methods.

The Bureau of Land Management has prepared a mosaic of ERTS imagery at a scale of 1:1 million of the Powder River Basin, Wyo., which is to be used as baseline information in monitoring the impact of strip mining about to begin in the Great Plains coal basin. The Bureau is also using ERTS–I imagery to prepare broad vegetative rangeland maps, and in several districts have used it for soils and wildlife habitat identification.

The Bureau of Mines investigated the applicability of aircraft and satellite remote sensing for locating problem fault-fracture systems important to evaluation of structural conditions prior to surface and underground mine development. At least five rock types have been discriminated to date and related fault systems have been successfully located using airborne multispectral scanning, particularly in the UV and thermal regions of the spectrum. Comparisons of findings with satellite-derived data have been made, but only moderately successful results were obtained.

Fault and fracture trace maps have been derived from low-altitude aircraft data and ERTS–1 imagery of east-central Kansas and central Appalachia are being examined to test the potential applications of remote sensing to petroleum and natural gas exploration and for locating sites for underground coal gasification.

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

The data relay capability of the ERTS–1 satellite is being tested by the Bureau of Reclamation in the San Juan Mountains of southwestern Colorado under severe environmental conditions. Data from seven remote reporting stations are relayed via the ERTS–1 satellite through NASA Goddard Space Flight Center to the Engineering and Research Center in Denver in near real time. Measured variables include temperature, precipitation, wind speed, wind direction, solar radiation, and streamflow.

Preliminary evaluation of ERTS–1 imagery by the Bureau of Sport Fisheries and Wildlife for determining numbers and distribution of prairie ponds and lakes in North Dakota has shown that surface water areas larger than 2 acres can be recognized. The feasibility of pond and lake mapping using concurrent aircraft and spacecraft data has been demonstrated. A project is being conducted to evaluate Skylab EREP sensors for measuring surface-water conditions and vegetation types in waterfowl breeding habitat. Habitat quantity and quality as well as seasonal changes will be determined. Skylab and aircraft multispectral scanner and photographic data were collected over test sites in North Dakota during May, June, and August of 1973. Extensive ground truth was collected to verify the remote-sensing data. The assessment of the relationship between caribou winter range and snow cover, the evaluation of snow cover disturbance as a result of caribou grazing, and determination of succession of grazing forage types are the focal points of an ERTS–1 investigation in northern Alaska. Certain winter component units have been identified and their areas of distribution have been defined using ERTS–1 imagery. Cooperation of the U.S. Navy Photo Reconnaissance

Squadron VQ–1 enabled the Bureau to acquire multispectral imagery from a number of test plots in Alaska. This imagery will be used to provide an intermediate stage of interpretation between ground track surveys and space-acquired imagery. The goal is to substitute multispectral imagery obtained from fixed-wing aircraft for ground truth surveys whenever possible.

The Geological Survey utilizes data from manned and unmanned spacecraft to improve remote-sensing techniques as a supplement to conventional and airborne research methods in geological and geophysical investigations. Objectives include: Determination of variations of physical properties such as spectral reflectance or thermal inertia, which can be used to discriminate materials or conditions; 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. Significant results of investigations include: Indication of advance warning of the February 23, 1973, eruption of Fuego Volcano in Guatemala by satellite telemetered data showing an increase in microseismic activity. Computer ratioing of ERTS imagery of Goldfield, Nev., to identify rock types and hydrothermally altered areas some of which are related to mineralization. Worldwide mapping of desert sand seas being completed using ERTS imagery promises a better understanding of ancient windblown sandstone deposits important as reservoirs for oil and water. Study of Alaskan ERTS imagery has revealed a significant number of linear features, probably faults, which will help better understand the complicated structure of the State. ERTS imagery of coastal areas has provided a better insight into near-shore currents and coastal processes. Landform and land-use characteristics and geologic surficial materials in the Midwest and Great Plains can be differentiated using ERTS imagery more accurately than on 1: 250,000-scale topographic maps. Also, for the first time the existence of an isolated crustal anomaly, located in central Africa, has been discovered on the basis of POGO satellite magnetic data.

Geological Survey experiments using the ERTS Data Collection System are testing its application to hydrologic problems and the system is under study for possible nationwide application. One experiment became a practical operation when snow moisture content and streamflow data from central Arizona that were relayed to the Salt River project enabled the project managers to successfully anticipate runoff and thereby regulate release of reservoir water preventing flooding in Metropolitan Phoenix. In southern Florida, water stage data relayed via ERTS Data Collection System can be correlated with the area under water as identified on the ERTS image. It was then possible to determine the volume of water in storage in the Loxahatchee Reservoir by electronic density analysis of successive ERTS images.

A new description of the dynamics and morphology of the ice over the Beaufort Sea has resulted from investigations using measurements from drifting stations, aircraft, ERTS, and Nimbus satellites. The ERTS images have also been used to identify surging glaciers and to delineate spring snowlines which can then be correlated with an "equivalent snowline altitude" to provide estimates of snowmelt runoff.

The Geological Survey has examined ERTS–1 imagery for its cartographic application. Sample satellite image maps have been prepared, both in black and white and in color, at scales of 1: 250,000, 1: 500,000, and 1: 1,000,000 scales. These maps carry a geodetic (Universal Transverse Mercator) grid from which positions can be determined to national map accuracy standards. In conjunction with NASA, ERTS parameters have been established that insure that successive ERTS images (18 days apart) will cover the same nominal scene on the Earth's surface. Moreover, the printing of ERTS images has been redefined so that such imagery may be printed on a mathematically defined map projection referred to as the Space Oblique Mercator. The establishment of such parameters and projection means that mapping from an ERTS-type satellite can be automated. Steps required to achieve such automation have been defined and procedures are being established. Implementation of such procedures would accompany the conversion of ERTS from an experimental to an operational system.

The U.S. Geological Survey published and made available for public sale its first gridded image mosaic. The mosaic of the State of New Jersey, derived from three consecutive images in a single orbit, meets national map accuracy standards. A mosaic of the State of Florida is being prepared for publication early in 1974.

As part of the Geological Survey's Census Cities Project, an experiment to map land use in an urban area by automatic digital processing of ERTS–1 data shows promise. Computer maps of a large part of the San Francisco-Oakland and San Jose urbanized areas have been produced using a segment of an ERTS–1 frame. Classification was achieved by grouping 28 spectral classes into 11 functional classes. Reliability was checked by comparing computer results to high-altitude color air photographs.

Operations.—The Geological Survey provided support to NASA for mission planning, including the Venus-Mercury flyby, and postmission analysis. Geologic analysis and mapping of Apollo and Mariner

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data continued. Guidance was provided on the application of remote-sensing techniques to planetary exploration.

International Cooperation

The launch of the Earth Resources Technology Satellite (ERTS–1) led to widespread interest in using imagery from the satellite for experimental mapping of resources and brought many requests for training and assistance in remote sensing. As a result, in 1973 the USGS conducted training courses or seminars in Mali, the Philippines, Indonesia, and Thailand. The Sahelian Seminar, held in Bamako, Mali, from April 17–28, emphasized applications to the Sahelian Zone in the disciplines of agriculture, forestry, hydrology, ecology, geology, and economics. The East Asian Seminar, held in Quezon City, Philippines, from May 7–18, addressed the disciplines of agriculture, forestry, cartography, geology, oceanography, fishery, and land use. The Indonesian course was presented in Jakarta between January 12 and February 2 as the first phase of the multispectral photographic remote-sensing survey of Bali. In addition to lectures on remote-sensing theory and techniques, especially multispectral photographic theory, application of these techniques to agriculture, forestry, fishery, geology, hydrology, oceanography, land use, and soils were presented. Some of the trainees will be involved in the actual survey of Bali for which the aerial survey was flown in July 1973. In Thailand, a 4-week course in application of remote sensing to problems in geology, agriculture, forestry, land use, and hydrology was given to a class of 27 students from southern Asia. In the field of geology, emphasis was given to training in the use of ERTS data and of aerial multiband data from a camera available in Thailand. In a class exercise, most of Thailand was mapped at a scale of 1:1,000,000 from ERTS imagery. Even in this rough first attempt by students, tectonic provinces could be defined which have interesting possible correlations with the known distribution of mineral showings. A follow-up program of ERTS mapping was started in two divisions of the Thailand Department of Mineral Resources.

An international remote-sensing training course was also held in Sioux Falls, S. Dak., June 2–29, for students from 11 foreign countries. The course, which emphasized ERTS technology and data applications, covered the disciplines of geology, hydrology, cartography, agriculture, forestry, and soils.

As a direct result of courses given by USGS personnel in Brazil near the end of 1972, a remote-sensing group was organized in the Companhia de Pesquisas de Recursos Minerais (CPRM) and equipment was obtained to provide capability for remote-sensing data gathering and analysis. The CPRM program is to include large-scale geologic mapping from ERTS images and radar mosaics, as well as detailed aerial surveys of specific economic areas.

The EROS program also sponsored two training courses at Inter American Geodetic Survey Headquarters, Fort Clayton, Canal Zone for approximately 60 Latin American scientists. Four in-country demonstration projects were initiated and mechanisms for data and reference material distribution were established.

X Department of Agriculture

Introduction

The Department of Agriculture continues to recognize the need for a technically feasible and economically sound remote sensing program that can effectively utilize aerospace technology to collect real-time Earth resources data for more efficient inventory, protection, and management of our agricultural and forestry resources. This involves testing the feasibility and operational utility of using aerospace-acquired data, along with other relevant data, to inventory and make more accurate quantitative predictions of the food and fiber resources of the Nation; to evaluate the productivity of the land; and to monitor changes affecting the total production and quality of our resources and environment.

Remote Sensing and Space Activities

Research planning in USDA is being aimed at the full utilization of aerospace remote sensing data capabilities, and the efficient processing and interpretation of the massive data potential where it can best serve toward the improvement of our agricultural, forestry, and related resource production and development systems. During 1973, a number of significant findings and advances were made, and important programs developed, utilizing remote sensing technology, as follows:

Agricultural Research Service.—1. In crop identification studies, data from Band 7 of the ERTS–1 multispectral scanner was found to be the most effective in discriminating bare soil and five categories of vegetation. Utilizing all four channels permitted a 91-percent accuracy in correctly identifying crops. Fields having more than 40-percent plant cover were more accurately identified than those with less cover. Fields above 20 acres in size were more correctly identified than those of 10 acres or less.

2. Earlier crop data handling experience required approximately 14 days of computer time to process data over a 1-million-acre tract of cropland. Modifications have been made that permit this data to be displayed and read out in 3 hours. Software and hardware improvements have enabled this increased efficiency.

3. Areas of iron-deficient (chlorotic) grain sorghum down to 2.8 acres in size have been detected and isolated from ERTS–1 magnetic tape data.

4. ERTS–1 imagery is being used to locate and determine the extent of highly erodible (by wind) soil areas in Texas and New Mexico. Feasibility studies thus far indicate a good possibility for utilizing this approach to prognosticate erodible potentialities before erosion actually occurs.

5. Low concentrations of sediment are important in the transport of pesticides and ionic pollutants. Spectral reflectance of water, containing sediment, was measured for several increasing concentrations of clay particles in water. Measurements indicate that low (75 ppm) concentrations of some sediments may be measured by remote sensing techniques.

6. Utilization of a discriminative analysis technique has provided the ability to use ERTS magnetic tape data to distinguish, with good discrimination, grassland watersheds with high runoff from those having low runoff. The best discrimination occurs using MSS Bands 5, 6, and 7. Irregularly shaped areas can readily be determined by the application of computer techniques to isolate ERTS digital data. Extension of these techniques could lead to a rapid analysis system for large grassland watersheds.

Agricultural Stabilization and Conservation Service.—1. A complete set of ERTS–1 color composite 9 inch by 9 inch imagery is being prepared for a demographic survey and census operation of Afghanistan. This undertaking is being accomplished at the Salt Lake City photographic laboratory in cooperation with USAID and the Department of Commerce under an Afghanistan project agreement. During the past year this facility, in addition to its regular aerial photograph processing, has also processed over 4,000 ERTS–I images and transparencies in black and white, color, and color infrared for various U.S. Federal, State, and local agencies in addition to universities and the public at large. Over 300 ERTS–1 color composites have been rendered by this laboratory.

2. An extensive ground-truth-gathering project over 18 U.S. counties is being conducted with NASA-Houston in an investigation to develop an automated crop identification and classification system utilizing a digital data processing approach.

3. In cooperation with the Canadian Department of Agriculture, an experiment is in progress to correlate ERTS–1 digital imagery with ground truth observations of selected spring wheat sites. The purpose is to develop techniques for estimating acreage yield and crop vigor from satellite data utilizing ancillary information such as soil moisture, ground temperature, and other relevant parameters.

Animal and Plant Health Inspection Service.—Extensive gypsy moth damage to millions of acres of trees in Eastern United States occurs annually. A sterile male technique may aid in the control or elimination of this insect provided a diapause (hibernation) can be terminated at will. The ability to break this stage by chemical or physical means in the laboratory has not been possible.

A proposed experiment, in cooperation with NASA on Sklab 4, is to terminate diapause of gypsy moth embryonated eggs by exposure to zero gravity in space and thus remove the barrier to the use of the environmentally sound sterile male technique to aid in the control of this pest.

Forest Service.—1. A space-related research spinoff has been the development of a unique surveying instrument for boundary line location. The instrument system is based on NASA laser research, and a prototype instrument was developed under a NASA contract. The instrument is undergoing field testing. A vertically aimed laser beam is detected by a remote electro-optical detection device located up to a mile in distance, regardless of intervening terrain or cover. The system, named LEAPS, is expected to more than double the speed of boundary line detection work.

2. Continual use is being made of aerial photography for resource surveys and revision of inventory maps. Increasing advantage is being taken of improved cameras and films to cover larger areas with a single photograph while still retaining the required image resolution, positional accuracy, and stereoscopic coverage.

3. ERTS–1 images enlarged to 1:250,000 scale have proved useful as an aircraft navigation tool for the acquisition of small-scale photography. In areas of rapid change, the ERTS photolike images improve the performances of the pilot team and photographer in obtaining photos of particular areas with greater precision.

4. An unsupervised computer-learning technique has been programed for automated separation of forested versus nonforested areas using ERTS tapes or microdensitometer data obtained from photographs.

5. Fully operational remote sensing techniques for forest fire detection and mapping have been expanded. Including the prototype equipment designed and built by the Fire Laboratory of the Forest Service, three fire scanner-mapper units will soon be in operational use. A contract has been let for a first commercially manufactured bispectral scanner based on research and development by the Forest Service.

6. In Southern United States, a comparison of fall ERTS imagery with late winter or early spring imagery permitted the detection of Kudzu vine (used for soil erosion control) which damages forest stands when not kept under control.

7. As a result of a severe frost in the bay area of California, over 2 million eucalyptus trees were killed or severely damaged. Aerial photos were used to map, plan firebreaks, and to assess the damage and excessive tree-removal costs by private landowners and insurance companies. The actual damage is being correlated with the aerial photography and ERTS imagery.

Soil Conservation Service.—1. The Cartographic Division, in cooperation with the Joint Federal-State Land Use Planning Commission for Alaska, has compiled an available mosaic of Alaska at a scale of 1: 1,000,000, using MSS Band 7 of ERTS–1.

2. Under a contract for NASA, ERTS imagery (Bands 5 and 7) is being used to compile mosaics of conterminous United States at a scale of 1: 1,000,000. The entire project is expected to be completed during the summer of 1974.

Other Activities

Worldwide cognizance of USDA expertise in agriculture and forestry has brought representatives from many nations to seek advice and assistance on agricultural and forestry applications of remote sensing. During 1973, many briefings were given to visitors from Afghanistan, Canada, Colombia, England, India, Indonesia, Italy, Jamaica, Japan, and Korea.

Cooperative ventures with the Department of State (USAID) and the Department of the Interior (USGS) occurred during the year in providing expertise assistance to the central West African countries of Mali, Niger, and Upper Volta. ERTS and other remote sensing technologies were used to assist in a more rapid and accurate inventorying of their natural resources and to expedite an expanded resource management program.

XI Department of Commerce

Introduction

Department of Commerce agencies that actively utilize or contribute to aeronautics and space in carrying out their missions are the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Maritime Administration, the Office of Telecommunications, and the Bureau of the Census. Indirect contributions are made by the U.S. Patent Office and the National Technical Information Service.

Use of Satellites in Environmental Monitoring and Prediction

Environmental Satellite Operations.—As the year began, the National Environmental Satellite Service (NESS) of the National Oceanic and Atmospheric Administration (NOAA) had operational control of three polar-orbiting satellites: ESSA 8 and 9 of the older TIROS Operational Satellite (TOS) series, and NOAA 2 of the new Improved TOS (ITOS) series. ESSA 9 was deactivated on November 29, 1973. ITOS E, whose sensor complement was identical to NOAA 2, was launched on July 16, 1973, but failed to achieve orbit because of a hydraulic pump failure in the second stage of the launch vehicle. ITOS F, the backup satellite, was successfully launched on November 6, 1973, and named NOAA 3. NESS assumed control of NOAA 3 on November 29, 1973, following the NASA postlaunch systems checkout. NOAA 3 will become the operational satellite in 1974 and NOAA 2 will then serve as an "in-orbit" backup. Like its predecessor, NOAA 2, the satellite is equipped with radiometers that provide visible and infrared images of cloud cover, snow, and ice, and the sea surface, and gathers information on temperatures and moisture in the atmosphere. Another sensor provides data on the solar proton count and distribution in polar regions. A new feature introduced on NOAA 3, direct readout from the Vertical Temperature Profile Radiometer (VTPR), has evoked considerable international interest. Several foreign countries, including France and Norway, are receiving the VTPR direct transmissions. A VTPR workshop was held at NESS in July to familiarize representatives of European and South American environmental services with NOAA 2 VTPR products.

Vertical Temperature and Wind Profiles.—Approximately 1,000 vertical profiles of atmospheric temperatures are derived daily from VTPR data by NESS. These are transmitted to users worldwide via the Global Telecommunications System. These VTPR soundings have become a primary source of temperature information for the National Meteorological Center (NMC) upper-air analyses over Northern Hemisphere oceans. NMC is now testing a global analysis and forecast scheme which will rely almost entirely upon VTPR for data in the Southern Hemisphere. A preliminary test of the impact of VTPR data on NMC forecasts over North America showed some improvement in forecast skill. Research is underway to develop a four-dimensional data assimilation technique for direct use of satellite information in numerical forecast models.

The launch of NASA's Nimbus 5 in December 1972, provided data from three new sounding instruments: the Infrared Temperature Profile Radiometer (ITPR); the Selective Chopper Radiometer (SCR); and the Nimbus E Microwave Spectrometer (NEMS). The results of NESS studies using these sensor data have demonstrated the ability to determine the vertical thermal structure of the atmosphere at selected levels from the Earth's surface up to 50 kilometers through broken cloud or cloudless skies from infrared radiometer measurements and through dense clouds from microwave radiometer measurements. Indications are that temperature fields observed in the Northern Hemisphere by satellite instruments are markedly similar to those observed by radiosonde instruments. The satellite sounders can economically produce many more soundings per day than is possible with ground-released radiosondes. This is particularly advantageous over oceans and inaccessible land areas.

Cloud vector data, derived from the Applications Technology Satellite (ATS) 3, have been used to supplement high- and low-level winds obtained from balloon and rawinsonde observations. In meteorologically disturbed areas where multilevel clouds often pre-

clude the tracking of low-level clouds, inferences about the nature and intensity of the disturbance frequently can be obtained from a pattern of high-cloud vectors.

Environmental Warning Services.—With the advent of the Geostationary Observational Environmental Satellite (GOES) system, expected to be in operation by the summer of 1974, the development and movement of destructive weather phenomena will be observed almost continuously. An important aspect of the GOES system is the regional service provided by the Satellite Field Services Stations (SFSS) already established at Washington, D.C., Miami, Kansas City, and San Francisco. These stations, established in preparation for GOES and currently utilizing ATS–3 data, will provide analysis and interpretation of near-continuous GOES imagery to regional centers for use in preparation of short range forecasts, advisories, and warnings of severe local disturbances such as thunderstorms, tornadoes, and gales and for tropical storms and large-scale mid-latitude storms.

Determining Ocean Conditions.—Following the 1972 launch of NOAA 2, research was renewed to develop improved methods for mapping global sea surface temperatures using the Scanning Radiometer (SR) and the Very High Resolution Radiometer (VHRR) data. Multiday compositing of the infrared SR data is combined with climatological information to produce global sea-surface temperature charts.

The VHRR data have been used extensively in detailed studies of temperature fields associated with phenomena such as the Gulf Stream, warm and cold eddies, coastal upwelling, and discharge of river water into the oceans. Experimental charts showing many of these thermal features of the sea surface in the Western Atlantic are derived routinely from analyses of VHRR imagery; these charts are transmitted experimentally to subscribers via the National Weather Service facsimile circuit. Response to this new satellite product from a diverse group of Government and non-Government users has been favorable. Using these data, NESS scientists have suggested that the satellite-observed cold water eddies that have broken away from the Gulf Stream may some day be used for ship routing purposes.

VHRR imagery has proved to be nearly ideal for sea-ice studies. Satellite observations of ice conditions in the Ross Sea and McMurdo Sound in Antarctica assist the U.S. Navy Fleet Weather Facility, Suitland, Md., in routing resupply ships. The Fleet Weather Facility, using VHRR and Earth Resources Technology Satellite (ERTS) imagery, prepared sea-ice and weather forecasts that were transmitted via the ATS 3 Weather Facsimile (WEFAX) to Jacques Cousteau's ship *Calypso* after it sustained ice damage in Antarctic waters.

Ice Analysis charts based on VHRR satellite imagery were prepared for the Bering and Beaufort Seas and also transmitted experimentally via facsimile circuit to the Alaskan area. Such information was useful for routing ships for resupply of Arctic ports and for search and rescue, for supporting Coast Guard icebreaker activities and for scientific studies such as the Arctic Ice Dynamics Joint Experiment (AIDJEX).

Determining Lake Conditions.—The VHRR and ERTS 1 imagery have also proved to be of considerable value in the International Field Year for the Great Lakes (IFYGL) and related Great Lakes studies. For example, spring warming processes, which occur in different stages in each lake, are clearly delineated in a time sequence of VHRR infrared images. Cloud-free VHRR observations, together with virtually simultaneous ERTS coverage of Lake Erie ice conditions, were obtained during freezeup, growth, and breakup stages. Furthermore, the added capability of near-infrared sensing on ERTS permitted detection of melt water on the ice surface. This type of information is useful for routing merchant ships and extending the navigation season on the Great Lakes.

Determining Hydrological Conditions.—Quantitative estimates of snow cover, in terms of percent of basin coverage, were derived from VHRR imagery, and snow maps were prepared for the American River, Feather River, Upper Columbia River, Red River of the North, and Genesee River basins. These compared favorably with ERTS snow maps and showed a considerable cost improvement over more conventional high-altitude aircraft photography. Quantitative snow cover data needed for river and flood potential forecasts were sent to the appropriate River Forecast Centers within 36 hours after sufficiently cloud-free satellite images of each basin were received.

Estimating Rainfall.—NOAA's Environmental Data Service Center for Experiment Design and Data Analysis conducted a review of methods for estimating rainfall from satellite data. The primary purpose was to determine the usefulness of the methods for the GARP Atlantic Tropical Experiment (GATE). The methods include the use of cloud-top temperatures deduced from radiation measurements, visible image brightness, image area, and qualitative cloud-type identification from visible images. Ground-truth data have been obtained from various rain gage networks and radar records.

Pollution Monitoring.—A Marine Ecosystems Analysis (MESA) program pilot experiment using satellite data was carried out over the New York bight [1] area during

[1] Area covering Long Island, New York City, and New Jersey coastline out to a depth of 100 fathoms.

April 1973. The principal aims of the MESA program are to develop a better understanding of the biological, chemical, geological, and physical properties of the area, to assess man's impact on the system, and to predict the consequences of current and future actions. The experiment, a cooperative effort of a number of Government agencies and private industry, involved the use of two satellites (NOAA 2 and ERTS 1), two helicopters, and supporting oceanographic vessels and equipment. Detailed photography, multispectral imagery, and ocean-surface data were acquired in a 500-square-mile area in the vicinity of Sandy Hook, N.J., and the west end of Long Island. The remote sensing experiment verified that strong physical and chemical features manifest themselves throughout the apex of the New York bight area. For example, ERTS imagery clearly showed large pollution areas such as acid and sewage dumps.

Weather Modifications.—Using NOAA 2 Satellite nighttime infrared imagery from the SR and VHRR sensors, data were provided to Niger describing the location and size of cloud formations. This information was used to support Niger's cloud seeding project which was part of an effort to alleviate that country's prolonged drought.

The Atmospheric Physics and Chemistry Laboratory continued its experimental work in lightning suppression. Seeding thunderstorms from a B–26 aircraft with aluminum-coated nylon chaff significantly reduced electric fields in thunderstorms. Benefits derived from these studies were the reduction of lightning induced forest fires (about 70 percent of the world's forest fires are lightning caused), protection of exposed explosive stores, and the suppression of lightning at Kennedy Space Center during spacecraft launches.

Skylab Experiments.—In connection with the Skylab program, experiments were conducted for development of global wind and wave forecast models utilizing satellite-borne microwave sensors. Surface wind and wave data over test sites in the Pacific Ocean and Gulf of Mexico were collected concurrently from ships, aircraft, meteorological charts, and the Radiometer/Scatterometer sensor of the Skylab Earth Resources Experiment Package.

International Cooperation.—The United States and the Soviet Union completed the ninth year of environmental data exchange over the direct Washington-Moscow circuit. These data include visible and infrared cloud cover pictures from the U.S. NOAA 2 and 3 and the U.S.S.R. Meteor 12, 13, 14, and 15 Satellites.

The second and third coordination meetings on geostationary meteorological satellites were held in Zurich and Tokyo in January and October 1973, respectively. Representatives from the United States, Japan, and the European Space Research Organization participated. Observers from the Soviet Union attended both meetings. Among the subjects considered were determination of satellite locations, standardization of communication frequencies, data rates and formats, message codes, data collection, telecommunications, and uniformity of archival products.

Under the World Meteorological Organization (WMO) Voluntary Assistance Program, the National Weather Service (NWS) installed Automatic Picture Transmission ground stations in 17 countries and procured stations for installation in 4 others.

Fisheries.—Studies conducted by the NOAA National Marine Fisheries Service (NMFS) in cooperation with NASA and industry demonstrated the usefulness of remote sensing from satellites for improving fisheries research, management, and utilization. Image density levels from the ERTS 1 MultiSpectral Scanner were correlated with menhaden distribution patterns in the Mississippi Sound. The correlations were explained statistically using water transparency, color, salinity, and depth measurements. From these, regression models could be developed and used to predict areas of potential menhaden fishing success or failure in the study area.

The data acquisition phase of the Skylab Gamefish Experiment dealing with the North Central Gulf of Mexico was completed during the summer of 1973. Preliminary analysis of sea surface data collected by research and sportfishing vessels suggest that statistically significant correlations may exist between selected oceanographic parameters and the distribution and abundance of billfishes.

Environmental Monitoring Using Data Buoys.—The NOAA Data Buoy Office is adapting technology and improving environmental data buoys; these buoys are equipped with sensors to measure oceanic and atmospheric environmental parameters and are linked through telemetry to Earth satellites and shore stations. Four severe environment buoys were deployed for evaluation: two in the Gulf of Mexico, one off the U.S. mid-Atlantic coast, and one in the Gulf of Alaska. Although these buoys are experimental in nature, synoptic data were collected routinely for dissemination on the national environmental data networks for use in analysis and forecasting. Tests and evaluations were completed on six experimental polar applications buoys deployed as part of the initial phase of AIDJEX using Nimbus 4 satellite for data relay and position location. Tests and analyses are continuing on position location devices for drifting buoys which utilize the previously developed Omega and navigational satellite systems.

Demographic Studies.—The Bureau of the Census, using Agency for International Development funds, is studying the utility of ERTS–1 imagery for demographic studies and census operations in three less-developed countries. The first project is concerned with Afghanistan; similar studies will be done for two other countries, yet to be selected. The countries to be chosen will differ from each other and from Afghanistan in their cultural and physical geographic environments; the willingness and ability of their governments to participate in such a project also will be a determining factor. The ERTS 1 imagery together with correlative ground-truth data will be used to classify land use areas. This information in turn will be used in the development of population distribution models. If expectations are realized, information on population trends, urban growth, and internal structure of national land areas will be obtainable from satellite imagery.

Other Satellite and Space Applications

Navigation/Communications Satellite.—The Maritime Administration completed a 6-month test in which nine U.S.-flag ships and NASA's ATS 5 and ATS 3 satellites were used to evaluate shipboard equipment and techniques in communications and radionavigation. During collection of the technical data for this test, fleet management techniques were developed and evaluated by the participating shipping companies.

Determination of the Earth's Shape and Gravity Field.—The Worldwide Geometric Satellite Triangulation program was completed and its results published. The system consists of a global network of 45 stations, whose relative configuration was determined by simultaneously photographing the PAGEOS satellite from various locations on the ground. The scale was determined by seven baselines established by direct ground measurements. The entire system was referred to the Earth's center of mass as origin by comparison with 37 stations whose positions were obtained by Doppler satellite measurements and tied to the geometric network by ground surveys. The Earth's gravitational field was determined by using satellite orbital data and ground gravity measurements, using as a constraint the relative configuration of 17 of the Doppler observing stations. This program increases the density of stations on the North American Continent.

Prediction of Earthquakes by Using Lunar Ranging.—The successful placement of a laser retroreflector package on the Moon by Apollo astronauts has made possible very accurate measurements of the lunar orbit which can, in turn, be used to obtain information about Earth dynamics such as polar motions, rotation, and large-scale crustal movements. The National Bureau of Standards (NBS) has worked with the Jet Propulsion Laboratory and the University of Texas to determine the distance to the moon to an accuracy of about 10 centimeters over a distance of 400 million meters. The Bureau has also analyzed the accuracy limitations inherent in lunar ranging measurements attributable to atmospheric uncertainties and tidal corrections. For studies using the new-lunar ranging station being constructed in Hawaii, an accuracy goal of 2 to 3 centimeters has been set. Based on the results of these calculations, it appears it will be feasible to locate a moveable station to a 5-centimeter accuracy and by this means to determine strain buildup, and to map motions in the tectonic plates of the Earth's crust to establish their relation to earthquakes.

Space Support Activities

Skylab and ERTS Support.—Other NOAA support to the Skylab and ERTS programs included National Weather Service forecasts of cloud cover for use in scheduling Earth sensing experiments from Skylab, supporting aircraft, and ERTS–1. In addition, forecasts were made for Skylab launchings and recovery areas.

The NOAA Space Environment Laboratory provided continuous observations and forecasts of phenomena on the sun for daily planning of observations by Skylab astronauts with the Apollo Telescope Mount (ATM) experiment. The specialized needs of the ATM program were satisfied by a network of globally dispersed solar observations and by real-time data from ITOS satellites.

Computer Processing of Satellite Images.—Screening and reading the information content in large quantities of Earth satellite photographs pose formidable problems in coding, sorting, and analyzing the data. The National Bureau of Standards (NBS) has devised an automated computer image processing procedure which permits complex analysis of large-scale bulk data. This methodology permits more complete and more accurate use of the information content of satellite photographs in Earth resources and environmental surveys. Structural and dynamic behavior of significant geological features, resource distributions, pollution in rivers and oceans and crop and land population densities can now be subjected to sophisticated pattern analysis.

Humidity Instrumentation for Mars Viking Mission.—NBS has provided to NASA apparatus capable of generating reference frost-points in a simulated Martian atmosphere and has designed procedures for calibrating sensors to be used on the Mars Viking Mission.

NBS has developed a continuous-flow humidity generator for experimental use by NASA in evaluation of life-support breathing systems.

Radiation Effects Studies.—NBS continues to provide NASA-Goddard with information about the efforts of radiation on electronic components and semiconductor materials. Recent studies deal with the effects of nuclear radiation on microwave (mixer) diodes used for communications and radar systems. Results of these studies will be of use in the design of shielding to prevent equipment failure under exposure to space radiation. These studies are complemented by calculations of the energy transport of high-energy radiation and the deposition of this energy by impact on various materials to determine the effectiveness of radiation shielding.

Cryogenic Technology.—NBS is engaged in special studies for NASA to establish engineering data and techniques needed to evaluate the future use of liquid-solid (slush) and solid hydrogen as an improved space vehicle fuel. These studies will provide NASA with basic data and engineering information on cryogenic fluids and systems for use in spacecraft application. Technical data on the thermal, electrical, and mechanical properties of metals at cryogenic temperatures, and criteria for selection of reliable materials have recently been furnished to NASA.

Analysis of Apollo Lunar Samples.—NBS is determining the chemical and isotopic composition of lunar samples collected on the various Apollo missions. Analyses of Apollo 14, 15, and 16 samples are complete, and work on Apollo 17 samples is well underway. A variety of high precision and accurate analytical techniques are being used in the analysis.

Early work indicated the concentrations of many elements in lunar materials were remarkably similar to those in terrestrial materials, and their isotopic abundances were identical to those found in Earth samples. Recently, however, unique isotopic differences have been found in lunar materials, most notably in the element potassium, where the ratios vary by more than 1 percent in lunar soils. The presence of these variations in isotopic abundances could have important implications in future theories about the formation and the source of lunar soils.

Space Shuttle Experiments.—NBS is assisting NASA in efforts to utilize the Space Shuttle as an orbital workshop for materials science and manufacturing in a zero gravity and vacuum environment. Projects include research and development in crystal growth, purification of materials, physical processes in fluids, and preparation of composite materials. These projects are expected to yield new and innovative materials processing methods of broad commercial importance.

Measurements and Calibrations.—NBS develops many measurement techniques and calibration procedures for NASA. These are used to evaluate the design and monitor the performance of electronic equipment used in communications, satellite tracking and spacecraft control equipment, optical and radiation detection systems used in space experiments, and temperatures and mechanical sensors used to insure adequate performance of aircraft and spacecraft. This program includes antenna measurements, electronics design, performance specifications, radar network evaluations, vibration and shock instrumentation, and the design of humidity sensors for water vapor determinations.

NBS has provided several calibrated antenna horns to the Jet Propulsion Laboratory for monitoring the performance of its Deep Space Tracking Station. The station's massive antenna array is being used for space communications, radio-astronomy observations, and radar mapping of Venus. Assistance was also provided to help the Army determine the radar efficiency of a satellite ground station.

Skylab radiometer systems measurements were evaluated and recommendations were made for improved measurement procedures. Special facilities were established at NBS to test windows of the Skylab spacecraft for structural integrity and to estimate their life under operating conditions.

NBS also is calibrating instrumentation used in upper-atmosphere and space measurements of gamma ray intensity and distribution profiles, and is working on the design of a high resolution solar spectrometer for space use. The Bureau calibrates the ultraviolet radiation detectors used on space missions and furnished vacuum ultraviolet calibrations for the Skylab mission.

Atmospheric and Solar 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 gaseous species, has developed several models of active regions in the solar chromosphere. Proposed models of the lower chromosphere and upper photosphere of the sun, including descriptions of the chromospheric network, supergranule cells, plaques, and sun spots, are being compared with solar observations.

Kinetic and photochemical processes in planetary atmospheres are the subject of continuing studies at NBS. Photochemical studies of the reactions of carbon, methane, and methane radicals with various substances are expected to provide significant insight into the atmospheric chemistry of Jupiter whose major constituent is methane.

Ionospheric Physics.—NOAA's Aeronomy Laboratory, in collaboration with the Institut de Physique du Globe, Paris, made radar observations of electron irregularities in the equatorial electrojet from two sites in Chad,

Africa, during the June 30, 1973, solar eclipse. The purpose was to observe the effects of the reduced electron densities during the eclipse on the distribution of irregularities and electrical currents in the electrojet. These observations will contribute toward the development of a better model of the electrojet, which can be an important medium of communication in equatorial countries.

NOAA's Aeronomy Laboratory has discovered that ground-based measurements of twilight emission from molecular oxygen can be used to observe both ozone densities and atmospheric temperatures at altitudes of 80 to 120 kilometers. These emissions in the night-glow yield mesospheric temperatures that show major fluctuations at midlatitudes for several days after auroral-zone geomagnetic activity. NOAA's Air Resources Laboratories are studying coincident stratospheric ozone and water vapor data to determine possible relationship between these constitutents. The Laboratories also are studying data from the NASA Backscatter Ultraviolet (BUV) instrument to provide a benchmark of global total ozone amount (2–3 year data record) for comparison with future data, and also to determine if any impact on increased oxides of nitrogen (NO_x) is observable in the data obtained near the time of several recent nuclear detonations. Results of these studies also should be useful for assessing the impact of supersonic aircraft on the environment.

Atmospheric Photochemistry.—In assisting the Department of Transportation (DOT), NBS has determined what data are needed to assess the impact of high altitude aircraft on the chemistry of the stratosphere. Critical data evaluations have been prepared on the photochemistry of various important reactions in the Earth's atmosphere. NBS also has made measurements of radiation extinction coefficients of NO_2 in the near ultraviolet region. This information provides the technical basis for determining the photochemical behavior of pollutants in the Earth's atmosphere.

Aeronautical Programs

Aeronautical Navigation and Communications.—The Office of Telecommunications (OT) is preparing a handbook for the Federal Aviation Administration (FAA) on the problems of performance degradation in radar communications and navigation systems caused by multipath phenomena in propagation links. Such multipath degradation results in loss of communications, ambiguity in radar systems, and errors in navigation equipment for worldwide aeronautical applications.

A preliminary study also was completed to determine the feasibility of navigating aircraft on Loran-C skywaves to great distances from transmitters. Since the Loran-C chains cover a large part of the Northern Hemisphere with skywaves, precision navigation may be quite possible in areas remote from transmitters, particularly in the vast areas of the Pacific Ocean.

Safety Services for Aeronautics.—In support of the FAA, OT is making extensive laboratory measurements of three potential aircraft collision avoidance systems to determine their electromagnetic compatibility with existing radar altimeters and with a proposed air mobile satellite avionics system. These measurements are a critical part of determining the most effective Collision Avoidance System.

The NOAA National Severe Storms Laboratory conducted experiments, utilizing dual Doppler radars, to obtain information on the processes that occur in and around severe storms such as thunderstorms and tornadoes. Among the parameters explored were turbulence, winds, and wind shear. Also investigated were possibilities for using Doppler radar to detect signs of severe weather development.

The Aeronomy Laboratory has developed a radar technique for detecting flying birds hazardous to aircraft near airport runways. The technique uses the distinctive Doppler radar spectrum arising from the moving wings of the birds to distinguish the size and species of the birds observed.

The National Bureau of Standards is helping the Federal Aviation Administration to improve the utilization of available air-ground navigational and communications channels. Through its continuing program in illumination technology, NBS has developed procedures for the evaluation and design of aircraft landing lights, airfield lighting systems, and cockpit illumination. International standards on colors of signal lights have been completed and approved. A major part of these studies was determining the limits of navigational seeing under various atmospheric viewing conditions.

NBS continues to provide information related to aerospace fire safety to the NASA Aerospace Safety Research Data Institute. Data on fire growth in enclosures and NBS studies of smoke and gases produced by burning aircraft interior materials have been used for evaluating potential hazards and for designing fire extinguishing procedures to be used in oxygen enriched atmospheres under reduced gravity. NBS is also field testing NASA-developed fire protective clothing to assess its usefulness for firefighters.

Use of Remote Sensing to Study Coastal Processes.—Airborne and spacecraft remote sensors are being evaluated for use in studying and monitoring coastal processes and estuarine dynamics, and in cartography. A photographic and thermal remote sensing survey was conducted in Boston Harbor to investigate circulatory patterns and to develop new remote sensing techniques

for water quality studies. The circulatory survey will provide additional data for charting tidal currents; the data also will be included in the Tidal Current Tables published by the National Ocean Survey.

Aeronautical Charts.—Two new Controller Chart Supplements have been prepared for the Federal Aviation Administration and updated on prescribed revision cycles. The supplements are Alaska, Hawaii, and Puerto Rico Airways and Standard Terminal Arrival Routes. These supplements provide precise geographic position information along airways and routes not otherwise readily available to Air Traffic Facility personnel for the management and control of air traffic.

The Federal Aviation Administration, the Defense Mapping Agency, and the National Ocean Survey agreed on the production of a joint civil/military issue of combined Alaska Terminal (Airport) publications. The publication will be produced every 56 days and will include Instrument Approach Precedure Charts, Standard Instrument Departure Charts, and Standard Terminal Arrival Routes.

Support to Environmental Programs.—Aircraft equipped with remote sensors designed to measure water equivalent of snow and soil moisture were flown on field surveys over the Lake Ontario basin in support of the IFYGL. During the winter of 1972–73, surveys were flown along 28 selected ground tracks; water equivalent of snow was computed for each mile segment of track flown. Ground surveys provided corroborating information for evaluating soil moisture measurements obtained by remote sensing.

Environmental Data Programs

The National Geophysical and Solar-Terrestrial Data Center, (NGSDC), of NOAA's Environmental Data Service (EDS), in its capacity as World Data Center A for Solar-Terrestrial Physics, is collecting reports of the times and nature of solar observations made by ground-based observatories, rockets, and satellites that coincide with Skylab solar observations. Global scientists are interpreting Skylab observations by comparing them with the many different types of ground-based observations made during the same time periods. NGSDC has already produced a preliminary data catalog covering the period May 28 through June 21, 1973, when the first group of Skylab astronauts were on duty, and for the intervening period before the second Skylab manned mission began, when some experiments were running automatically.

Data users can now obtain from NGSDC 35-millimeter film copies of auroral photographs taken by U.S. Air Force DAPP (Data Acquisition and Processing Program) satellites. The auroral phenomena are photographed on the dark side of the Earth by these satellites. The ground features that appear in the photographs are useful for locating the position of the aurora with respect to the ground.

XII United States Information Agency

Introduction

In the first post-Apollo year, the U.S. Information Agency shifted emphasis in its space programing from the challenge of lunar exploration and the scientific benefits obtained, to Skylab and other space technologies that hold or promise direct benefits to man.

The Skylab missions, with their focus on Earth, the Sun, and man, received the most attention from USIA media. Of all space missions this year, they also carried the widest impact abroad. The Mariner 10 mission to Venus and Mercury, and Pioneer 10's flight to Jupiter, together with Skylab, were treated as the most ambitious examination of the solar system to come out of the space age.

The Moon landings and the Apollo astronauts continued to hold attention overseas and to build up goodwill for the United States. The Apollo 10 spacecraft was viewed by a quarter of the people of France during exhibits in that country. A tour by the Apollo 17 astronauts, who criss-crossed the equator from east to west to visit 12 countries between Dakar and Saipan, was highly successful; USIA was cosponsor with NASA and the State Department, and USIA officers served as escort and advance men. Five lunar rocks, placed under USIA control by NASA after the first Moon landing and already seen in most countries of the world, continued to draw crowds in the fourth year of circulation.

Astronaut Jack Schmitt addressed the Latin-American Geological Congress in Caracas, Venezuela, and Astronaut Ronald Evans, also of the Apollo 17 crew, appeared in Guatemala City to be at the Guatemala Fair and to speak to Guatemalans on lunar discoveries. A mockup of the Skylab workshop and a replica of the lunar rover at the Teheran Fair drew such crowds that the police had to shut down the U.S. pavilion temporarily.

While USIA used all its media to tell the story of space, various special events arranged by the Agency and posts, frequently in collaboration with NASA and the Smithsonian Institution, produced unusual results, and had special impact on foreign audiences.

Radio

Skylab was easily the leading space story on the Voice of America during the year. In addition to live coverage carried on special broadcasts in English, the VOA Science Editor prepared 129 special programs on all aspects of Skylab. These were carried on regularly scheduled broadcasts in all 36 languages, as were 150 reports by correspondents.

Virtually every aspect of Skylab was covered, as these sample titles indicate: "The Skylab Cluster," "Skylab Wardrobe," "Medical Care in Space," "The Tool Chest," "Many Nations Will Use Skylab Results," and "Skylab: A Promise More than Fulfilled."

Altogether the Voice devoted over 400 hours of broadcast time to space, using close to 3,500 features, interviews, and reports on space.

VOA reported fully on the Pioneer and Mariner 10 probes, on results from the Earth Technology Resources satellite, and on preparations for the Apollo-Soyuz mission. The cosmonauts were interviewed in Houston and Los Angeles, and the U.S.-Soviet conferences in Moscow and Washington were covered. The European Spacelab agreement was prominently featured. So were Space Shuttle developments.

Press and Publications

The Agency's Press and Publications Service, which reaches many newspapers and audiences not serviced by U.S. commercial news services, was especially active. Over 120 stories and 350 photos and drawings on space were distributed overseas during the year. About half the articles were carried on the Agency's Wireless File—the audioteletype system connecting Washington with United States Information Service (USIS) posts daily.

UIA publications carried 26 space stories and 61 photos, and an Agency-prepared pamphlet, "Project Apollo," received worldwide distribution. The Pictures Branch supplied over 150 black and white and color items to posts. Among these were pictures screened from the 27,000 Earth photographs taken by Skylab crews, and many of the 100,000 terrain pictures from

the Earth Resources Technology Satellite selected for distribution by USIS posts in appropriate regions.

Thirty Wireless File stories on the 87 days two Skylab crews spent in orbit emphasized that this record voyage was devoted to research to advance science and technology for the benefit of man. Typical headlines on the articles read: "Skylab Shows How Space May Become Major Resource," and "Immediate Uses Foreseen for Skylab's Earth Observations."

Weeks before Skylab's initial launch, science writers and radio and television space specialists abroad received a Press Service packet of 21,000 words containing an outline of the missions, interviews of the astronauts with photos, and a four-part series on Skylab's scientific and technical aspects. Skylab Sighting Predictions over various countries, furnished by NASA, were sent out biweekly by wireless.

Pioneer 10's journey to Jupiter was covered, prelaunch, in two Wireless File articles, "Jupiter Launch to Open Big U.S. Space Year," and "U.S. Spacecraft Proves Distant Universe Accessible." All posts received for distribution a special article written by Dr. A. H. Abdel-Ghani, Chief of the Outer Space Affairs Division of the United Nations, "What Space Exploration Means to Developing Nations."

America Illustrated, USIA's monthly magazine distributed in the U.S.S.R. and Poland, used 10 space stories, 5 of them in a special issue on the 500th anniversary of the birth of the Polish astronomer, Copernicus. Another issue carried three stories on Skylab, while stories on weather satellites and the mapping of Mars by space satellites appeared in other issues.

Topic, distributed in sub-Sahara Africa, carried six space stories, one of them on the value to agriculture of ERTS and another on Dr. George Carruthers, the black-American scientist who designed the camera spectograph left on the Moon. *Al Majal,* distributed in Arabic-speaking countries, published three space stories, *Economic Impact,* one, and *Insight,* a London USIS magazine, ran a piece on the U.S. Viking project for landing on Mars in 1976.

The Special Projects Office collected from business and commercial publications 20 space stories and 153 photos, drawings, or paintings placed in local newspapers and magazines by posts, or used in post-produced magazines and pamphlets. Among these were a National Geographic Magazine painting of all 32 Apollo astronauts on a simulated lunar surface, distributed as a poster in the U.S.S.R. and Poland, and an article and 11 pictures on Apollo-Soyuz from Rockwell International's *Skyline* magazine.

Motion Pictures and Television

This medium of the Agency used various means to tell the space story. "Science Report," a half-hour monthly report distributed by posts in 95 countries to national television networks, ran seven major segments on space. These included the complete story of Apollo 17, two films on the Earth Resources Technology Satellite, and pre- and postlaunch reports on Skylab.

"Ahora," a monthly television series for 17 Latin-American countries, produced "New Star in the Sky," a review of what Earth satellites do for man. An Indonesian series, "Laporan Dari Amerika," produced a special on Skylab. Two other television series shown worldwide, "Vision U.S.A." and "Washington Correspondent," featured Skylab reports.

NASA's film on Apollo 17, "On the Shoulders of Giants," was distributed in 126 prints (77 English, 23 French, 12 Spanish, 8 Russian, 2 Romanian, 4 Polish). Fully 291 prints of the NASA Apollo 16 film, "Promise of the Moon," were distributed in 16 languages. Also distributed were NASA's "New View of Space," on uses of photography in the space program, and three NASA backgrounders for television on Skylab, ocean research, and the Apollo-Soyuz project.

A dozen film clips on Apollo 17 and Skylab were distributed worldwide for use in telecasts and newsreels abroad. Through the U.S. Mission to International Organizations in Geneva, two NASA films were offered to foreign television systems; one of them, "A Man's Reach Should Exceed His Grasp," getting screening in nine European countries as well as Korea, Israel, Singapore, Qatar, Pakistan, Sudan, Kuwait, and Libya.

At the Skylab launch, television facilities for "stand-up" programs at the launch site were arranged for a half-dozen European commentators. USIS posts in 12 countries worked to program astronauts or otherwise support space programs on television—in Paris, Raymond Loewy, designer of the Skylab interior, appeared on a prime-time network talk show. In Buenos Aires, the post arranged two television talk shows for Astronauts Donald Slayton and James Lovell, while in Sarajevo, Yugoslavia, USIS-provided space photos were used on a Skylab TV program.

The Agency has placed a wide variety of Agency- and NASA-produced space films in 28 film festivals abroad. USIA's "Windfall from Space" was shown at the Brisbane Film Festival, while NASA's "Blue Planet" was seen at film festivals in Argentina, Brussels, Colombo, Cracow, Edinburgh, Grenoble, Islamabad, Rio de Janeiro, Trento, and Trieste. NASA's "New View of Space" won the Silver Cup and Diploma of Cinematographic Merit at the 20th International Exhibition of Special Cinematography in Rome.

Information Centers and Exhibits

World audiences viewing both major and minor space exhibits continued to be unquestionably positive in reaction. The Apollo 10 spacecraft generated attention in the press and on radio and television as it

moved through Central and Northern France, a quarter of the people in the nation filing past it for a close look. Officials at the Lyons, Strasbourg, and Metz Fairs, where Apollo 10 was shown, insisted the 10- to 16-percent increase in attendance over the previous year was due to the Apollo hardware. Apollo 10 proved to be the centerpiece attraction at the Marseilles Fair in the autumn.

At the Izmir International Fair in Turkey, Soviet space hardware was shown in the Soviet pavilion, while the U.S. pavilion exhibited a Moon rock, the spacesuit and helmet of Astronaut James Lovell, and the visor worn by Astronaut Edwin E. Aldrin on the first Moon landing. At the Intercamera Exhibit in Prague, space as seen by the astronauts was shown in 26 color transparencies and photo panels, together with a Moon rock and a photomural of the lunar surface. In Poznan, Poland the U.S. exhibit at the World Philatelic Exposition was easily the most popular attraction. In the Copernicus Pavilion, USIA has assembled a "Moon Letter," cancelled on the moon by the Apollo 15 astronauts, plus a Moon rock and lunar exploration tools. At a Warsaw event commemorating the 500th anniversary of the birth of Copernicus, a U.S. exhibit featured instruments used in lunar exploration.

The mockup of the Skylab workshop presented in full size at the Teheran Fair, together with a full size Lunar Rover was credited with getting the Teheran Fair in Iran off to a smashing start. Preopening press and video coverage concentrated on the space items in the U.S. exhibit. Opening attendance soared, and police were forced to close, briefly, the U.S. pavilion before restoring order. An Iranian viewing the U.S. exhibit commented, "Really, what we are seeing is the magic of USA."

The Information Center Service continued to provide posts with lunar maps, space posters, models, and slides.

Eight new titles of books on space were added to the "Current Books" list recommended for USIS libraries. The Agency published seven books on space; Richard S. Lewis' "Appointment on the Moon," the story of the first Moon landing, was serialized for publication in Bengali in India, and John Noble Wilford's "We Reach the Moon" was published in Chinese.

Summary

The bulk of the Agency's communications effort on the subject of space went into publicizing the Skylab missions as potential sources of practical benefits to man. Agency media emphasized this theme in Voice of America broadcasts, in motion pictures and television, and in dozens of news stories and magazine articles. The same theme was used in Agency coverage of the Earth Resources Technology Satellite and of the upcoming Space Shuttle. Other coverage emphasized the scientific benefits from the Mariner mission to Venus and Mercury and the Pioneer mission to Jupiter. Agency press, radio, and films officers overseas worked to place special stories, provide film on space activities, arrange television facilities for covering space, and place broadcasts of space activities on national networks abroad. It was typical of the Agency's involvement that when the press service's chief space correspondent lectured on "Space in the Seventies" to audiences in East Asia, and the Agency's science adviser spoke to scientific groups in East Europe on Skylab, both officers, while not representing NASA directly, were received as expert analysts and authoritative space spokesmen by their audiences.

XIII National Science Foundation

Introduction

The National Science Foundation is an independent agency established to promote the progress of science through the support of research and education in all fields of science and in engineering. A number of NSF programs contribute to the aeronautics and space sciences, principally scientific research project support, the polar research programs and a variety of educational programs including institutes and fellowships. Most of the research work supported by the Foundation in the aeronautics and space sciences is carried out by investigators affiliated with U.S. colleges and universities, many of whom use the specialized facilities available at the national research centers or the unique facilities of the Antarctic Continent. While the activities carried out with Foundation support rarely result directly in the production of material for commercial use, they are directed to improving our understanding of natural phenomena from which stem new opportunities for further technological accomplishment.

Astronomy

The U.S. effort relating to the June 30, 1973 total solar eclipse was coordinated by the National Science Foundation. Support was provided for two major scientific expeditions to Africa comprising 38 major experiments manned by approximately 100 scientists and technicians: one expedition site was located in Chinguetti, Mauritania (West Africa) and the other in Loiyengalani, Kenya (East Africa). Smaller groups were supported at three other sites, including one in Chad, as well as at sea and aboard aircraft. Infrared emission and the polarization of different parts of the Sun's corona were measured; the apparent positions of stars near the sun were recorded to test the theory of the relativistic bending of light; and the time variations in the Sun's corona and chromosphere were recorded with instruments flown on the French Concorde SST aircraft. In the more distant universe, one of the most important discoveries has been the observation of two quasars with the largest red shifts ever observed. These objects provide information on the state of the universe in its very earliest stage. Other important work includes theoretical calculations on how a star develops into a supernova which has improved our understanding of the mechanism of stellar exposion. Other events of importance in astronomy are discussed in the following paragraphs.

Kitt Peak National Observatory.—The purpose of the Kitt Peak National Observatory is to provide the U.S. scientific community with facilities for astronomical research in the fields of stellar, solar, planetary, galactic, and extragalactic astronomy. The facilities include nine ground-based telescopes and the instrumentation necessary to make astronomical observations in the optical and infrared regions of the electromagnetic spectrum. The major observing facilities are located at an elevation of 6,800 feet on Kitt Peak, 40 miles southwest of Tucson, Ariz. The research programs conducted at KPNO increase our knowledge about the origin and evolution of stars, the physics of the outer layer of the Sun, and the characteristics of planetary atmospheres. Using the 4-meter Mayall telescope that was dedicated in June 1973, astronomers at KPNO have initiated new observing programs directed toward the study of nebulae, pulsars, quasars, and other faint galactic and extragalactic objects. Among the highlights during the calendar year were observations of a new class of galaxy called a "ring" galaxy. Galaxies of this type consist of a luminous elliptical ring and have either a displaced nucleus or none at all. These galaxies have nearby normal companion galaxies, believed to be triggering mechanisms for the formation of the "rings." The "ring" galaxies, composed of relatively young stars less than 100 million years old, are moving rapidly away from their normal companions. Astronomers believe these galaxies are collapsing clouds of interstellar gas.

National Radio Astronomy Observatory.—The National Radio Astronomy Observatory (NRAO) is headquartered in Charlottesville, Va., on the grounds of the University of Virginia. Three major radio telescope systems are operated at the principal observing site at Green Bank, W. Va. A 36-foot telescope de-

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signed to operate at millimeter wavelengths is located on Kitt Peak, near Tucson, Ariz., and a major new telescope designated the Very Large Array (VLA) is under construction near Socorro, N. Mex. During the year, visitor use of the 36-foot telescope resulted in the discovery of sulfur monoxide molecules in interstellar space. Because most of the 22 molecules discovered to date (for the most part at NRAO) are organic in nature, the discovery of an inorganic species is particularly significant. During the year, NRAO scientists have provided important new information tending to support the hypothesis that quasars are located at or near the edge of the observable universe.

National Astronomy and Ionosphere Center.—The unique, 1,000-foot diameter reflector of the radio/radar telescope at the Arecibo (Puerto Rico) Observatory of the National Astronomy and Ionosphere Center (NAIC) has been resurfaced with 38,000 aluminum panels. The smoother surface, completed in 1973, is capable of adjustment to within ⅛ inch of the contour of a true sphere 1,740 feet in diameter, and will permit radio astronomy research operations to wavelengths as short as 4.2 centimeters. The National Aeronautics and Space Administration is sponsoring the installation of a high-power S-band radar transmitter on the feed platform suspended high above the reflector. The transmitter is designed to take advantage of the upgraded surface for radar astronomy research directed to mapping the surface of Venus with a resolution of about 1 mile. The ionospheric physics research program concerned with the complicated processes that govern the behavior of the upper atmosphere has been continued during these upgrading activities. A new technique of continually sweeping a 430-megahertz radar beam for backscatter measurements has been successfully applied to the measurement of three-dimensional vector velocities in the F-region. A sufficiently short time resolution has been obtained to show that the nighttime ionospheric plasma is given a distinctive east-west motion as a result of interaction with the winds in the neutral atmosphere.

Cerro Tololo Inter-American Observatory (Chile).—The Cerro Tololo Inter-American Observatory (CTIO) was established in Chile, South America, to provide a visitor-oriented astronomical research facility in the Southern Hemisphere for the U.S. scientific community. During calendar year 1973, CTIO operated and maintained, at the observing site on Cerro Tololo, six major optical telescopes. In addition, a dome and building are nearing completion to house the recently relocated 1.0-meter reflector of the Yale University Observatory. During the past year, visiting astronomers conducted successful searches for the optical counterparts of X-ray sources. Using positions determined by satellite observations, one group of investigators found an optical component of an X-ray source in a neighboring galaxy, the Small Magellanic Cloud. The source is a binary system whose primary is a luminous young star and the secondary an invisible source believed to be a collapsed "neutron star." In addition, studies of X-ray sources located in our galaxy revealed a source associated with a spectroscopic binary system. The mass of the X-ray source was estimated at 2.5 solar masses, a value in excess of that permitted for neutron stars. This object is regarded as a possible "black hole," a compact stellar body whose gravitational field is so strong that no electromagnetic radiation can escape from it.

Atmospheric Sciences

Solar-Terrestrial Research.—The Solar-Terrestrial program is concerned with the space physics of the Earth's environment and the interaction of this environment with the earth's atmosphere. Topics studied include the outer reaches of the solar atmosphere, the interplanetary plasma, and the Earth's magnetosphere. The normal Sun continuously forces out from its surface a flow of charged particles—the Solar Wind. Intermittently, much smaller numbers of particles in disturbed solar regions are accelerated to high energies, by mechanisms not yet understood, and are spewed into space. A large part of the program is devoted to these particles and their interactions. Optical and radio studies of the dynamics of the atmosphere are supported. Investigations of the Solar Wind which use cosmic rays as a probing tool are funded. Observational and theoretical research on the interaction of the Solar Wind with the Earth's magnetosphere and the atmospheres of other planets are sponsored. Major attention is also devoted to the Earth's magnetosphere and particles and fields in it. Trapping and release of particles, wave-particle interactions, currents and magnetic fields, are all associated with spectacular aurora, magnetic storms, interference with radio, long-line telephonic communication, and with surges on large power networks. During the year progress was made on several new areas. For example, a study of radio waves transmitted from the Antarctic, through the magnetosphere and received in Canada, unexpectedly showed that the North America electric power grid is depositing energy in the near-earth magnetosphere. Analysis of this new effect will be continued. Other new results indicated space-weather coupling and a quantitative understanding of magnetospheric electric fields.

Aeronomy.—The atmosphere of the Earth from an altitude of about 50 kilometers to roughly 1,000 kilometers is generally taken as the domain of aeronomy. The Foundation supports theoretical and field studies of phenomena which 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 now involve the auroral zone in Alaska and center about an incoherent scatter radar located near Fairbanks. Striking new information about electric currents and winds in the high atmosphere is being obtained. Ionospheric instabilities in the tropics involving complicated plasma phenomena are of considerable current interest. The atmospheres of the other planets are being investigated as testing grounds for theories developed for the Earth's high atmosphere.

Meteorology.—A broad range of investigations into the dynamical and physical behavior of the atmosphere is supported, including field observations, laboratory experiments, and theoretical and numerical analysis of the data together with the development of techniques for remote sensing. An area applicable to space sciences is the development of techniques for remote sensing of atmospheric motions, and particulate and gaseous species. A variety of radar and lidar studies are supported, together with other investigations aimed at monitoring the build-up of carbon dioxide in the global atmosphere and changes in concentrations of atmospheric particulates. In this latter category, the records of a variety of astronomical observatories around the world are being analyzed for atmospheric turbidity changes over the past 50 years.

National Center for Atmospheric Research (NCAR).—In May 1973, the Skylab space station was launched. The successful operation of NCAR's White Light Coronagraph experiment, developed under NASA sponsorship and installed on the Apollo Telescope Mount portion of Skylab, was the culmination of 10 years of effort by NCAR staff. Three film magazines totaling some 20,000 frames of coronal photographs have been returned to Earth by the astronauts thus far, and the quality of the pictures has exceeded all expectations. Much fine detail can be seen in the coronal structure, and a wide variety of changes in the corona, some induced by solar flares, has been documented. The instrument has performed without serious problems, and the staff anticipates that it will continue to gather excellent data during the remainder of Skylab's mission.

NCAR scientists have developed an airborne instrumentation system to measure basic properties of atmospheric aerosols which have significant effects on propagation of light in the atmosphere. The instrument was flown on the NASA Convair 990 Airborne Laboratory during January 1973, to measure size-number distribution, scattering phase function (angular variation of scattered-light intensity), and refractive index of atmospheric participates throughout the troposphere and lower stratosphere. Additional measurements were carried out in cooperation with the NASA Marshall Space Flight Center to provide data necessary for interpretation of their tests of an airborne laser device for detecting clear air turbulence. Isotopic studies of sulfate and nitric acid vapor in the stratosphere have shown a similar composition in both hemispheres. This tentatively rules out manmade pollution as the prime source of atmospheric sulfur and points to natural phenomena (e.g. volcanoes) as the prime causes for this contamination. Isotopic studies of nitrogen are underway to discover if the source of nitric acid vapor is the photodissociation of molecular nitrogen at very high altitudes or the oxidation of nitrous oxide. These studies are important in determining the impact of supersonic aircraft on the stratosphere. Members of the Upper Air Project (UAP), in conjunction with Florida State University, Drexel University, and NASA, have been developing a series of experiments for remotely determining the vertical distributions of temperature and chemical constituents in the stratosphere on a global scale. The first of these experiments is scheduled for flight on Nimbus–F in 1974 and a more comprehensive set of measurements will be provided for Nimbus–G in 1978.

Engineering

Fundamental areas of engineering research which are directly related to space and aeronautical applications are supported. Stability and laminar to turbulent transition, unsteady boundary-layers, laminar-turbulent interface represent some of the currently supported areas. Emphasis has been on the understanding of the basic physical phenomena and to reduce empiricism. Support has also been provided in the areas of vortex formation and decay, unsteady wake structure, and computational fluid mechanics. A continuing effort is being made to upgrade laboratory instrumentation and to support the development of dynamic measurement and real-time data processing techniques.

Materials Research

Two areas of research currently underway in fundamental properties of materials are potentially of importance to the aeronautics and space-related materials field: mechanical properties and electronic properties of solids. In the former, investigations include the propagation of shock waves through materials to study dislocation motion and its relation to mechanisms of dynamic failure—a type of failure not evident in a static environment; theoretical studies of deformation at high strain rates to provide information of possible failure mechanisms resulting from meteorite impact, and efforts to strengthen copper-titanium alloys without compromising corrosion resistance or

fabricability. Recent studies of the electronic properties of materials include: alloying compounds to produce materials having enhanced luminescent properties for use as diodes, and thin-film nucleation, growth, and diffusion research for the development of coatings for solar energy collectors. Other space-related investigations include work with energy storage mechanisms and environmental properties of materials.

Chemistry

The NSF supports a broad program of research in modern chemistry. Although terrestrially based and aimed largely at solving Earth-bound problems, this research creates knowledge that is essential for progress in the aeronautics and space sciences. For example, research in chemical analysis leads to improved methods for characterizing and understanding matter, ranging from new materials for space vehicles to the chemical composition of interstellar space. The identification of new molecules and the study of molecule formation in space is made possible by the prior chemical synthesis and spectroscopic analysis of molecules on Earth.

U.S. Antarctic Research Program

Siple Station, 950 miles from the South Pole, had its first full year of operation in 1973. Primary feature of the station is a 13-mile long dipole antenna that transmits very low frequency signals (vlf) into the magnetosphere. In 1973, scientists at Siple succeeded in transmitting a series of vlf signals that were detected at the magnetically conjugate station near Roberval, Quebec. Analysis resulted in the discovery that emissions caused by alternating the transmissions between two frequencies are somehow "trapped" between the two frequencies. Also, a vlf receiver on Explorer 45 received Siple transmissions while at 10,000 miles altitude and 14° north of the equator. This was the first time that a satellite received signals ducted along magnetic field lines.

Education Activities

In fiscal year 1973 the Foundation's Education Directorate obligated $989,251 for activities which were related to the aeronautic and space sciences. The greatest proportion of those funds supported the training of 61 graduate students through fellowships and traineeships. These funds also provided for upgrading the aeronautic and space sciences subject matter background of 164 teachers in secondary schools and 44 faculty in colleges and universities. Also supported were projects wherein 209 superior secondary school students obtained unusual independent study and research experiences related to the aeronautic and space sciences and 13 projects designed to improve instructional programs in these disciplines at the undergraduate level of education.

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

Introduction

The National Academy of Sciences (NAS) and the National Academy of Engineering (NAE) are private organizations dedicated to the furtherance of science and engineering and their use for the general welfare. The charter of the 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 Academy of Engineering 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.

Highlights of the work of the Academies-Research Council during 1973 in aeronautics and space include a special study by the Space Science Board on the scientific uses of the Space Shuttle; the Aeronautics and Space Engineering Board's counselling on future directions in commercial aircraft and on engineering and management aspects of the Space Shuttle; recommendations of the Space Applications Board on practical uses of space systems; studies of high-altitude aircraft effects by the Climatic Impact Committee and Committee on Toxicology; studies on noise and vision by committees of the Assembly of Behavioral and Social Sciences; applications of remote-sensing programs to Earth resources surveys and the International Hydrological Decade; advice on aerospace materials by the National Materials Advisory Board; the Committee on Atmospheric Sciences' reports on atmospheric chemistry and weather modification; and planning for participation in the Global Atmospheric Research Program and International Magnetospheric Study.

Space Science Board (NRC)

The Space Science Board is a consultative group concerned with shaping the most effective national program in space research. The Board also acts as Academy representative to the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU).

Particular attention during the year was given to scientific uses of the Space Shuttle, flight programs in astronomy, cooperative experiments for the joint U.S.-U.S.S.R. manned space mission in 1975, biological effects of high-energy ions, and maintenance of a viable and balanced program of space science in an era of constrained budgets. In April 1973, the Board's chairman presented testimony on the space-science program to the Senate Committee on Aeronautical and Space Sciences. Close liaison was maintained with the National Academy of Engineering's Aeronautics and Space Engineering Board and Space Applications Board, and the Board is assisted by its specialized committees and panels.

A special study on Scientific Uses of the Space Shuttle, held in July 1973, with some 50 U.S. and 10 foreign scientists, focused on the scientific potential of NASA's space transportation system, to become operational in the 1980's; and it examined the usefulness of a shuttle-borne space laboratory and pallet to be developed by a European consortium. Findings and recommendations were presented informally to the NASA Administrator at the conclusion of the study and to members and staff of the House and Senate Space Committees in October. The report of the study will be published in early 1974.

Two new committees were established during 1973 to advise the Board on astronomy and planetary science. The Committee on Space Astronomy began its review of the NASA astronomy program, emphasizing plans for the restructured high-energy astronomy observatories (HEAO), the forthcoming orbiting solar observatory (OSO), and the proposed large space telescope (LST). The Committee on Planetary and Lunar Exploration, meeting for the first time in late November, began its activities with a briefing and review of the NASA planetary program.

The report of the Committee on Space Biology and Medicine's Radiobiological Advisory Panel, "HZE-Particle Effects in Manned Spaceflight," was published in April 1973. This report discusses the potential bio-

logical hazard of high-energy heavy ions in space and recommends a program of research, predominantly ground based, to pinpoint the hazard to man in long-duration space missions. A review of NASA's programs in microbiology by a committee panel evaluated both ground based research programs and operational plans for Skylab. Biomedical initiatives during the year included formation of a Panel on Renal and Metabolic Effects of Spaceflight to look into mechanisms responsible for physiological changes observed in manned space flight, and formation of an ad hoc Exobiology Panel to consider investigations after the Viking 1975 mission.

The Committee on International Relations assists and advises the Board, particularly on U.S. participation in the international Committee on Space Research (COSPAR). The chairman of the Committee also serves as the Academy's national representative and as vice president of COSPAR. In preparation for the 1973 COSPAR meeting in Konstanz, West Germany, an ad hoc panel of the Committee met to judge U.S. scientific papers and to make recommendations to the COSPAR Program Committee.

Aeronautics and Space Engineering Board (NAE)

The Aeronautics and Space Engineering Board (ASEB) was established in 1967 to provide advisory services in aeronautical and space engineering to interested Government agencies, principally NASA. During 1973 the ASEB continued its review of current and proposed NASA programs in aeronautics, especially those with greatest potential for the next generation of commercial aircraft. The Board continued considering other problems associated with the future of civil aviation research and development, as identified by the Joint NASA–DOT Policy Study Group on the subject; and in aerospace engineering, the ASEB continued its review of engineering and program management of the Space Shuttle. The Board has expressed a special interest in reducing costs of future space flight and experimentation.

Key ASEB members and staff participated in the Space Science Board's study on Scientific Uses of the Space Shuttle. Afterward, the two Boards met jointly to review the study's conclusions and recommendations. The ASEB maintains continuing contact with the Space Applications Board and plans to work more closely with both Boards in order to help insure optimal utilization of funds allocated to space research and applications.

The Board's conclusions and recommendations have been transmitted informally by its Chairman to the President of the Academy and to the Administrator of NASA. The Board will continue to stress research and development that is critical to achieving a dynamic, forward-looking, advantageous aeronautics and space engineering program.

Space Applications Board (NAE)

The Space Applications Board was established in 1973 to provide advice and recommendations to the Federal Government on applications of space techniques and capabilities and to stimulate collaboration among the pertinent components of Government and industry. The Board's membership is extremely broad, encompassing natural and social sciences, public affairs, and communications. Liaison is maintained with the relevant Academies' groups.

As its initial action, the Board identified for NASA the salient national problems that the practical application of space systems may help to resolve. It also advised NASA that institutional factors are pacing the rate at which space systems are being usefully applied; the Board now plans to examine how such factors may affect achievement of the potential benefits of Earth observations by satellities. From a preliminary review of NASA's space applications, the Board found that potential users and the general public are not sufficiently aware of some important capabilities of space systems; consequently it suggested to NASA some corrective measures, including preparation of manuals on the Earth Resources Technology Satellite, ERTS–1.

Climatic Impact Committee (NAS-NAE)

The Climatic Impact Committee (CIC) is a multidisciplinary group concerned with potential, inadvertent climate modification resulting from high-altitude aircraft or other manmade activities affecting the upper atmosphere and particularly the stratosphere. In its advisory role to the Department of Transportation and other Federal agencies, the tasks of CIC include: (1) advising on research priorities; (2) following the progress of research, especially that sponsored by DOT's Climatic Impact Assessment Program (CIAP); (3) predicting the effects, if any, of projected fleets of high-altitude aircraft on the Earth's climate, and the biological, social, and economic ramifications; and (4) advising on development of international regulations for high-altitude traffic to avoid climate degradation, risks to health and safety, and other undesirable consequences.

To accomplish these tasks, the Committee held regular meetings in 1973 and convened specialist panels in such fields as risk-benefit analysis and atmospheric modeling. It conducted a workshop on methodology in August 1973 as a precursor to a major study in 1974. The scope of problems addressed included possible global changes in ultraviolet light at the Earth's surface due to ozone depletion by aircraft engine effluents, possible changes in temperature and precipitation due to particulates of burned fuels introduced into

the stratosphere, corresponding biological effects, and the economic and social costs of such changes. The study's tasks included consideration of methods for projecting a realistic aircraft fleet size, including SST's and Space Shuttle, in the next 15 to 20 years; methods for estimating likely changes in climatologic factors based on projected fleets; methods for determining costs of designing and operating aircraft fleets that would produce no variations in the climatologic factors; and methods for applying regulatory constraints on high-altitude aircraft operation to insure no harmful effects. The conclusions of this study and the 1974 study will be published at the end of 1974.

Assembly of Behavioral and Social Sciences (NRC)

Committee on Hearing, Bio-Acoustics, and Biomechanics.—CHABA is advisory to the Federal Aviation Administration, NASA, DOT, the armed services, Environmental Protection Agency, and National Institutes of Neurological Diseases and Stroke and of Occupational Health and Safety. An ad hoc panel of the Committee assisted NASA in the preparation of the 1973 edition of Bioastronautics Data Book by selecting chapter authors and reviewers and guiding its progress to publication.

Several of the Committee's working groups are concerned with transportation noise. Advice was given to NASA, FAA, and EPA on the research that should be initiated or continued concerning noise near airports. A study undertaken in 1973 assesses the impact of aircraft noise resulting from closing Love Field and opening the Greater Dallas-Fort Worth Airport. A Committee group is recommending standards for noise levels within aircraft that are safe for hearing as well as levels that are acceptable for voice communication among crewmembers. The Committee works with DOT and FAA in advising on the U.S. position on the sonic boom for the International Civil Aviation Organization, and during 1973 it assisted FAA in reviewing and advising on contracts to investigate the effects of sonic boom on fish and wildlife. The Committee, on request, advises NASA on noise research proposals and critically reviews contractor reports.

In a broadly applicable study of research on crash injury, a CHABA working group advised interested agencies about restraint systems and protective helmets. The effects of sustained (30–40 second) linear accelerations of 6–8 g's from future fighter aircraft are also being investigated. The Committee periodically advises the NATO Advisory Group on Aerospace Research and Development on hearing and vision problems of NATO pilots.

Committee on Vision.—The substitution of simulators for aircraft in the training of pilots would permit a large reduction in the cost of many aerospace activities. A working group on Visual Elements in Flight Simulation surveyed the current state of technological development of simulation of the pilots' visual environment; a summary of its findings was published late in 1973.

Since many sources of radiation in the aerospace environment are potentially damaging to the eye, limits of tolerable exposures must be established. Current interpretations diverge on research results concerning safe levels of exposure to laser radiation; consequently, a working group has been formed to study retinal damage produced by exposure to both coherent and noncoherent radiation, ranging from the near-ultraviolet through the near-infrared portion of the spectrum.

Commission on Natural Resources (NRC)

Committee on Remote Sensing Programs for Earth Resource Surveys.—CORSPERS is advisory to the Departments of Interior (USGS), Commerce (NOAA), Agriculture, Navy, Army (Civil Works, U.S. Army Engineers), Environmental Protection Agency, and National Science Foundation on the use of remote sensing from spacecraft and aircraft platforms. It presently operates through eight panels: Biology, Cartography, Environmental Measurements, Geology, Geography, Hydrology, Information Management, and Oceanography. The Committee is engaged in a review of the usefulness of remotely sensed data, such as from the ERTS program. This usefulness will be related to the resource managemnt and the environmental monitoring responsibilities of the Federal agencies and State and local governmental interests.

Division of Earth Sciences (NRC)

U.S. National Committee for the International Hydrological Decade.—The Work Group on Remote Sensing in Hydrology of the U.S. National Committee for the International Hydrological Decade (IHD) is concerned with the applications of aeronautics and space-related activities to hydrological problems. The Work Group is preparing a report—"The Role of Remote Sensing in the International Hydrological Program"—that, in part, highlights how remote sensing can aid water resource research and day-to-day operations domestically in developing countries and internationally. The Work Group also helped plan the Interdisciplinary Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, held in December 1973. Space-related activities, which possess exceptional potential for management of snow and ice resources were among several areas of technological development discussed.

Division of Chemistry and Chemical Technology (NRC)

Advisory Center on Toxicology.—The Center serves as a central source of information and technical staff to enable the Committee on Toxicology to answer the specific questions presented by its 10-sponsoring agencies, one of which is NASA. In 1973, the Committee and the Center completed a 2-year review of possible deleterious effects of ozone on flightcrews in high-flying aircraft. Since ozone is an atmospheric constituent at altitudes above 30,000 feet, its presence in these aircraft is a real possibility. Because of limitations of the presently available data, it was not considered advisable to change the present threshold limit value of 0.1 parts per million. As more data become available, the Committee will reconsider the problem.

In conjunction with advice from the Space Science Board, Environmental Studies Board, and other groups within the Academies, the Center is currently investigating the environmental effects of the mercury-ion engine. NASA wants to use this engine in its solar electric propulsion system (SEPS) now under development, and it sought the Committee's advice for the necessary Environmental Impact Statement. The Center also served as liaison between NASA and manufacturers of various nonflammable substances such as Teflon, Vitron, and Fluorel. NASA was interested in the pyrolysis products of the substances and asked the Center to obtain any information from the manufacturers as well as pure samples of these materials.

Other questions from NASA during 1973 included: Possible irritation from exposure to printing inks thought to include cashew nut shell liquid; sensitization from Hoppe's Powder Solvent No. 9; identification of data on chronic continuous toxicity of methylchloroform; identification of compounds known to cause bone marrow depression; and association of polyurethane foam and pyrolysis products to loss of red blood cell mass and bone marrow suppression. The Skylab astronauts apparently had bone marrow suppression that NASA suspected to be a result of exposure to these products. But since no published indications of such an association were found, other possible causes were discussed with NASA.

Division of Engineering (NRC)

National Materials Advisory Board.—The Board's general goal is the advancement of materials science and engineering in the national interest; more specifically, it attempts to identify technical problems and to propose potential solutions. A significant part of the Board's activities are devoted to studying aerospace materials and furnishing advice to the Government and indirectly to industry and academia.

Early in 1973, the ad hoc Committee on Application of Fracture Prevention Principles to Aircraft completed its assessment of the latest concepts for fracture prevention. Its report (NMAB–302) reviewed the elements of current fracture controls plans and associated technologies, recommending some trade-off studies coupled with caution and flexibility in the use of existing criteria.

Several of the other studies completed in 1973 relate to materials in aerospace applications. A NMAB ad hoc committee, in its report "Materials Science Application and Coordination" (NMAB–299), provided suggestions for improving technology transfer and strengthening the role and utilization of voluntary standards in the development of Government regulations. The ad hoc Committee on Directional Solidification in its report (NMAB–301) provided a comprehensive evaluation of this emerging new technology. In a report "Opportunities in High-Pressure Technology" (NMAB–303), the potential applications of high-pressure technology, with particular reference to Department of Defense needs, were reviewed.

Several studies involving aerospace materials, initiated late in 1972 and in 1973, are continuing. Among them are: a study of materials for detecting electromagnetic radiation; a study to define the technical potential of HY-steel and titanium castings; a survey of needs and opportunities for adhesives for structural use in aerospace vehicles; a survey of the firesafety aspects of polymeric materials with attention to available materials, production costs, data requirements, test methods, and toxicity problems.

Division of Physical Sciences (NRC)

Committee on Atmospheric Sciences.—The Committee on Atmospheric Sciences, through its examination of scientific and technological advances, encourages research and development that will provide a balanced national program in atmospheric sciences. Two major studies were completed in 1973—"Weather and Climate Modification: Problems and Progress" (NAS, 1973) and "Atmospheric Chemistry: Problems and Scope" (in press).

These studies—in conjunction with an earlier study, "Atmospheric Sciences and Man's Needs" (NAS, 1971)—point to the necessity of a system of regional and global observations to meet increasing requirements for improved short- and long-term weather forecasting, better understanding of atmospheric chemical and photochemical processes, expanded research in weather modification potentials, and improved explanation of the interactive roles of the atmosphere, oceans, and land masses. Most such observations and measurements must be obtained by remote sensing devices, through an integrated system including ground-based, satellite, and aircraft-borne sensors.

Increasingly, data must be obtained from polar-orbiting and geostationary satellites on atmospheric

temperature, moisture, and trace constituents in order to cope with problems bearing on global weather, climate, and pollution. Also, space platforms will be utilized to gather data from remote platforms on the Earth's surface and in the atmosphere in regions where information is not now obtainable through conventional means. Studies of severe storms will likewise require satellite data to develop better forecasting capabilities and warning systems; moreover, studies must be undertaken to find ways to decrease the severity of violent storms.

These efforts will require advanced computer models. Experimental studies of the atmosphere and oceans are presently both data- and computer-limited.

U.S. Committee for the Global Atmospheric Research Program.—The Global Atmospheric Research Program (GARP), an international effort, is being developed through the International Council of Scientific Unions (ICSU) and the World Meteorological organization (WMO). GARP's primary objective is to provide a sound physical and mathematical basis for extended prediction of the large-scale atmospheric motions; in addition, GARP will provide data for experimental studies of numerical climatic models for the globe.

The U.S. Committee for GARP serves as the principal scientific mechanism for the formulation of U.S. scientific objectives and plans, specification of observational and measurement requirements, and for assistance in the detailed design and planning of experiments. The USC–GARP has been serving as the communication link, both nationally and internationally, between scientists and Government.

The first major field experiment, the GARP Atlantic Tropical Experiment (GATE), will be carried out during June–September 1974. It will emphasize the study of the interaction and interdependence of convective and synoptic scales of motions in the tropics, which in turn interact with atmospheric processes at higher latitudes. The observational phase of GATE will involve ships, aircraft, buoys, balloons, and polar-orbiting, and geosynchronous satellites. A geostationary satellite, singled out by scientists as the most important element of the program, will provide 24-hour imaging of tropical cloud systems.

A second major program of the GARP will be initiated in 1977, to obtain similar data on a global scale. In this way GARP will contribute to improved global weather services and to a better understanding of the physical basis for climatic variations.

Committee on Solar-Terrestrial Research.—The Committee on Solar-Terrestrial Research (CSTR) of the Geophysics Research Board is the NAS' affiliate to the Inter-Union Commission on Solar-Terrestrial Physics (IUCSTP), which is now being converted to an ICSU Special Committee. The Committee reviews the status of U.S. research in solar-terrestrial problems, assists in coordinating this research with that of other countries, and provides advisory services to the Federal Government. Although the Committee's studies deal principally with ground-based research, the work of CSTR is directly relevant to the space program, because these observations are used in support of, are supported by, and in some cases are used in lieu of, observations with space vehicles.

For example, a key part of the IUCSTP program is the International Magnetospheric Study 1976–78, which is aimed at international coordination of long-term magnetospheric experiments including space, ground-based, balloon, and rocket measurements. In January 1973, in cooperation with the Space Science Board, CSTR conducted a study to identify the fundamental unanswered scientific questions regarding the Earth's magnetosphere and to appraise opportunities for U.S. participation in the IMS. "International Magnetospheric Study: Guidelines for United States Participation" was issued as an NAS–NRC report in May 1973. As a result of this study a new CSTR panel on IMS has been established to examine the needs for ground-based experiments to support the IMS, to define in light of recommendations of the joint study a specific program of ground-based research for the IMS, and to recommend any possible redirection of the existing U.S. ground-based research program. The panel's conclusions will be published in early 1974.

Committee on Radio Frequencies.—The Committee on Radio Frequencies (CORF) 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 works 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 to be held in Geneva in March 1974. These documents represent the U.S. position on CCIR questions relating to the communications for vehicles and to interference problems with radio astronomy and radar astronomy. CORF is making arrangements with NASA to conduct a radio-astronomy interference experiment in May 1974, using ATS–F to determine what measures can be taken to protect radio astronomy observatories from interference from broadcast satellites.

Office of Scientific Personnel

The Office of Scientific Personnel administers the NRC–NASA Resident Research Associateship Program (postdoctoral and senior postdoctoral) and the NASA International University Fellowship program. The Associateship awardees have an opportunity to

conduct research, largely of their choice, in science and engineering related to the objectives of the NASA centers. Their work contributes to the total research effort of the centers; and through the associates, research results from NASA laboratories are made available to universities and other components of the science and engineering communities. On August 31, 1973, there were 185 associates on tenure, including 101 from the United States and 84 from 17 other countries.

The NASA International University Fellows, who are from abroad, study and conduct research at U.S. universities. Since the inception of the program in 1961, 357 graduate and postdoctoral fellows from 20 countries have held these appointments at 36 universities. NASA and the space agencies or other scientific organizations of the cooperating countries jointly finance this fellowship program. During 1973, 57 fellows were on tenure. No new appointments have been made in the International Fellowship Program since February 1973, as NASA has decided to terminate the program for budgetary reasons.

XV The Smithsonian Institution

Introduction

Through research conducted in many laboratories and at observation sites around the world and by the public education and information programs conducted by its museums, the Smithsonian Institution continues its active role in national aeronautics and space efforts. The bureaus most directly involved are: the Smithsonian Astrophysical Observatory (SAO), the National Museum of Natural History (NMNH), and the National Air and Space Museum (NASM); and the Center for Short-Lived Phenomena (CSLP), a unit of the Office of International and Environmental Programs.

During the past year, Smithsonian observing stations gathered astrophysical and geophysical data, much of it from an extensive laser-camera satellite tracking network. Other space experiments in high-altitude ballons and satellites observed energy sources unattainable from ground-based sites. This work included solar observations aboard the Skylab and the possible identification of a "black hole." In both Washington and Cambridge, Mass., laboratory techniques were used to analyze returned lunar samples and meteoritical material recovered on the Earth.

In addition, the Smithsonian's museums added to man's appreciation of the new discoveries in space science through exhibits and displays.

Smithsonian Astrophysical Observatory

The Smithsonian Astrophysical Observatory (SAO) continued to support a broad program of investigations designed to increase man's understanding of the universe. More specifically, this program included satellite tracking for Earth-physics research, study of extraterrestrial materials, and active paticipation in space flight missions.

Geoastronomy.—A new Earth Dynamics Program (EDP) combined many aspects of SAO's highly successful satellite-tracking and geophysical research programs in anticipation of NASA's proposed Earth and Ocean Physics Applications Program (EOPAP). The EDP's main objectives are to develop theoretical models and to improve understanding of the kinematics, internal structure, and dynamics of the Earth. The program will include the mapping, with 1- to 2-centimeter accuracy, of polar motion, rotation, plate motion (continental drift), crustal motions in active regions such as fault zones and rifts, and core-mantle interactions. The results of this research will be used in applications such as earthquake predictions.

SAO scientists helped plan the first satellite in this program, the LAGEOS satellite designed to measure tectonic motions.

The Earth Physics Satellite Observation Campaign, a major 21-month-long international tracking effort organized by SAO as a precursor of EOPAP, was completed this year, with SAO's observing network producing nearly 91,000 laser-range measurements.

This same network produced data that, when combined with other satellite and surface-gravity data, formed the foundation for the complex calculations culminating in the SAO Standard Earth III. For these calculations, SAO greatly extended those computer programs treating lunar and solar perturbations, air drag, tidal effects, radiation pressure, and other effects to derive a highly significant model of the Earth as a whole with respect to gravitational variations and geodetic positions and networks.

Satellite-tracking data were also used to produce models of the Earth's upper atmosphere. In addition to continuing studies of the relationship between solar activity and upper atmosphere densities, recent findings show that the effects of Earth radiation pressure relative to those of atmospheric drag increase with height through the lower thermosphere.

A spacecraft-to-spacecraft Doppler tracking experiment is being prepared for the Apollo-Soyuz space mission. The primary objective of this experiment is to detect and measure the localized anomalies of the Earth's gravitational field. Gravity anomalies associated with major tectonic plate boundaries may be detectable from space with this experiment.

Mapping of the East African Rift system using ERTS-1 images continued and has led to the completion of sheets (1:1 million scale) showing the

revealed geological lineaments of Ethiopia, Somalia, and Yemen.

Extraterrestrial Materials.—A Lunar Petrology group studied soil samples from the Apollo 15, 16, and 17, and Soviet Luna 20 missions. Of particular interest were studies of the breccia chipped from a large boulder by the Apollo 17 astronauts at the foot of the South Massif in the Taurus-Littrow area. The samples are the first to be positively linked with a known lunar surface feature and the first possible example of a deposit from a maria-basin forming event. Also, a search for ancient meteoritic components in lunar materials was conducted with electron microprobe techniques.

Theoretical studies have begun in an effort to explain irregularities in the thickness of the Moon's low-density crust, the offset position of the Moon's center of mass, and the differences in moments about the lunar axes of inertia.

Mineralogical and petrological techniques for analyzing lunar samples were also used in studies of meteorite samples recovered on the Earth, particularly the Allende meteorite, a carbonaceous chondrite with important cosmochemical implications.

Another SAO group used radioisotopic techniques to investigate both lunar samples and meteorites. The lunar work was designed to relate the intensities of recent solar flares with those averaged over the past 1,000 years to determine the production of neutrons in the Moon by both galactic cosmic rays and solar flares. The neutrons provide information on the mixing rates and depths of the lunar regolith.

Similar radioisotopic techniques were used in a program to detect muons and, by implication, neutrinos at various depths in the Earth. Muons are extremely unstable secondary particles produced by both cosmic rays and neutrinos. According to theory, the number of muons produced by cosmic rays should decrease the deeper one goes into the Earth. At a depth of some 2,000 feet below sea level, the only muons detectable would be those produced by the neutrinos. The SAO muon detector, then, is a relatively small and portable device that so far has been carried to locations in Massachusetts railway tunnels and to a deep gold mine in India to establish baseline levels.

The primary and secondary impact rate of interplanetary dust particles onto the lunar surface was determined from direct measurements using polished surfaces exposed on the Surveyor 3 and from indirect measurements of lunar rock samples. In related research, microprobe analyses of particles from the Boxhole and Wabar meteorite craters allowed a comparison with lunar meteoritic spherules.

Space Experiments.—A new group at the Observatory continued satellite observations of the universe in the X-ray range of the spectrum using the UHURU spacecraft. In addition to general investigations of high-energy radiation from stellar and galactic sources, the group found evidence to support the existence of a suspected "black hole" in the constellation Cygnus. These regions of intense gravitational attraction have been described previously only in theory. Earlier rocket and satellite data showing powerful X-ray emissions were combined with optical observations this year to describe the suspected source more precisely. This same research group is participating in the planning of scientific payloads for the HEAO–A and HEAO–B satellites.

Ultraviolet results from SAO's Celescope experiment aboard the Orbiting Astronomical Observatory (OAO–2) were compared with ground-based observations of the same objects during several observing programs conducted in both Arizona and Chile. In addition to allowing an improvement and extension of Celescope results, the observational programs were used for a better determination of the distribution and properties of the interstellar medium and the early-type stars.

A major reference work related to the Celescope experiment was completed this year. Blanketed Model Atmospheres for Early-Type Stars, designed as a companion volume to the Celescope Catalog of Ultraviolet Stellar Observations will be issued by the Smithsonian Press.

A 40-inch-aperture balloon-borne telescope, constructed by SAO in collaboration with Harvard and the University of Arizona to observe infrared radiation from sources at the center of the Milky Way, was flown for the second time. No scientific data were taken on this flight, but valuable engineering and operational information was obtained.

Gamma-ray results obtained on previous balloon flights were analyzed this year and produced baseline levels used for ground-based tests at SAO's Mount Hopkins Observatory.

Smithsonian scientists participated in the planning for space experiments related to observations of Comet Kohoutek. Indeed, the first determination of the comet's orbit and potential brightness was made at SAO.

Work continued on a NASA-supported experiment to test the equivalence principle of Einstein's Theory of Relativity by employing a maser clock in a rocket probe. This 3.5-hour experiment will use the stability of the hydrogen maser to measure the theoretically predicted gravitational redshift to an accuracy of about 20 parts per million, which is some 500 times more accurate than the best previous measurement.

Analysis of data from the Orbiting Solar Observatories continued at SAO, with particular interest in the spectra of solar prominences and filaments obtained by

extreme ultraviolet (EUV) spectrometers. Smithsonian scientists also were involved in similar experiments prepared by Harvard University for the Apollo Telescope Mount aboard the Skylab satellite. Initial examination of the Skylab data shows them to exceed all expectations in terms of quality and importance. Researchers now expect to make revolutionary progress in understanding the physical mechanisms of coronal heating, the solar wind, and solar flares.

National Museum of Natural History

Lunar and meteorite research continued at a high level of activity in the Museum's Department of Mineral Science. Most of the departmental staff have been involved in lunar research under NASA grants. Several papers describing this work have been published this year and others will appear shortly. Currently the staff is engaged in intensive research on the Apollo 17 collections.

Current research in meteoritics includes the analysis and description of several recently fallen meteorites, the study of phosphorus distribution in iron meteorites, and a review of the mesosiderites.

National Air and Space Museum

The National Air and Space Museum (NASM) continued its role as both a repository and display center for the artifacts of space research and exploration. Among the many new exhibits opening this year was a special display of telescope systems from the Orbiting Astronomical Observatories, including the Smithsonian's own Celescope experiment from OAO–2 and the large Princeton-designed experiment from OAO–3. The latter experiment, dubbed "Copernicus," was displayed during the week of festivities in Washington marking the 500th anniversary of the birth of Nicolas Copernicus.

In addition to its education activities, the NASM initiated a Center for Earth and Planetary Studies designed to apply the results of Apollo lunar exploration to Earth and planetary sciences.

In cooperation with the U.S. Geological Survey, a geologic map of the lunar farside was prepared based on interpretations of both the lunar orbital photographs taken by Apollo missions and the geochemical and geophysical data obtained from lunar orbit. Geological provinces were correlated with physical and chemical provinces to understand the Moon's petrological evolution. Studies of the orbital photographs also revealed numerous features which shed new light on both impact and volcanic processes on the Moon.

Staff members contributed to the establishment of NASA's newly instituted lunar mapping program, including the selection of areas for large-scale orthophoto maps and, with the cooperation of the International Astronomical Union, application of new nomenclature to lunar features.

Joint studies of lunar volcanism conducted with the University of Utah resulted in quantitive description of many different levels of lunar lavas. Determination of lava-flow levels was obtained from the Apollo 17 Lunar Sounder radar data and confirmed by laser altimetry and metric camera mapping.

Center for Short-Lived Phenomena

As an international alert system for science, the Smithsonian Center for Short-Lived Phenomena receives and disseminates rapidly 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 1973 included the report of four fireballs in Czechoslovakia, California, Germany, and Wales; and two meteorite falls in Upper Volta and California. The Center assisted in efforts to recover the meteoritical material and to distribute samples to the scientific community.

The Center provided operations support for a joint NASA–SAO project to study the feasibility of observing large-scale short-lived events by the Earth Resources Technology Satellite (ERTS–1) instrumentation.

During the flights of the Skylab missions, 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 floods, oil spills, volcanoes, and earthquakes.

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XVI Office of Telecommunications Policy

Introduction

Against the backdrop of a growing number of proposed new international and domestic communications satellite systems and services, the Office of Telecommunications Policy (OTP) carries out Presidentially delegated functions in accordance with Reorganization Plan No. 1 of 1970 and Executive Order No. 11556 of September 4, 1970. The Office provides oversight and coordination for interagency and Government/industry communications satellite activities with a view toward facilitating the orderly application of developing technology.

During 1973, international activities centered on proposals to provide aeronautical and maritime satellite services and efforts by other nations to create new international regulatory frameworks for future satellite broadcasting directly into the home. OTP participated with the State Department and the FCC in the coordinated oversight of the Communications Satellite Corporation (COMSAT) as the U.S. designated entity in the International Telecommunications Satellite Organization (INTELSAT).

Another major OTP function was the continuing review of space-related communications activities to insure the coordinated, effective use of the electromagnetic spectrum. A survey on satellite launch insurance was also conducted.

Aerosat

OTP continued to work with the State Department and the DOT/FAA to conclude a Memorandum of Understanding between the European Space Research Organization (ESRO), Canada, and the FAA which would establish an experimental aeronautical satellite program. The program is intended to evaluate the use of satellite communications in improving air traffic control over the high seas. This international arrangement, the result of a U.S. Government position developed jointly with the State Department and DOT/FAA, calls for the creation of a new industry/Government entity to provide the satellite channels for the program. The major portion of this telecommunications entity would be owned equally by ESRO and a private U.S. communications corporation, with Canada owning approximately 6 percent.

Direct Broadcast Satellites

Growing international interest in the possible use of satellites to broadcast programs directly into the home was reflected in increased U.N. and UNESCO activities. The major development was the reactivation of the U.N. Working Group on Direct Broadcast Satellites, which met in June to review recent technological developments in light of pending proposals by other nations to establish new international legal regimes. The Working Group is scheduled to meet again in March 1974. OTP is actively participating with the State Department, FCC, USIA, and other interested agencies in the formulation and presentation of the U.S. position.

OTP funded two contract studies on direct broadcast satellites. One, conducted at MIT's Center for International Studies, concerned foreign attitudes and motivations toward international control of such satellites. The other concerned cost-analyses of utilizing direct broadcast satellite technology for education in three developing country models.

Marsat

The International Maritime Consultative Organization (IMCO) was the principal international forum for discussions concerning the provision of international satellite communications to civilian ships on the high seas. OTP assisted in coordinating the preparation of the U.S. Government position with interested agencies and with prospective private industry participants. It actively participated in the IMCO deliberations. OTP will continue to promote efforts to identify requirements for international maritime satellite services while avoiding prejudgements on the operational or organizational means of providing such services.

OTP is following closely the policy implications of the development of a maritime satellite capability to meet U.S. Navy requirements between 1974–76. As authorized by the FCC, the satellite will also offer com-

mercial communications satellite services for maritime users.

Frequency Management

The introduction of new international satellite systems and services, as well as proposed U.S. governmental and domestic commercial systems, created new demands on the already limited electromagnetic spectrum.

The Director of OTP established a new system review procedure with emphasis on Government space programs. This procedure is designed to insure the availability of frequency support before the expenditure of funds for the development and procurement of communications-electronic systems.

Under OTP guidance, the Interdepartment Radio Advisory Committee (IRAC), including an FCC liaison representative, developed proposals of the United States for the World Administrative Radio Conference for Maritime Mobile Telecommunications (WARC–MAR), to be held in Geneva, 1974. The proposals include guidelines to facilitate the development of maritime satellites.

IRAC also participated in formulating Government positions on space telecommunications issues and planning decisions dealt with during the Plenipotentiary Conference of the International Telecommunication Union in Spain, September–October 1973.

Satellite Launch Insurance

In furtherance of the national "open skies" policy for domestic satellite systems, OTP conducted a survey of prospective entrants and insurance industry representatives to determine whether the planned level of commercial insurance against launch failure is a significant barrier to market entry. The Office is continuing to examine the adequacy of commerically available insurance and the necessity for continued Government involvement in this area.

XVII Federal Communications Commission

Introduction

During 1973 the INTELSAT Definitive Arrangements came into force and the fifth in the series of INTELSAT IV satellites was successfully launched. Construction was also commenced on a new series of INTELSAT IV–A satellites. The Commission authorized construction of satellites for four domestic satellite systems, and authorized two U.S. entities to provide U.S. domestic satellite service by using Canadian Telesat satellites. The Commission also authorized construction of three satellites to provide service to the U.S. Navy as well as to other maritime users. Rules were adopted to govern the broadcasting satellite and fixed satellite services to reflect the results of the 1971 International Telecommunication Union (ITU) World Administrative Radio Conference on Space Telecommunications (WARC–ST).

Communications Satellites

INTELSAT.—On February 12, 1973, the INTELSAT Definitive Arrangements entered into force. There are now 83 member countries in the organization. The fifth satellite in the INTELSAT IV series was launched on August 23, 1973, and is now in position for service in the Atlantic Ocean region. At the end of the year there were three INTELSAT IV satellites in the Atlantic Ocean region and one INTELSAT IV satellite in both the Pacific and Indian Ocean regions. Another INTELSAT IV satellite, an operational spare for the Pacific Ocean region, is scheduled to be launched in early 1974.

INTELSAT has approved a "follow-on" program to the INTELSAT IV series, providing for the construction of three INTELSAT IV–A satellites, which will have approximately twice the capacity of the INTELSAT IV's. The first of these satellites, which are planned for use in the Atlantic Ocean region, is scheduled for operation in 1975. Planning is now underway for an INTELSAT V series of satellites for use in approximately 1978.

In 1973, the Commission adopted definitive policies for the authorization of domestic communication-satellite facilities and gave authority to proceed with the construction of four different domestic satellite systems. The first of these is expected to go into operation in late 1974. Two U.S. entities have been authorized to offer U.S. domestic satellite service even earlier by using their own Earth stations in conjunction with satellite transponders leased from the Canadian domestic Telesat system. Earth stations to operate with the various domestic systems have been authorized in all parts of the contiguous United States, as well as in Alaska and Hawaii.

The systems now planned will provide long-distance domestic telephone circuits and private line services for a wide variety of customers needing voice, data, and video circuits. One of the systems also plans to distribute specialized video programs to CATV systems throughout the country by means of individual small receive-only Earth stations.

International Telecommunication Union.—The International Telegraph and Telephone Consultative Committee (CCITT) and the International Radio Consultative Committee (CCIR) are permanent organs of the International Telecommunication Union (ITU), that study technical and operating questions on telegraphy and telephony, and radio, respectively, and issue recommendations on such matters. Many of these questions deal directly or indirectly with space communications.

The World Plan Committee is a joint CCITT/CCIR study group and the parent body of the four Regional Plan Committees (Africa, Asia and Oceania, Europe and the Mediterranean Basin, and Latin America).

The work of the Plan Committees generally deals with technical and economic aspects of telecommunications and involves the development of traffic and circuit forecasts and the compilation of data on major arteries and routing.

During April 1973, Commission personnel were members of U.S. delegations to the World Administrative Telegraph and Telephone Conference held in Switzerland and to the ITU Plenipotentiary Conference held during September–October in Spain. Members of the Commission's staff also participated in a regional Plan Committee meeting for Latin America

held in Brazil and in a meeting of a working party of the World Plan Committee held in Switzerland.

Frequency Allocations.—During 1973, the Commission's rules were brought into conformity with the revised International Radio Regulations adopted by the 1971 ITU WARC–ST which became effective internationally on January 1, 1973. Amendments, effective on March 1, 1973, were made to the Table of Frequency Allocations and Definitions in Part 2 of the Commission's rules. These included revisions to the frequency bands available to the broadcasting-satellite and fixed-satellite services.

Frequency allocations were adopted for the amateur, mobile, radio-navigation, Earth exploration and meteorological satellites services as well as for the space research, space operation, standard frequency, and time, and radio astronomy services as originally proposed by the Commission in accordance with the WARC–ST results.

For long range planning purposes, bands were allocated to the various space radiocommunications services and the radio astronomy service between 40 and 300 gigahertz. Twenty frequency bands were made available by the WARC–ST for the fixed satellite service, most of which are shared with microwave relay services. To assist in the effective sharing of these frequencies, the Commission, on April 2, 1973, amended parts 21 and 25 of the rules to establish revised methods for the determination of coordination areas and for the calculation of interference.

The Commission agreed to a 1-year use of non-Government frequencies by a program sponsored by the Department of Health, Education, and Welfare which will use the Advanced Technology Satellite (ATS–F) to provide educational and medical communication services to areas in the Rocky Mountain region, Appalachia, certain Southeastern States and Alaska. The experiment is scheduled to begin with the launching of the ATS–F satellite in early 1974.

Specialized Satellite Services

Aeronautical Mobile Satellite Service.—The Commission staff is continuing to assist in the development of a future aeronautical mobile satellite service. Negotiations have been taking place with European and Canadian authorities to establish an initial developmental satellite system in the North Atlantic area. It is anticipated that this initial system will provide a limited VHF capability (the frequencies now normally used by aircraft over land) in addition to a L-band (approximately 1600 MHz) capability to be used for evaluation and experimentation only. U.S. participation in the experimental joint system will be by a commercial entity.

Maritime Mobile Satellite Service.—The Commission staff 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 communictions 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 its Panel of Experts on Maritime Satellites met twice in 1973 to expedite the implementation of a maritime mobile satellite service. Operational requirements have been stated and technical, financial, and economic studies are in progress. A meeting of governments is planned early in 1975 to further refine the work of the Panel of Experts and to negotiate any international agreements that are found to be necessary.

In April 1973, the Commission allowed the construction to proceed of three satellites that will be part of a 5-year system intended to provide maritime service to the Navy as well as to other maritime users beginning in September 1974. One satellite is planned for deployment over the Atlantic and another over the Pacific with the third held as an on-the-ground spare. In August 1973, the Commission authorized a consortium of four carriers to participate in this Navy/Maritime system.

The Navy communication services will be provided in the UHF-band on a lease basis for a period of years beginning in 1974. The satellite capacity used by the Navy will be under its control and will be used to provide fleet communications. The commercial maritime communications will be provided utilizing a L/C band capability. 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.

Amateur-Satellite Service.—The Commission has established a new Amateur-Satellite Service conforming with the WARC–ST Radio Regulations, as revised by the Geneva Conference in 1971. Certain frequencies within the Amateur Radio Service were allocated to this new service on a shared basis with other amateur radio activities. The Commission is now proceeding to establish rules for this new service.

The OSCAR 6 satellite, sixth in the "Orbiting Satellite Carrying Amateur Radio" series exceeded its 1-year design life on October 15, 1973. The satellite continues to operate satisfactorily on a 910-mile, circular.

Sun-synchronous, polar orbit. Designed and constructed by amateur radio operators, and launched piggyback by a NASA Delta vehicle, OSCAR 6 is testing a variety of communication techniques with small amateur radio station terminals of various types. Over 1,500 amateur radio operators at user stations in all 50 States and in 70 countries have succeeded in establishing two-way communications through the 2- to 10-meter repeater station aboard the satellite. Two-way transcontinental communications tests using relatively unsophisticated terminals in automobiles and aircraft have been successful. Other successful experiments include the transmission of telegraphy, teleprinting, facsimile, television, and FM, AM and single-sideband AM telephony.

Schools throughout the country are using OSCAR 6 as an instructional tool. Material is available showing how to construct an inexpensive ground terminal for use in the classroom and how to use it to teach space-age concepts such as Doppler measurement, orbit plotting, orbital period determination, and telemetry experiments. Several amateur operators using the satellite have reported observing an upward or "inverted" Doppler effect on the signals received from the 435.1 megahertz beacon transmitter, the mechanism of which has not yet been fully explained.

XVIII Environmental Protection Agency

Introduction

The Environmental Protection Agency (EPA) has a strong continuing interest in both aircraft and spacecraft for research and operational use of remote sensing. The case for remote sensing in the detection of pollutants is substantial and gives impetus to establishing remote sensing as a management decision and evaluation tool in the Agency. The remote identification of specific local instances of pollution has been accomplished from aircraft through visual identification and photographic documentation. Recent years have brought the rapid evaluation of new instrumentation with a unique capability of monitoring pollution. These instruments include the laser, multispectral scanner (MSS), microwave radiometer, and others. It is expected that further testing and evaluation of these sensors from aircraft and possibly spacecraft could result in the full appreciation of remote sensing technology for monitoring the environment. The objectives of environmental monitoring are to characterize existing environmental conditions, identify trends, evaluate compliance with standards and assess the interchange of pollutants among air, water, and land. Since EPA is essentially mission oriented, all its work in research and development is directed toward the solution of problems.

The effective control of variables which determines environmental quality requires the use of reliable and timely information such as can be provided by aerial surveillance. Thus a significant facet to effectuate environmental quality management lies in the ability to monitor environmental characteristics and provide timely interpretation of data obtained. Such timely data are essential throughout the pollution abatement effort—from initially identifying the problems, from aircraft or spacecraft, to finally providing direct evidence in enforcement actions. When such data are provided in support of an enforcement action, these data must be legally defensible. Photographic camera and multispectral scanner (MSS) data show great promise for enforcement measures. However to insure uniformity and reliability these data require standardized measurement and calibration procedures.

Aeronautics

During 1973, the EPA utilized aircraft and helicopters as platforms for overhead monitoring in both operational and research programs. The primary facility for conducting overhead monitoring for the Agency is the National Environmental Research Center (NERC), in Las Vegas, Nev. The NERC air fleet consists of 12 surplus military aircraft, which includes 2 helicopters. The helicopters are committed to the National Eutrophication Survey Program and the St. Louis Regional Air Pollution Study and for support of EPA Regions, Staets and cities. The fixed wing aircraft are heavily committed for low altitude surveillance of areas where enforcement actions are contemplated. Examples of the objectives and missions flown by the NERC–Las Vegas aircraft are:

—identify isotherms in the vicinity of power plants,
—detect and monitor algae and phytoplankton in lakes,
—identify land misuse as it relates to cultural growth,
—identify, map, and track oil spills,
—monitor sedimentation and turbidity of water,
—identify and quantify pollutants in air,
—identify secondary effects of pollution from sanitary landfills,
—identify and monitor acid mine drainage,
—identify and monitor industrial outfalls,
—identify and monitor hazardous mine tailings,
—identify salinity seeps in ground water,
—monitor nutrient and salinity balance of estuaries,
—identify and monitor agricultural runoff,
—monitor secondary effects of dredging,
—determine appropriate control and preventive measures of pollution,
—assess environmental impact from all types of pollution,
—monitor environmental trends,
—monitor ocean dumping.

Because of the busy flight schedule for the NERC aircraft, the available overhead monitoring capability for general use in monitoring ambient conditions and

environmental trends, and for testing and demonstration of new sensors, is limited. Therefore EPA has developed mutually beneficial cooperative programs with other Federal agencies. A formal interagency agreement exists with the National Aeronautics and Space Administration (NASA), Langley Research Center for the conduct of tests and evaluation of sensors on NASA aircraft. These sensors include metric and multiband cameras with various film/filter combinations, multispectral scanners, lasers for oil and algae detection, and microwave radiometers for oil and salinity measurements. Flights are scheduled and coordinated with EPA field teams for the collection of ground truth information to corroborate the aerial data. The analyses of the combined data are conducted collaboratively between EPA and NASA, under the technical direction of the NERC-Las Vegas.

Flight tests are usually conducted in conjunction with EPA regional personnel, and often involve State and local environmentalists in the test plan. As an example, the State of Maryland conducted a 25-hour study of the Patuxent River, collecting extensive ground truth data, that is, samples of water, earth, air, etc. The State requested EPA assistance for some remote sensing during this study for detecting chlorophyll, mapping the tidal areas, and in mapping a powerplant effluent. The EPA regional personnel coordinated the aircraft flight tests while participating in the ground truth acquisition with State personnel. The two NASA aircraft were equipped with multiband cameras, a multispectral scanner (MSS), and an infrared scanner. The data are presently being analyzed jointly by EPA, NASA and the State of Maryland.

Other flight tests were conducted in early 1973 when the Ann Arundel County Health Department of Maryland requested assistance in the South River where there are increasing numbers of problems with outflow from municipal sewage treatment plants and private homes. The present situation has resulted in the closure of significant portions of the South River to the seafood industry. Of course, control and abatement actions are underway. However, there is a need by the county health department for efficient means to regularly monitor the area to assure that the problem is not recurring. The remote sensor capability available at NASA/Langley was tested and the resultant data are being analyzed in conjunction with the EPA Annapolis Field Station. The long-term objective of the flight tests is to identify which sensors are most applicable to the monitoring role for areas rapidly becoming urbanized.

On occasion, the Agency has requested and received support from the Department of Defense for overhead monitoring photos. Such data are obtained during routine flights and are used for determining environmental trends.

Space

EPA has direct contact with NASA's Goddard Space Flight Center and has been receiving Earth Resources Technology Satellite (ERTS–1) imagery on a regular and timely basis. This imagery is sent to the various EPA regions for evaluation.

ERTS–1 data will be used to monitor and quantify algae blooms in reservoirs in Idaho and Washington. Satellite data are being used to monitor the size, shape, and movement of the "green water effect" in Lake Superior, where 250,000 liters of taconite tailings per day are being dumped into the lake.

A detailed ERTS–1 and aircraft monitoring study of Puget Sound is being conducted to:

(1) Determine the effect of image contrast and scale with altitude;
(2) Determine pollution dispersion problems; and
(3) Monitor dissolved oxygen and chlorophyll.

Movement of near-surface water in Wicomico Creek basin in Maryland has been mapped using the ERTS–MSS. Turbidity patterns and algal concentrations are being monitored in the bays in the San Francisco area. Oil slicks identified near Baltimore augurs well for spotting and tracking oil pollution using remote sensing.

Several State and Federal Government agencies have recognized the utility of ERTS–1 to show changes induced by strip mining activity. One group, the Geological Survey of Indiana, has already used ERTS–1 imagery to revise strip mine maps compiled in the 1960's. In Ohio, comparison of ERTS–1 imagery with aerial photography taken only 1 year earlier revealed a significant increase in the area of disturbed land.

The impact of strip mining of coal is expected to be especially significant in the Western States. In Montana, for example, the output of less than 3.5 million tons in 1971 is expected to grow to more than 80 million tons by 1980. The ability of an ERTS-type satellite to routinely depict this change and to monitor the effectiveness of land rehabilitation on a State or regional basis would be extremely useful to planners in assessing future land use priorities and alternatives.

Sources of siltation from construction along rivers and lakes are being monitored using ERTS data. Monitoring of sources and potential sinks of pollutants will be investigated as an extension to land-use mapping.

An EPA acid mine drainage experiment is being conducted with ERTS in the States of Pennsylvania and West Virginia where seepage from shaft and open coal mines mix into the surrounding streams which feed the Potomac River. The resulting acid stream causes destruction of adjacent vegetation. Knowledge of the source of the seepage is required in order to enforce present laws or to take measures to prevent seepage from abandoned mines. The purpose of this investigation is to determine the most cost effective

system for detecting and monitoring the effects and extent of acid mine drainage, utilizing ERTS as appropriate. ERTS should be most effective in providing a synoptic view and in identifying large areas of vegetation destroyed by acid mine drainage. ERTS imagery is not expected to be adequate for monitoring the water quality in small streams—this will perhaps only be possible with in situ sampling. The emphasis on land use results from the fact that land-use maps do not exist for the selected test area and from the requirement to correlate land use with acid mine drainage effects. The end effort of the experiment is to define the optimum mix of sensing techniques for performing the required monitoring.

An automated in situ sensor system has been developed with a data link to the NASA Nimbus satellite which has led to a program utilizing sensors in tandem with a satellite data relay system. The project provides for the automatic sensing, recording, and transmittal of 5 to 8 water quality parameters from the Greater Miami River to the satellite, where the data are, in turn, transmitted via the NASA Lewis Research Center to the NERC-Cincinnati for near real time analysis. Such programs are intended to demonstrate the real time capability of data relay systems and the potential of geostationary satellites.

International Cooperation

The EPA is participating in the United Nations Environment Program, which was set up by the United Nations General Assembly to develop recommendations of the United Nations Conference on the Human Environment held July 1972, in Stockholm, Sweden. A U.S. basic paper on Monitoring and Surveillance of the Environment is being prepared by a Policy Level Committee with representation from EPA and other Federal agencies. The submission to the committee for a system for atmospheric monitoring is outlined below.

A combination of remote sensing and aerial in situ sensing provides the best promise for application to global, regional, and impact atmospheric monitoring needs. Use of these techniques provides: (a) Wide geographical coverage; (b) Three-dimensional data through the atmosphere; (c) Synoptic coverage responding to effects of topography, meteorology, and atmospheric structure; (d) Dispersion and removal rate data; (e) Trend documentation; (f) Interbasin or interregional effects; (g) Microscale health effect data; and of great importance; (h) Cost effectiveness. The goal of this program would be a monitoring system to develop baseline, trend and impact data on atmospheric pollutants in a timely fashion rather than tedious data collection from limited ground level in situ measurements followed by a lengthy collation and extrapolation/estimation to three-dimensional atmospheric effects. This system would provide an integrated view of atmospheric pollutants.

A well-developed system of aerial monitoring for air quality parameters of interest could provide the necessary data in a timely fashion and at much less cost than a ground-based system. The mobility afforded by aircraft and the addition of monitoring devices to regular cargo and civil transport aircraft would permit a relatively small number of personnel and much less equipment to cover large regions and still provide satisfactory data on small local areas of interest.

Appendixes

APPENDIX A–1

U.S. Spacecraft Record

Year	Earth orbit		Earth escape	
	Success	Failure	Success	Failure
1957	0	1	0	0
1958	5	8	0	4
1959	9	9	1	2
1960	16	12	1	2
1961	35	12	0	0
1962	54	12	4	1
1963	60	11	0	0
1964	69	8	4	0
1965	94	8	3	0
1966	95	12	5	[1] 1
1967	77	4	10	0
1968	61	15	3	0
1969	58	1	8	1
1970	36	1	3	0
1971	45	2	8	1
1972	33	2	8	0
1973	23	2	3	0
Total	770	120	61	12

[1] This earth escape failure did attain earth orbit and therefore is included in the earth-orbit success totals.

NOTES: The criterion of success or failure used is the attainment of earth orbit or earth escape rather than a judgment of mission success.

This tabulation includes spacecraft from cooperating countries which were launched by U.S. launch vehicles.

APPENDIX A–2

World Record of Space Launchings Successful in Attaining Earth Orbit or Beyond

Year	United States	U.S.S.R.	France	Italy	Japan	Chinese Peoples Republic	Australia	United Kingdom
1957		2						
1958	5	1						
1959	10	3						
1960	16	3						
1961	29	6						
1962	52	20						
1963	38	17						
1964	57	30						
1965	63	48	1					
1966	73	44	1					
1967	57	66	2	1			1	
1968	45	74						
1969	40	70						
1970	28	81	2	[1] 1	1	1		
1971	30	83	1	[1] 2	2	1		1
1972	30	74		[1] 1	1			
1973	23	86						
Total	596	708	7	5	4	2	1	1

[1] Includes foreign launchings of U.S. spacecraft.

Note: This tabulation enumerates launchings rather than spacecraft. Some launches did successfully orbit multiple spacecraft.

Successful U.S. Launches—1973

Launch date (G.m.t.) spacecraft name Cospar designation launch vehicle	Spacecraft data	Apogee and perigee (in statute miles)— period (minutes)— inclination to equator (degrees)	Remarks
Mar. 6 Defense 13A Atlas-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	22, 792 22, 280 1, 435. 0 0. 2	Still in orbit.
Mar. 9 Defense 14A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	163 94 88. 6 95. 7	Decayed May 19, 1973.
Apr. 6 Pioneer 11 19A Atlas-Centaur	Objective: To obtain, by a launch during the 1973 Jovian opportunity, precursory scientific information beyond the orbit of Mars with the following emphasis: (a) Investigation of the interplanetary medium; (b) investigation of the nature of the asteroid belt; (c) exploration of Jupiter and its environment. Spacecraft: Hexagon-shaped spacecraft with an auxiliary offset hexagonal compartment for scientific instruments and 9-ft diameter parabolic antenna reflector; 4 radioisotope thermoelectric generators (RTG) on trusses 120° apart extend 5.6-ft radially beyond the periphery of the antenna reflector. A 4-segment folding magnetometer boom extends radially 15.4 ft beyond the reflector and 120° from the RTG's; from the top of the high-gain antenna feed to the bottom of the low-gain antenna measures 9.6 ft. 12 scientific instruments will measure magnetic fields, plasma, cosmic rays, and charged particles, electromagnetic radiation in the ultraviolet, visible and infrared ranges, and asteroid/meteoroid population. 6 thrusters; spin stabilized. Weight: 570 lb.	Heliocentric, later to become solar escape trajectory	Second in new Pioneer series, spacecraft following Jupiter flyby path of its twin, Pioneer 10. Spacecraft began 7 month journey through the asteroid belt on Aug. 18, 1973. Spacecraft functioning normally and all 12 science instruments are operational. By Dec. 31, 1973, spacecraft was 360 million miles from the Earth. Jupiter encounter planned for early December 1974.
Apr. 20 Anik 2 23A Thorad-Delta	Objective: To provide transmission of television, voice, and other data throughout Canada. Spacecraft: Cylindrical 6-ft diameter and 11-ft high; 60-in optically transparent antenna weighing 9 lb affixed to top of spacecraft remains stationary, pointed toward Canada as satellite revolves; spin stabilized. Provides 10-color TV channels or up to 9,600 telephone circuits; 23,000 solar cells. Weight at launch: 1,200 lb; weight in orbit: 600 lb.	22, 189 22, 123 1, 430. 7 0. 1	Launched by NASA for Canadian Domestic Communications Satellite System into transfer orbit. Apogee kick motor fired by Canada April 23 and spacecraft placed in stationary equatorial orbit off the west coast of South America. The American Satellite Corp. signed an agreement with Canada to lease satellite time, and on June 18 conducted the first relay of a telecast across the United States by a domestic communications satellite.

Successful U.S. Launches—1973

Launch date (G.m.t.) spacecraft name Cospar designation launch vehicle	Spacecraft data	Apogee and perigee (in statute miles)—period (minutes)—inclination to equator (degrees)	Remarks
May 14 Skylab 1 (SL-1) 27A Saturn V	Objective: To establish the Skylab Orbital Assembly in Earth orbit; to obtain medical data on the crew for use in extending the duration of manned space flight; to perform inflight experiments. Spacecraft: Consists of 4 major modules: Orbital workshop (OWS), airlock module (AM), multiple docking adaptor (MDA), and Apollo telescope mount (ATM). Cylindrical spacecraft measures 85.3 ft when deployed in orbit and has habitable volume of about 12,200 ft³. Weight in orbit: 164,869 lb.	273 263 93.2 50.0	Skylab Workshop successfully placed in circular orbit but during launch, vehicle vibration resulted in meteoroid shield loss and solar array damage. Shield failure had released the securing mechanism on solar array 2 which ripped off and also prevented solar array wing 1 from deploying. Solar array damage and shield loss resulted in electrical power shortage and temperatures inside Workshop which reached 125° F. Temperature was reduced somewhat by pitching Workshop axis to and away from Sun. Skylab 2 three-man crew docked with Workshop, deployed solar parasol lowering temperatures and freed solar array wing 1 restoring electrical power. Workshop was employed for 3 manned visits (Skylab 2, 3, 4).
May 16 Defense 28A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	247 83 89.8 110.4	Decayed June 13, 1973.
May 25 Skylab 2 (SL-2) 32A Saturn IB	Objective: To establish the Skylab Orbital Assembly in Earth orbit; to obtain medical data on the crew for use in extending the duration of manned space flight; to perform inflight experiments. Spacecraft: Apollo Block II command and service modules (CSM) modified for Skylab use. Command module is conical n shape, 12 ft 10 inches diameter and 11 ft 5½ in high, and has a habitable volume of 210 ft. Service module is cylindrical, 12 ft 10 inches in diameter and 24 ft 10 in long, with a 20,000-lb thrust main propulsion system, reaction control system, fuel cells, oxygen, and radiators. CSM/S-IVB weight in initial Earth orbit: 67,163 lb. CSM weight after S-IVB separation: 30,817 lb. Total weight of docked assembly (CSM/Workshop): 193,589 lb.	273.4 263.5 93.2 50.0	Crew consisted of Charles Conrad Jr., commander; Paul J. Weitz pilot; Joseph P. Kerwin, science pilot. First manned Skylab mission. CSM hard docked with Skylab Workshop on May 25. Next day crew entered Workshop and deployed makeshift solar parasol through the solar airlock. Temperatures decreased. On June 7, jammed solar array wing manually released during 3 h 30 min 2-man EVA. Power restored. On June 19, 1 h 36 min 2-man EVA to retrieve and replace Apollo Telescope film cassettes. CM splashdown at 9:50 a.m., e.d.t., June 22. Total flight time 28 days 50 min. Despite mission anomalies, 80 percent of solar data planned was obtained; 12 of 15 Earth resources data runs were accomplished; and all 16 medical experiments were conducted.

Successful U.S. Launches—1973

Launch date (G.m.t.) spacecraft name Cospar designation launch vehicle	Spacecraft data	Apogee and perigee (in statute miles)—period (minutes)—inclination to equator (degrees)	Remarks
June 10 Explorer 49 (RAE) 39A Thorad-Delta	Objective: To make measurements of galactic and solar radio noise at frequencies below ionospheric cutoffs and external to terrestrial background interference by utilization of the Moon for occultation, focusing, or aperture blocking for increased resolution and discrimination. Spacecraft: Truncated cylinder 36 inches in diameter and 31 in high with 4 fixed solar paddles mounted on main body; outside skin of aluminum honeycomb material; lunar insertion motor attached to upper end of body is jettisoned after lunar orbit insertion. Overall measurements with the 2 cameras mounted on the solar arrays are 72 in wide, 58 in high, and 63 in long. Spacecraft contains 1-libration damper boom extendable to 630 ft and 1 retractable 120-ft dipole antenna for calibration tests. The experiment antennas consist of 2 back-to-back V antennas formed by deploying 4 0.6-in diameter elements up to a maximum length of 750 ft each measuring 1,500 ft tip-to-opposite-tip. The Velocity Control Propulsion Subsystem (VCPS) utilizes hydrazine fuel and a thruster for velocity correction and is jettisoned after spacecraft is properly oriented in lunar orbit. Also carries tape recorders, battery, and the telemetry and command subsystem. The 730-lb weight at liftoff includes the lunar insertion motor and the VCPS; weight in lunar orbit: 442 lb.	660.6 653.7 221.2 38.7 Lunar orbit	Last scheduled U.S. space mission to the Moon. Will conduct the most extensive study ever undertaken of low-frequency signals from galactic and extra-galactic radio sources. Spacecraft uses the Moon as a shield from extraneous radio noise from Earth. Lunar orbit insertion at 3:21 a.m., e.d.t., June 15; all experiments turned on.
June 12 Defense 40A Titan IIIC	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	22,237 22,232 1,436.0 0 3	Still in orbit:
July 13 Defense 46A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	170 96 88.7 96.2	Decayed Oct. 12, 1973:
July 28 Skylab 3 (SL–3) 50A Saturn IB	Objective: To perform unmanned Saturn Workshop operations; to reactivate the Skylab orbital assembly in Earth orbit; to obtain medical data on the crew for use in extending the duration of manned space flights; to perform inflight experiments. Spacecraft: Apollo Block II command and service modules (CSM) modified for Skylab use. Command module is conical in shape, 12 ft 10 inches in diameter and 11 ft 5½ in high, and has a habitable volume of 210 ft. Service module is cylindrical, 12 ft 10 inches in diameter and 24 ft 10 in long, with a 20,000-lb thrust main propulsion system, reaction control system, fuel cells, oxygen, and radiators. CSM/S–IVB weight in initial Earth orbit: 67,721 lb. CSM weight after S–IVB separation: 31,234 lb. Total weight of docked assembly (CSM/Workshop): 193,050 lb.	273.4 262.8 93.2 50.0	Crew consisted of Alan L. Bean, commander; Owen K. Garriott, science pilot; Jack R. Lousma, pilot. Second manned Skylab mission. CSM docked with Skylab Workshop at about 4 p.m., e.d.t., July 28. Leak in 2 of 4 clusters of CSM steering rockets threatened safe reentry and rescue preparations initiated but not required. Crew's motion sickness caused rescheduling of tasks. 2-man EVA on Aug. 7 lasted 6 h 31 min; during space walk astronauts deployed twin-pole Sun shield and experiments, inspected ATM, and retrieved film. 2-man EVA on Aug. 25 lasted 4 h 31 min. Final 2-man EVA on Sept. 23 lasted 2 h 41 min. CM splashdown at 6:20 p.m., e.d.t., Sept. 25. Total flight time 59 days, 11 h 9 min. Experiment accomplishments surpassed all plans. 150 percent of observing time scheduled for ATM was accomplished; EREP sensors were operated on 39 data runs, exceeding scheduled 28 passes; all crew medical experiments successfully conducted.

Successful U.S. Launches—1973

Launch date (G.m.t.) spacecraft name Cospar designation launch vehicle	Spacecraft data	Apogee and perigee (in statute miles)—period (minutes)—inclination to equator (degrees)	Remarks
Aug. 17 Defense 54A Thor-Burner II	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	530 502 101.5 98.8	Still in orbit.
Aug. 21 Defense 56A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	24,317 244 701.0 63.3	Still in orbit.
Aug. 23 Intelsat IV F-7 58A Atlas-Centaur	Objective: To provide equivalent of 3,000 to 9,000 telephone circuits simultaneously or 12-color TV channels or a combination of telephone, TV, and other forms of communications traffic. Spacecraft: Cylindrical 93.7-in diameter and 17.3 ft high; spin stabilized; 12 communications repeaters (transponders); 6 antennas (2 global transmit antennas, 2 global receive antennas, and 2 steerable spot-beam antennas); 45,012 solar cells. Weight at liftoff: 3,058 lb. Weight after apogee motor fire: 1,544 lb.	22,232 22,229 1,435.6 0.4	Launched by NASA for Comsat Corp., manager of Intelsat. 5th satellite in improved Intelsat IV series. Apogee motor fired by Comsat on Aug. 25 and satellite stationed at 330° east longitude over the Atlantic Ocean. Commercial operations began Sept. 9, 1973.
Sept. 27 Defense 68A Titan IIIB-Agena	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	239 80 89.8 110.5	Decayed Oct. 29, 1973.
Oct. 26 Explorer 50 (IMP) 78A Thorad-Delta	Objective: To perform detailed and near continuous studies of the interplanetary environment for oribital periods comparable to several rotations of active solar regions; to study particle and field interactions in the distant magnetotail including cross sectional mapping of the tail and neutral sheet. Spacecraft: 16-sided drum-shaped structure 62 in high and 53-in diameter. Upper portion of spacecraft contains an aluminum honeycomb shelf which supports experiments and spacecraft electronics. The lower portion has an 18-in thrust tube to accommodate solid propellant kick motor. Spacecraft structure consists of aluminum honeycomb RF shield panels and 3 bands of solar panels (16 panels per band) mounted on an aluminum honeycomb substrate. 2 diametrically opposed experiment booms (each 10 ft long) and 2 attitude control system booms (each 4 ft long) spaced 90° from experiment booms, are appended to spacecraft exterior and deployed after launch. 2 weeks later, 4 200-ft antennas are extended in support of electric and magnetic fields experiments. The spacecraft is fitted with 8 equally spaced, RF antennas (4 active 4 passive turnstile type) which extend radially. Spacecraft is spin stabilized and contains 12 scientific experiments and 2 engineering tests. Weight at launch: 875 lb.	179,496 87,732 17,279.1 28.7	Spacecraft launched into elliptical transfer orbit. Kick motor fired 1 a.m., e.s.t., Oct. 29, to place spacecraft in near-circular orbit halfway between Earth and Moon. Spacecraft functioning properly and all 12 experiments turned on. Returning good data.
Oct. 30 Defense 81A Scout	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	708 561 105.6 90.2	Still in orbit.

Successful U.S. Launches—1973

Launch date (G.m.t.) spacecraft name Cospar designation launch vehicle	Spacecraft data	Apogee and perigee (in statute miles)—period (minutes)—inclination to equator (degrees)	Remarks
Nov. 3 Mariner 10 85A Atlas-Centaur	Objective: During the 1973 opportunity to conduct exploratory investigations of the planet Mercury by obtaining measurements of its environment, atmosphere, surface, and body characteristics, and to conduct similar investigations of Venus during its flyby. First priority is assigned to Mercury investigations. Spacecraft: Basic octagonal structure measures 54½ in wide diagonally and 18 in high. 2 solar panels each 106 in long and 38.4 in wide are attached by outriggers to the top of the octagon; the 2 panels have a combined photovoltaic cell area of 51.7 ft². When fully deployed, spacecraft measures 12.2 ft from the top of the low-gain antenna to the bottom of the heat shield of the thrust vector control assembly of the propulsion system; span is 26.2 ft with solar panels extended; the 20-ft magnetometer boom adds an additional 10.8 ft to the overall span. Low gain antenna consists of 2 conical plates slotted into the outer end of a pair of concentric tubes, each 9.35 ft long and measuring 2.25 in and 1.0 inch in diameter. Motor-driven high gain antenna consists of aluminum honeycombed parabolic dish reflector 54 inches in diameter. 2 sets of reaction control jets consisting of 3 pairs of jets each are mounted at the tips of the solar panels and also on the outrigger structures supporting the high-gain antenna and magnetometer boom. Canopus star tracker assembly located on upper ring structure of octagon. 7 experiments include 2 TV cameras, an infrared radiometer, an ultraviolet airglow spectrometer, UV occultation spectrometer, 2 magnetometers, plasma science experiment detector, charged particle telescope, and dual frequency radio system. Propulsion subsystem is a multistart monopropellant hydrazine system. Weight at launch: 1,108 lb.	Heliocentric.	Mariner Venus/Mercury successfully launched on dual flyby mission. Spacecraft will arrive at point of closest approach to Venus on Feb. 5, 1974, after a 148-million-mile trip in 94 days. During Venus flyby, spacecraft's speed reduced and trajectory path bent in toward Sun; as craft travels toward Mercury, its speed will be accelerated by the Sun's gravitational force. Spacecraft will pass 621 miles above surface of Mercury on Mar. 29, 1974. Spacecraft will conduct first exploration of Mercury; will be first to send back real time TV of Venus and Mercury; and will be first to use the gravity of one planet to reach and explore another planet. As of Dec. 31, 1973, Mariner 10 was less than half way to Venus.
Nov. 6 N0AA 3 (ITOS F) 86A Thorad-Delta	Objective: To place spacecraft in a Sun-synchronous orbit having a local equator crossing time of approximately 8:30 am., descending to permit regular and dependable daytime and nighttime meteorological observations in both direct readout and stored modes of operation. Spacecraft: Rectangular, box-shaped spacecraft with a deployable 3-panel solar array. The base of the main body is about 40 in by 40 in and the overall height is about 48 in. The total area of the array is 48 ft² with each of the 3 panels measuring 36.4 in by 63.8 in. 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. Thermo-control system; 4 antennas. Weight: 760 lb.	938 931 116. 1 102. 1	First to transmit local-area atmospheric temperature measurements to ground stations around the world. Becomes primary satellite in NOAA global weather watch program. Spacecraft functioning normally and turned over to NOAA on Nov. 29, 1973, for operational use.

Successful U.S. Launches—1973

Launch date (G.m.t.) spacecraft name Cospar designation launch vehicle	Spacecraft data	Apogee and perigee (in statute miles)— period (minutes)— inclination to equator (degrees)	Remarks
Nov. 10 Defense 88A Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	165 101 88.7 96.9	Still in orbit.
Nov. 10 Defense 88B Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	314 303 94.5 96.3	Still in orbit.
Nov. 10 Defense 88D Titan IIID	Objective: Development of space flight techniques and technology. Spacecraft: Not announced.	906 881 114.6 96.9	Still in orbit.
Nov. 16 Skylab 4 (SL-4) 90A Saturn IB	Objective: To perform unmanned Saturn Workshop operations; to reactivate the Skylab orbital assembly in Earth orbit; to obtain medical data on the crew for use in extending the duration of manned space flights; to perform inflight experiments. Spacecraft: Apollo Block II command and service modules (CSM) modified for Skylab use. Command module is conical in shape, 12 ft 10 inches in diameter and 11 ft 5½ in high, and has a habitable volume of 210 ft. Service module is cylindrical, 12 ft 10 inches in diameter and 24 ft 10 in long, with a 20,000-lb thrust main propulsion system, reaction control system, fuel cells, oxygen, and radiators. CSM/S-IVB weight in initial earth orbit: 68,856 lb. CSM weight after S-IVB separation: 32,849 lb. Total weight of docked assembly (CSM/Workshop): 192,061 lb.	272 262 93.2 50.0	Crew consisted of Gerald P. Carr, commander; Edward G. Gibson, science pilot; William R. Pogue, pilot. 3d and final manned Skylab mission. CSM docked with Skylab Workshop at 5:02 p.m. e.s.t. Nov. 16. Next day crew entered workshop and activated all systems. On Nov. 22, Pogue and Gibson repaired broken radar antenna during record 6 hr 34 min 35 sec EVA. 3 more EVA's planned. Crew performing medical experiments and taking earth resources photos; also studying comet Kohoutek. 1 of 3 control gyroscopes failed but full 84-day mission still planned.
Dec. 13 DSCS F-3 100A Titan IIIC	Objective: Defense communications link. Spacecraft: Not announced.	22,447 22,245 1,445.0 2.0	Still in orbit.
Dec. 13 DSCS F-4 100B Titan IIIC	Objective: Defense communications link. Spacecraft: Not announced.	22,455 22,335 1,449.0 2.0	Still in orbit.
Dec. 16 Explorer 51 101A Thorad-Delta	Objective: To investigate the photochemical processes accompanying the absorption of solar ultraviolet radiation in the Earth's atmosphere by making closely coordinated measurements of the reacting constituents from a spacecraft with onboard propulsion to permit perigee and apogee altitudes to be varied by command. Spacecraft: Cylindrical 16-sided satellite 53 inches in diameter and 45 inches high. Consists of 2 shells, inner shell holds 14 scientific instruments and outer shell is covered with solar panels. Orbit adjust propulsion subsystem carries 367 lbs of hydrazine fuel and employs 3 thrusters. Spin-stabilized satellite also contains an omnidirectional S-band antenna and redundant nickel-cadmium batteries. Weight at launch: 1,473 lbs.	2676.3 97.2 132.5 68.1	First of a series of 2d generation spacecraft. Placed initially into elliptical orbit; the onboard propulsion system permits the satellite to dip into the largely unexplored region of the lower atmosphere.

U.S. Applications Satellites 1958–1973

Date	Name	Launch vehicle	Remarks
		GEODESY	
Oct. 31, 1962	Anna 1B	Thor-Able Star	Used 3 independent measuring techniques: Doppler frequency shift, flashing lights, and radio triangulation.
Jan. 11, 1964	Secor I	Thor-Agena D	Used radio triangulation and trilateration.
Oct. 10, 1964	Beacon-Explorer XXII	Scout	Conducted reflecting-light geodetic measurements.
Mar. 9, 1965	Secor III	Thor-Agena D	
Mar. 11, 1965	Secor II	Thor-Able Star	
Apr. 3, 1965	Secor IV	Atlas-Agena D	
Apr. 29, 1965	Beacon-Explorer XXVII	Scout	
Aug. 10, 1965	Secor V	Scout	
Nov. 6, 1965	GEOS-I Explorer XXIX	Thor-Delta	
June 9, 1966	Secor VI	Atlas-Agena D	
June 23, 1966	Pageos I	Thor-Agena D	Spacecraft is a 100-ft-diameter balloon used as a photographic target to make geodetic measurements.
Aug. 19, 1966	Secor VII	Atlas-Agena D	
Oct. 5, 1966	Secor VIII	Atlas-Agena D	
June 29, 1967	Secor IX	Thor-Burner II	
Jan. 11, 1968	GEOS II	Thor-Delta	
Apr. 14, 1969	Secor XIII	Thor-Agena D	
Apr. 8, 1970	Topo I	Thor-Agena D	

U.S. Applications Satellites 1958–1973

Date	Name	Launch vehicle	Remarks
		COMMUNICATIONS	
Dec. 18, 1958	Score	Atlas B	First Comsat, carried taped messages.
Aug. 12, 1960	Echo I	Thor-Delta	100-ft balloon served as first passive Comsat, relayed voice and TV signals.
Oct. 4, 1960	Courier 1B	Thor-Able Star	First active-repeater Comsat.
Mar. 30, 1961	Lofti I	Thor-Able Star	Low-frequency experiment; failed to separate from rest of payload.
Oct. 21, 1961	Westford I	Atlas-Agena B	First attempt to establish filament belt around Earth; failed to disperse as planned.
Dec. 12, 1961	Oscar I	Thor-Agena B	First amateur radio "ham" satellite.
June 2, 1962	Oscar II	Thor-Agena B	
July 10, 1962	Telstar I	Thor-Delta	Industry-furnished spacecraft in near-Earth orbit.
Dec. 13, 1962	Relay I	Thor-Delta	Active-repeater Comsat.
Feb. 14, 1963	Syncom I	Thor-Delta	Successfully injected into near-synchronous orbit but communication system failed at orbital injection.
May 7, 1963	Telstar II	Thor-Delta	
May 9, 1963	Westford II	Atlas-Agena B	Filaments formed reflective belt around Earth as planned for emergency communications experiment.
July 26, 1963	Syncom II	Thor-Delta	First successful synchronous orbit active-repeater Comsat. After experimental phase, used operationally by DOD.
Jan. 21, 1964	Relay II	Thor-Delta	
Jan. 25, 1964	Echo II	Thor-Agena B	135-ft balloon, passive Comsat, first joint use by United States and U.S.S.R.
Aug. 19, 1964	Syncom III	Thor-Delta	Synchronous-orbit Comsat; after experimental phase, used operationally by DOD.
Feb. 11, 1965	LES I	Titan IIIA	Experimental payload did not reach intended apogee.
Mar. 9, 1965	Oscar III	Thor-Agena D	
Apr. 6, 1965	Intelsat I (Early Bird)	Thor-Delta	First Intelsat (Comsat Corporation) spacecraft, 240 2-way voice circuits: commercial transatlantic communication service initiated June 28, 1965.
May 6, 1965	LES II	Titan IIIA	All solid state advanced experiment.
Dec. 21, 1965	LES III	Titan IIIC	All solid state, UHF signal generator.
	LES IV		All solid state SHF or X band experiment.
	Oscar IV		
June 16, 1966	IDCSP 1–7	Titan IIIC	Initial defense communication satellites program (IDCSP)-Active-repeater spacecraft in near-synchronous orbit, random spaced.
Oct. 26, 1966	Intelsat II–F1	Thor-Delta (TAT)	First in Intelsat II series spacecraft; 240 2-way voice circuits or 1-color TV channel. Orbit achieved not adequate for commercial operation.
Nov. 3, 1966	OV 4–1T	Titan IIIC	Transmitter and receiver for low-power satellite-to-satellite F layer experiments.
	OV 4–1R		
Dec. 7, 1966	ATS I	Atlas-Agena D	Multipurpose, including VHF exchange of signals with aircraft.
Jan. 11, 1967	Intelsat II–F2	Thor-Delta (TAT)	Transpacific commercial communication service initiated Jan. 11, 1967.
Jan. 18, 1967	IDCSP 8–15	Titan IIIC	
Mar. 22, 1967	Intelsat II–F3	Thor-Delta (TAT)	Positioned to carry transatlantic commercial communication traffic.
Apr. 6, 1967	ATS II	Atlas-Agena D	Multipurpose, but did not attain planned orbit.
July 1, 1967	IDCSP 16–18	Titan IIIC	
	LES V		Tactical military communications tests with aircraft, ships, and mobile land stations from near synchronous orbit.
	DATS		Electronically despun antenna experiment.
	DODGE		Multipurpose, gravity stabilized.
Sept. 27, 1967	Intelsat II–F4	Thor-Delta (TAT)	Positioned to carry commercial transpacific communication traffic.
Nov. 5, 1967	ATS III	Atlas-Agena D	Multipurpose including communications.
June 13, 1968	IDCSP 19–26	Titan IIIC	
Aug. 10, 1968	ATS IV	Atlas-Centaur	Multipurpose; failed to separate from Centaur, did not reach planned orbit.
Sept. 26, 1968	LES 6	Titan IIIC	Continued military tactical communications experiments.
Dec. 18, 1968	Intelsat III (F–2)	Thor-Delta (TAT)	First in Intelsat III series of spacecraft, 1,200 2-way voice circuits or 4-color TV channels. Positioned over Atlantic to carry traffic between North America, South America, Africa, and Europe. Entered commercial service on Dec. 24, 1968.
Feb. 6, 1969	Intelsat III (F–3)	Thor-Delta (TAT)	Stationed over Pacific to carry commercial traffic between the United States, Far East, and Australia.
Feb. 9, 1969	Tacsat I	Titan IIIC	Demonstrated feasibility of using a spaceborne repeater to satisfy selected communications needs of DOD mobile forces.

U.S. Applications Satellites 1958–1973

Date	Name	Launch vehicle	Remarks
		COMMUNICATIONS—Continued	
May 22, 1969	Intelstat III(F–4)	Thor-Delta(TAT)	Stationed over Pacific to replace F–3 which was moved westward to the Indian Ocean. Completes global coverage.
July 26, 1969	Intelsat III(F–5)	Thor-Delta(TAT)	Spacecraft failed to achieve the proper orbit. Not usable.
August 12, 1969	ATS V	Atlas Centaur	Multipurpose; for millimeter and L band communications; entered flat spin.
Nov. 22, 1969	Skynet I (IDCSP–A)	Thor-Delta(TAT)	Launched for the United Kingdom in response to an agreement to augment the IDCSP program.
Jan. 15, 1970	Intelsat III(F–6)	Thor-Delta(TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, Latin America, and the Middle East.
Jan. 23, 1970	Oscar V (Australis)	Thor-Delta(TAT)	Ham radio satellite built by amateur radio operators at Melbourne University, Melbourne, Australia.
Mar. 20, 1970	NATOSAT–I (NATO–A)	Thor-Delta (TAT)	First NATO satellite, stationed over Atlantic to carry military traffic between the United States and other NATO countries.
Apr. 23, 1970	Intelsat III (F–7)	Thor-Delta (TAT)	Stationed over Atlantic to carry commercial traffic between the United States, Europe, North Africa, and the Middle East.
Jul. 23, 1970	Intelsat III (F–8)	Thor-Delta (TAT)	Spacecraft failed to achieve the proper orbit. Not usable. Last launch of Intelsat III series.
Aug. 22, 1970	Skynet II (IDCSP–B)	Thor-Delta (TAT)	Launched for the United Kingdom in response to an agreement to augment the IDCSP program. Spacecraft failed to achieve the proper orbit.
Jan. 26, 1971	Intelsat IV (F–2)	Atlas Centaur	First in Intelsat IV series of spacecraft; 3–9,000, 2-way voice circuits or 12-color TV channels. Positioned over the Atlantic.
Feb. 3, 1971	NATOSAT–II (NATO–B)	Thor-Delta (TAT)	Second NATO satellite, stationed over the Atlantic to carry military traffic.
Nov. 3, 1971	DSCS 2–1, 2	Titan IIIC	Operational defense communications satellites launched as a pair to 24-hour synchronous orbits to provide high capacity voice, digital, and secure voice communications for military networks.
Dec. 19, 1971	Intelsat IV (F–3)	Atlas Centaur	Second in new high-capacity series. 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.
		NAVIGATION	
Apr. 13, 1960	Transit 1B	Thor-Able Star	First navigation satellite. Used Doppler frequency shift for position determination.
June 22, 1960	Transit 2A	Thor-Able Star	
Feb. 21, 1961	Transit 3B	Thor-Able Star	
June 29, 1961	Transit 4A	Thor-Able Star	Used the first spacecraft nuclear SNAP–3 as a secondary power supply.
Nov. 15, 1961	Transit 4B	Thor-Able Star	
Dec. 18, 1962	Transit 5A	Scout	Operational prototype, power failed during first day.
June 15, 1963	NavSat	Scout	Used gravity-gradient stabilization system.
Sept. 28, 1963	NavSat	Thor-Able Star	Used first nuclear SNAP–9A as primary power supply.
Dec. 5, 1963	NavSat	Thor-Able Star	
June 4, 1964	NavSat	Scout	
Oct. 6, 1964	NavSat	Thor-Able Star	
Dec. 13, 1964	NavSat	Thor-Able Star	
Mar. 11, 1965	NavSat	Thor-Able Star	
June 24, 1965	NavSat	Thor-Able Star	
Aug. 13, 1965	NavSat	Thor-Able Star	
Dec. 22, 1965	NavSat	Scout	
Jan. 28, 1966	NavSat	Scout	
Mar. 25, 1966	NavSat	Scout	
May 19, 1966	NavSat	Scout	
Aug. 18, 1966	NavSat	Scout	
Apr. 13, 1967	NavSat	Scout	
May 18, 1967	NavSat	Scout	
Sept. 25, 1967	NavSat	Scout	
Mar. 1, 1968	NavSat	Scout	
Aug. 27, 1970	NavSat	Scout	
Sept. 2, 1972	Triad OI–1	Scout	First experimental station keeping Transit navigation satellite.
Oct. 30, 1973	NavSat O–20	Scout	

U.S. Applications Satellites 1958–1973

Date	Name	Launch vehicle	Remarks
		WEATHER OBSERVATION	
Apr. 1, 1960	Tiros I	Thor-Able	First weather satellite providing cloud-cover photography.
Nov. 23, 1960	Tiros II	Thor-Delta	
July 12, 1961	Tiros III	Thor-Delta	
Feb. 8, 1962	Tiros IV	Thor-Delta	
June 19, 1962	Tiros V	Thor-Delta	
Sept. 18, 1962	Tiros VI	Thor-Delta	
June 19, 1963	Tiros VII	Thor-Delta	
Dec. 21, 1963	Tiros VIII	Thor-Delta	First weather satellite designed to transmit continuously local cloud conditions to ground stations equipped with APT receivers.
Aug. 28, 1964	Nimbus I	Thor-Agena B	Carried advanced videcon camera system, APT, and a high resolution infrared radiometer for night pictures.
Jan. 22, 1965	Tiros IX	Thor-Delta	First weather satellite in a sun-synchronous orbit.
July 2, 1965	Tiros X	Thor-Delta	
Feb. 3, 1966	ESSA 1	Thor-Delta	First operational weather satellite; carried 2 wide-angle TV camera systems.
Feb. 28, 1966	ESSA 2	Thor-Delta	Complemented ESSA 1 with 2 wide-angle APT cameras.
May 15, 1966	Nimbus II	Thor-Agena B	
Oct. 2, 1966	ESSA 3	Thor-Delta	Odd-number ESSA spacecraft carry 2 advanced videcon camera systems. Even-numbered spacraft carry 2 automatic picture transmission camera systems.
Dec. 6, 1966	ATS–1	Atlas-Agena D	Provided continuous black-and-white cloud-cover pictures from a synchronous orbit, using a Suomi camera system.
Jan. 26, 1967	ESSA 4	Thor-Delta	
Apr. 20, 1967	ESSA 5	Thor-Delta	
Nov. 5, 1967	ATS–3	Atlas-Agena	Provided continuous color cloud-cover pictures from a synchronous orbit, using 3 Suomi camera systems.
Nov. 10, 1967	ESSA 6	Thor-Delta	
Aug. 16, 1968	ESSA 7	Thor-Delta	
Dec. 15, 1968	ESSA 8	Thor-Delta	
Feb. 26, 1969	ESSA 9	Thor-Delta	
Apr. 14, 1969	Nimbus III	Thor-Agena	Provided first vertical temperature profile on a global basis of the atmosphere from the spacecraft to the Earth's surface.
Jan. 23, 1970	ITOS I (Tiros M)	Thor-Delta	Second generation operational meteorological satellite.
Apr. 8, 1970	Nimbus IV	Thor-Agena	Fifth in a series of 7 advanced research and development weather satellites.
Dec. 11, 1970	NOAA–1 (ITOS-A)	Thor-Delta	Second generation operational meteorological satellite.
Aug. 16, 1971	Eole (CAS–1)	Scout	French satellite to gather data from constant density surface ballons relaying meterological data for the study of the characteristics and movements of air masses. New balloons are released daily from 3 sites in Argentian, 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	
		EARTH OBSERVATION	
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.

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	26 h 2 min.	First extravehicular activity (Leonov, 10 min).
Gemini 3	Mar. 23, 1965	Virgil I. Grissom John W. Young	4 h 53 min.	First U.S. 2-man flight; first manual maneuvers in orbit.
Gemini 4	June 3, 1965	James A. McDivitt Edward H. White, 2d	97 h 56 min.	21-min. extravehicular activity (White).
Gemini 5	Aug. 21, 1965	L. Gordon Cooper, Jr. Charles Conrad, Jr.	190 h 55 min.	Longest-duration manned flight to date.
Gemini 7	Dec. 4, 1965	Frank Borman James A. Lovell, Jr.	330 h 35 min.	Longest-duration manned flight to date.
Gemini 6–A	Dec. 15, 1965	Walter M. Schirra, Jr. Thomas P. Stafford	25 h 51 min.	Rendezvous within 1ft 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 takeoff 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 Vladislov 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 Charles 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	.....	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.

U.S. Space Launch Vehicles

Vehicle	Stages	Propellant [4]	Thrust (in thousands of lb)	Max. dia. (ft)	Height [3] (ft)	Payload (lb)[5] 300NM orbit	Payload (lb)[5] Escape	First launch
Scout	1. Algol III	Solid	107.2	3.75	64.4	410	85	[1] 1972(60)
	2. Castor II	Solid	61.1					
	3. Antares X-259	Solid	22.0					
	4. FW4	Solid	5.3					
Thor-Delta 2900 series.	1. Thor plus nine TX 354-3.	LOX/RP	205	8	116	3,900	1,050	1973(60)
		Solid	[2] 156					
	2. Delta (DSV-3)	N_2O_4/Aerozine	9.4					
	3. TE 364	Solid	15					
Atlas-Agena	1. Atlas booster and sustainer (SLV/3A).	LOX/RP	400	10	100	7,700	1,430	1968(60)
	2. Agena	IRFNA/UDMH	16					
Titan IIIB-Agena	1. LR-87	N_2O_4/Aerozine	464	10	119	[6] 7,500	[6] 1,100	1966
	2. LR-91	N_2O_4/Aerozine	102					
	3. Agena	IRFN/UDMH	16					
Titan IIIC	1. Two 5-segment 120-in diameter.	Solid	2,400	10x30	108	26,000	6,200	1965
	2. LR-87	N_2O_4/Aerozine	523					
	3. LR-91	N_2O_4/Aerozine	102					
	4. Transtage	N_2O_4/Aerozine	16					
Titan IIID	1. Two 5-segment 120-in diameter.	Solid	2,400	10x30	95	[6] 21,000	.....	1971
	2. LR-87	N_2O_4/Aerozine	523					
	3. LR-91	N_2O_4/Aerozine	102					
Titan IIIE-Centaur	1. Two 5-segment 120-in diameter.	Solid	2,400	10x30	128	.....	11,500	1974
	2. LR-87	N_2O_4/Aerozine	523					
	3. LR-91	N_2O_4/Aerozine	102					
	4. Centaur (Two RL-10).	LOX/LH	30					
Atlas-Centaur	1. Atlas booster and sustainer.	LOX/RP	431	10	103	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	142	34,000	.....	1966
	2. S-IVB (one J-2)	LOX/LH	230					

[1] The date of first launch applies to this latest modification with a date in parentheses for the initial version.
[2] Set of 3.
[3] Height to spacecraft interface.
[4] Propellant abbreviations used are as follows: Liquid Oxygen and a modified Kerosene—LOX/RP; Solid propellant combining in a single mixture both fuel and oxidizer—Solid; Inhibited Red Fuming Nitric Acid and Unsymmetrical Dimethylhydrazine—IRFN/UDMH; Nitrogen Tetroxide and UDMH/N_2H_4—N_2O_4/Aerozine; Liquid Oxygen and Liquid Hydrogen—LOX/LH.
[5] Due east launch.
[6] Polar launch.

Nuclear Power Systems for Space Applications

Designation	Launch date	Application	Remarks
SNAP-3	June 1961 November 1961	Navigation satellites (DOD).	Experimental units to demonstrate nuclear power capabilities.
SNAP-9A	September 1963 December 1963 April 1964 (Aborted)	Navigation satellites (DOD).	First satellites fully powered by nuclear systems.
SNAP-10A	April 1965	Space reactor test.	Demonstrated space reactor power system.
SNAP-19	May 1968 (Aborted) April 1969	Nimbus B weather satellite (NASA).	Fuel from aborted mission recovered from offshore waters.
SNAP-27	November 1969 April 1970 (Aborted) January 1971 July 1971 April 1972 December 1972	Apollo Lunar Surface Experimental Packages — ALSEP (NASA).	All 5 units still operating in excess of design requirements.
Pioneer	March 1972 April 1973	Jupiter flyby (NASA).	First spacecraft (Pioneer 10) passed Jupiter in December 1973.
Transit	September 1972	Navigation satellites (DOD).	Operated for 16 months of scheduled 5-year mission.
LES 8/9		Space communications (DOD).	Two spacecraft scheduled for simultaneous launch in 1975.
Viking		Mars lander (NASA).	Two spacecraft scheduled for launch in 1975.
MJS		Mariner Jupiter/Saturn flyby (NASA).	Two spacecraft scheduled for launch in 1977.

Space Activities of the U.S. Government

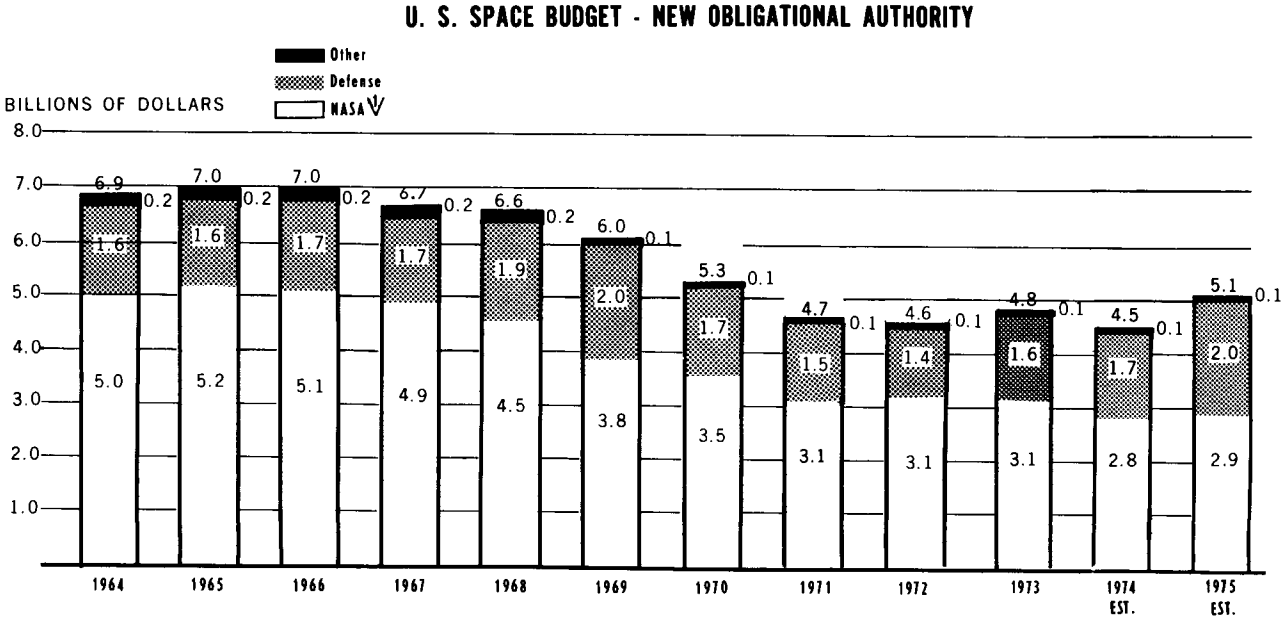
17-YEAR BUDGET SUMMARY—NEW FISCAL YEAR OBLIGATIONAL AUTHORITY

[In millions of dollars (may not add due to rounding)]

	NASA		Department of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total space
	Total	Space [1]							
1959	305.4	235.4	489.5	34.3	.....				759.2
1960	523.6	461.5	560.9	43.3	.....			.1	1,065.8
1961	964.0	926.0	813.9	67.7	.....			.6	1,808.2
1962	1,824.9	1,796.8	1,298.2	147.8	50.7	.....		1.3	3,294.8
1963	3,673.0	3,626.0	1,549.9	213.9	43.2	.....		1.5	5,434.5
1964	5,099.7	5,046.3	1,599.3	210.0	2.8	.....		3.0	6,861.4
1965	5,249.7	5,167.6	1,573.9	228.6	12.2	.....		3.2	6,985.5
1966	5,174.9	5,094.5	1,688.8	186.8	26.5	.....		3.2	6,999.8
1967	4,967.6	4,862.2	1,663.6	183.6	29.3	.....		2.8	6,741.5
1968	4,588.8	4,452.5	1,921.8	145.1	28.1	0.2	0.5	3.2	6,551.4
1969	3,990.9	3,822.0	2,013.0	118.0	20.0	0.2	0.7	1.9	5,975.8
1970	3,745.8	3,547.0	1,678.4	102.8	8.0	1.1	0.8	2.4	5,340.5
1971	3,311.2	3,101.3	1,512.3	94.8	27.4	1.9	0.8	2.4	4,740.9
1972	3,306.6	3,071.0	1,407.0	55.2	31.3	5.8	1.6	2.8	4,574.7
1973	3,406.2	3,093.2	1,623.0	54.2	39.7	10.3	1.9	2.6	4,824.8
1974 Est.	3,038.0	2,762.4	1.668.0	42.2	62.8	8.9	1.9	2.0	4,548.2
1975 Est.	3,244.7	2,933.5	2,032.0	36.6	62.2	7.6	1.9	2.0	5,075.8

[1] Excludes amounts for aviation technology.

Source: Office of Management and Budget.



V Excludes amounts for aviation technology.
Source: Office of Management and Budget

APPENDIX F–2

Space Activities Budget

[In millions of dollars]

	New obligational authority			Expenditures		
	1973 actual	1974 estimate	1975 estimate	1973 actual	1974 estimate	1975 estimate
Federal space programs:						
NASA[1]	3,093.2	2,762.4	2.933.5	3,069.4	2,888.9	2,962.8
Defense	1,623.0	1,668.0	2,032.0	1,557.0	1,688.0	1,900.0
AEC	54.2	42.2	36.6	51.1	40.1	42.1
Commerce	39.7	62.8	62.2	29.4	65.0	66.0
Interior	10.3	8.9	7.6	8.3	9.3	7.9
NSF	2.6	2.0	2.0	2.3	1.7	1.8
Agriculture	1.9	1.9	1.9	1.9	1.9	1.9
Total	4,824.9	4,548.2	5,075.8	4,719.4	4,694.9	4,982.5
NASA:						
Manned space flight	1,538.8	1,413.5	1,530.0	1,537.5	1,479.1	1,568.1
Space science and applications	1,092.4	897.7	939.0	1,063.6	947.8	936.0
Space technology	146.5	124.1	133.5	166.2	141.0	132.6
Aeronautical technology	313.0	275.6	311.2	241.6	288.4	309.7
Supporting operations	328.9	364.0	356.4	315.5	357.9	351.5
Less receipts	−13.4	−36.9	−25.4	−13.4	−36.9	−25.4
Total NASA	3,406.2	3,038.0	3,244.7	3,311.0	3,177.3	3,272.5

[1] Excludes amounts for Aeronautical Technology.

Source: Office of Management and Budget.

Aeronautics Budget

[In millions of dollars]

	New obligational authority		
	1973 actual	1974 estimate	1975 estimate
Federal aeronautics programs:			
NASA[1]	313.0	275.6	311.2
Department of Defense[2]	1,799.0	1,682.0	1,869.0
Department of Transportation[3]	75.3	73.6	83.0
Total	2,187.3	2,031.2	2,263.2

[1] Research and Development, Research and Program Management, Construction of Facilities.

[2] Research, Development, Testing, and Equipment of aircraft and related equipment.

[3] Office of Secretary of Transportation and Federal Aviation Administration Research and Development.

Source: Office of Management and Budget.

U.S. GOVERNMENT PRINTING OFFICE : 1974 O-528-338