REPORT TO THE CONGRESS

FROM THE PRESIDENT OF THE UNITED STATES

UNITED STATES AERONAUTICS AND SPACE ACTIVITIES

1966

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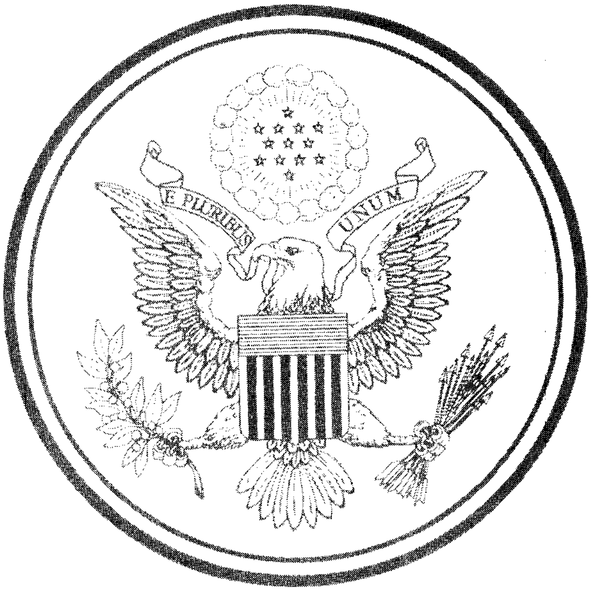


EXECUTIVE OFFICE OF THE PRESIDENT

NATIONAL AERONAUTICS AND SPACE COUNCIL

WASHINGTON, D. C. 20502

TO THE CONGRESS OF THE UNITED STATES

America's space and aeronautics programs made brilliant progress in 1966. We developed our equipment and refined our knowledge to bring travel and exploration beyond earth's atmosphere measurably closer. And we played a major part in preparing for the peaceful use of outer space.

In December the United Nations, following this country's lead, reached agreement on the Outer Space Treaty. At that time I said it had "historical significance for the new age of space exploration." It bars weapons of mass destruction from space. It restricts military activities on celestial bodies. It guarantees access to all areas by all nations.

GEMINI manned missions were completed with a final record of constructive and dramatic achievement. Our astronauts spent more than 1,900 pilot hours in orbit. They performed pioneering rendezvous and docking experiments. They "walked" in space outside their vehicles for about 12 hours.

We orbited a total of 95 spacecraft around the earth and sent five others on escape flights, a record number of successful launches for the period. We launched weather satellites, communications satellites, and orbiting observatories. We performed solar experiments and took hundreds of pictures of the moon from LUNAR ORBITERS. SURVEYOR I landed gently on the moon and then returned over 11,000 pictures of its surroundings for scientific examination.

Major progress was made during the year on the APOLLO-SATURN moon program and the MANNED ORBITING LABORATORY.

These accomplishments -- and the promise of more to come -- are the fruits of the greatest concerted effort ever undertaken by any nation to advance human knowledge and activity. Space, so recently a mystery, now affects and benefits the lives of all Americans.

Our national investment in space has stimulated the invention and manufacture of a flood of new products. Our new knowledge has made us more secure as a Nation and more effective as leaders in the search for peace. This knowledge is hastening the ultimate solution of social and economic problems that combined to obstruct peace.

It is with pride and pleasure that I transmit this record of achievement to you the members of Congress. Without your support, no achievement would be possible.

Lyndon B. Johnson

THE WHITE HOUSE
January 31, 1967

TABLE OF CONTENTS

CHAPTER I

U. S. AERONAUTICS AND SPACE ACTIVITIES *1966*

SUMMARY

In 1966, the national space program of the United States reached new heights of accomplishment and excellence. The challenge of the previous year was met and its impressive record was surpassed by the competence generated in 1966.

During this past year, we put into earth orbit or escape missions 100 spacecraft, the largest number ever successfully launched by any nation in an equal period of time; the GEMINI program was completed with a magnificent record; thousands of excellent pictures of the moon and the earth were taken from space; increasing space capabilities contributed to our national security; manifold benefits of our growing technology and managerial ability became increasingly evident; and international competition in space showed useful advances, particularly with the accomplishment of the United Nations Space Treaty.

The national space program continued to produce benefits for all mankind, and the knowledge gained from the program has created great potential for the solution of serious economic and social problems on earth.

The GEMINI program merits special mention. The crews of these spacecraft showed the advantages of native ability combined with superb training and reliable equipment. They added significantly to the knowledge essential to successful manned space flights and particularly to the scheduled manned flight to the moon. Through rendezvous and docking experiments and extravehicular activity, the GEMINI pilots made major contributions. Moreover, great credit for this successful program should also go to the producers of the GEMINI spacecraft, the TITAN booster, the AGENA target vehicle, and other essential equipment.

Even a summary report on the GEMINI program would be incomplete without special notice of the excellent teamwork between NASA and the Defense Department, as well as between agencies of Government and the private contractors.

The APOLLO lunar craft made successful suborbital reentry tests leading to its first manned launch scheduled for 1967. And the goal toward which the APOLLO is destined to travel, and on which its LUNAR EXCURSION MODULE will land, was photographed thousands of times in impressive detail by the soft-landing SURVEYOR I and by LUNAR ORBITERS I and II. Such photographic acquisitions contributed much new knowledge about the lunar environment and gave considerable information regarding possible landing sites for astronauts.

The moon was not all that was photographed from space, as numerous shots were taken of earth, furnishing added knowledge as well as dramatic pictures.

Also sharing the spotlight of this nation's forward thrust of technology during 1966 was the field of aeronautics. Significant strides were made toward increasing the safety of civilian transports. Progress was also made in improvements in existing aircraft as well as in the development of new aircraft. Probably the most important of the latter was in the field of the Supersonic Transport concerning which major studies and decisions were made.

The United States continued to implement its policies of peaceful space objectives and of international cooperation toward the attainment of such objectives. Of major importance was the successful leadership shown by the United States and the cooperation of the Soviet Union in the development of a United Nations Space Treaty banning nuclear weapons in space and specifying the moon and other celestial bodies as being available only for peaceful activities.

Important progress was made during the year in the development of the MANNED ORBITING LABORATORY, a project designed to evaluate the extent to which man in space can contribute to our national security. It is not a weapons system, it is not a means by which aggressive actions can be perpetuated, and it is in no way in conflict with the established peaceful policies of this nation. Rather, it is expected to improve the prospects for world peace.

The United States operational weather satellite system continued to warn the world of major weather disturbances, and four more weather satellites were successfully orbited and operated for this purpose. More parts of the world were linked together with live television and other forms of communications as the United States, through the Communications Satellite Corporation, continued to orbit synchronous communications satellites in conjunction with the INTELSAT international consortium.

Though the Soviet Union maintained its practice of putting more weight into orbit during a given year, the United States made significant progress in its program to develop large boosters, and the 58,537 pounds carried into space by an Uprated-SATURN I during an APOLLO test may be a world's record for a single launch. Development flights of the TITAN IIIB and IIIC were continued with the use of new and improved upper stages. The Uprated-SATURN I was used with complete success, and the giant 7,500,000 pound thrust SATURN V is being readied for its first test early next year.

In spite of the impressive record developed by the United States, there is no basis for complacency as the Soviet Union was far from idle. Though they have made no manned launches into space for about 21 months, the vigorous nature of the Soviet program indicates that this hiatus could be attributed to the transition from one manned project to the next, and that new and significant manned space flights will be witnessed in the near future. The Soviets continued to concentrate on their lunar program during the year, and landed two picture-taking spacecraft on the lunar surface while orbiting two spacecraft around it. The Soviet Union also implemented their weather and communications satellite programs. The U. S. S. R. gave tangible evidence of the advantages they attribute to space progress by devoting a significantly larger percentage of their gross national product to space than we do.

Among the many major accomplishments by the United States during 1966 were the following:

1. The five successful flights completing the two-man GEMINI program produced a number of major achievements, such as the first docking and the first station keeping with another spacecraft by use of a tether line, a manned spacecraft altitude record of 851 miles, and useful activity of man outside orbiting spacecraft.

2. The major studies were completed, and important decisions were made regarding the development and construction of a U. S. commercial supersonic transport (SST).

3. Development of the Department of Defense MANNED ORBITING LABORATORY continued, and twelve future astronauts were selected for the program.

4. A series of three unmanned flights of the APOLLO-SATURN I vehicle were successfully completed. The flights tested the heat shield during reentry conditions, the operation of the spacecraft systems under flight conditions, and testing of the Uprated - SATURN I second stage, which will be the third stage of the SATURN V.

5. Significant progress was made in the testing and qualification of the three-stage SATURN V for its initial launching in 1967. Problems which occurred in the second stage appear to have been solved.

6. The TITAN IIIC underwent three flight tests during the year, launching seven military communications satellites and a gravity gradient experiment during the first test, and a modified GEMINI heat shield along with other experiments associated with the MANNED ORBITING LABORATORY during the third test. On the second test flight the vehicle destroyed itself after the fairing failed.

7. SURVEYOR I landed gently on the moon and then returned over 11,000 pictures of its surroundings. Its power supply and housekeeping electronic systems survived through several lunar day-night cycles.

8. LUNAR ORBITERS I and II returned hundreds of useful pictures of potential APOLLO landing sites, pictures of the far side of the moon, and the first pictures of the entire visible face of the earth as seen from the vicinity of the moon.

9. The CENTAUR test program was successfully completed with the ninth and last ATLAS-CENTAUR test vehicle carrying a mass model of SURVEYOR to an imaginary rendezvous with the moon.

10. PIONEER 7 made a successful flight to measure radiation and particles in the interplanetary medium between the orbit of earth and an orbit 12 million miles farther out.

11. Tests of the nation's first NERVA nuclear-rocket engine (a "breadboard" engine which contained flight-type components but in a non-flight arrangement) demonstrated its high performance and stability over a wide range of operating conditions.

12. The United Nations, following the lead of the United States, reached agreement on a "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies." The treaty, which will be sent to the U. S. Senate for ratification, forbids the placing of weapons of mass destruction in outer space or on celestial bodies, restricts military activities on celestial bodies, and bars claims of sovereignty and national appropriation.

13. The Air Force F-111A fighter-bomber flew for the first time at Mach 2.5.

14. The U. S. operational weather satellite system continued to warn the world of impending storms and four more weather satellites were orbited for this purpose.

15. A space thermoelectric generator was fueled for the first time with curium 242 and was successfully tested for 90 days under simulated lunar conditions.

16. Improvements in the atomic clock have brought its accuracy to the equivalent of one second in 6,000 years. Modifications are being made to make it even more accurate.

17. An ORBITING OBSERVATORY (OGO III) was launched into earth orbit and continues to carry out its geophysical mission.

18. The XB-70 experimental aircraft was utilized for supersonic and sonic boom tests. Its sister ship was destroyed as a result of a mid-air collision.

19. PAGEOS I, a large sphere passive geodetic earth-orbiting satellite was launched into a near circular polar orbit, and simultaneous observation from 41 portable camera stations around the world makes it possible to obtain more accurate measurements of distance between widely separated points on earth.

20. Two more EXPLORER satellites were launched -- one to study the earth's atmosphere; the other to investigate possible radiation hazards to astronauts in deep space.

21. The first Applications Technology Satellite (ATS) was placed in synchronous orbit to conduct communications, meteorological, and geophysical experiments.

22. MARINER IV (launched in 1964) transmitted data to earth as it passed behind the sun, marking the first time that radio-frequency energy had passed through the solar corona and been received by an earth-based station.

23. Preliminary design of the Mars orbiting VOYAGER was completed.

24. A BIOSATELLITE was launched on a three-day flight to investigate the effects of weightlessness, radiation, and other stresses of the space environment on the various life forms on board. Difficulties prevented the spacecraft from being recovered, although telemetry developed some information.

25. The X-15 research aircraft continued to be used for a wide variety of aeronautical and space flight experiments, including flights with the large external tanks to be used later for Mach 8 speeds.

26. Studies were completed on the feasibility of using V/STOL concepts for short haul commercial transports.

27. Components of the 1.5 million pound thrust M-1 engine were successfully tested and yielded valuable data.

28. The 260-inch diameter solid rocket motor was static tested, burning for about 2 minutes and developing a maximum thrust of over 3.5 million pounds.

29. Two lifting body vehicles, the M-2 and the HL-10 were in the initial phases of their flight test program.

30. The first SNAP 8 power conversion system was operated, achieving a 35 KW electrical output.

31. A single ion engine was endurance tested for over 8,000 hours, leading to the decision to prepare a second flight in the Space Electric Rocket Test program.

32. Preparations were made for the PHOEBUS 1-B nuclear reactor tests.

33. The nation's largest fully steerable antenna, a 210-foot diameter parabolic antenna, was added to the Deep Space Network.

34. Through 1966, 72 countries had cooperated with the United States in space research. The following is indicative: 6 satellites launched for 4 countries, and 9 other satellites under agreement for later launches; 19 countries entered into agreements for cooperative sounding rocket programs; 4 experiments from 2 countries flown and 14 other experiments selected for subsequent flights; and automatic picture transmission facilities in over 30 countries for receiving cloud-cover pictures from U. S. weather satellites.

35. The U. S. launched a total of 100 payloads into earth orbit and on lunar and solar trips.

NATIONAL AERONAUTICS AND SPACE COUNCIL

CHAPTER II

INTRODUCTION

In accordance with established legislation and policy, the National Aeronautics and Space Council is responsible for advising and assisting the President in such matters as surveying and evaluating aeronautical and space activities of all departments and agencies engaging therein and in developing comprehensive programs for such activities, and in providing effective cooperation and coordination between the various agencies with aeronautical and space responsibilities.

During 1966, under the leadership of the Vice President, the Council continued to carry out its responsibilities, with due attention to resolving difficulties and recommending actions for improved efficiency through both formal and informal contacts with policy-level representatives of Government agencies.

BENEFITS

Continuous study and public emphasis have been given to the multiple benefits to be derived from the national space program as well as from advancements in the field of aeronautics. These benefits comprise the returns from the taxpayers' investment in progress, all of which investment helps broaden our economic base and increase the size of our gross national product. In so doing, new and improved methods, techniques, and procedures are developed, which can increase the efficiency of much of the Nation's business.

Benefits from our aerospace endeavors include positive contributions to our national security, inventions and improvements of products and services, enhancement of the quality of education, and progress toward the attainment of world peace. As an aspect of the peace role of the space program, its technological progress and contributions to higher standards of living reflect favorably throughout the world upon the nature and vitality of our economy. The space program contributes positively to the presentation of such an international picture of the United States. Moreover, it furnishes a constructive alternative to aggression and thereby gives a productive outlet for technological skills and the use of modern facilities.

INFORMATION

In addition to its being appropriate for the Federal Government to keep the public well informed regarding the advantages and developments in the aerospace field, it also is a reasonable responsibility for private companies and individuals with knowledge regarding aerospace benefits likewise to engage vigorously in such educational endeavor.

INTERNATIONAL COOPERATION

International cooperation in the field of space is a policy with practical implications, not only for other countries, but also for the United States. Operational space capabilities can advisedly be used to provide coördinated and compatible services to the domestic economy in communications, in weather prediction, in navigation, and in observation. In addition to giving a major amount of attention to the practical aspects of international cooperation, with specific attention to improving cooperation with international organizations and with individual nations; continuing assistance and encouragement was given to the United Nations Space Treaty, from its initiation to its successful conclusion.

FUTURE PLANS

In addition to speeches, visits to space and aeronautical facilities, briefings, and informal coordination sessions, the Council held both formal and informal sessions on a variety of important aerospace issues. For example, meetings were held for the exchange of information and the evaluation of views regarding both the FY 1967 and FY 1968 budgets on present and future space and aeronautical programs. Attention was given to all aspects of such programs, including operational defense satellites, plans for manned orbiting laboratories, nuclear rocket and space nuclear power projects, improved methods of propulsion, post-APOLLO proposals, and research and development in the field of aeronautics.

Considerable attention was focused upon identifying various options that this country might pursue in space after the initial manned landing on the moon and upon how best to utilize the large investment this country already has in space capability -- in trained manpower, in specialized equipment, and in hard-earned invaluable experience. Throughout all such evaluation, it was kept clearly in mind that this country is engaged in a technological competition and that only a leadership position can be justified. Leadership, however, can and should include increasing progress in international cooperation.

As for future space programs, consideration was given to the relative merits of large orbiting space stations, extended lunar exploration, manned and unmanned planetary exploration, space science needs for the coming years, and direct practical applications of space competence to communications, observation, navigation, and weather. These various plans and projects were not considered to be alternatives necessarily as various constructive activities can and should be carried on concurrently. Rather, careful thought was given to questions of priorities, emphasis, and timing.

Throughout all of the program evaluations, the Council members were urged to keep in mind the many demands for funds which the President has to consider and therefore to stress those projects and proposals which seemed the most urgent and which promised the greatest returns on the investment. The impact of delays on major projects was also examined and conclusions indicated that postponements or slowdowns may increase total costs and lessen total returns.

AERONAUTICS

Mindful of the aeronautical aspects of its responsibilities, the Council and the Council staff maintained continuing interest in the Supersonic Transport program as well as in what might be done to accelerate solutions to such problems as air safety and traffic control and aircraft noise and sonic boom. During the examination of such issues, it was emphasized that future airline growth, in both passenger traffic and freight cargo, will increase at a very rapid rate during the next decade. Those agencies with aeronautical responsibilities were urged to give special attention to see if enough was being done to solve civilian airline problems and whether current resources were effectively distributed to such end.

SOVIET SPACE PROGRAM

The United States continues to lead the space technology competition in number and variety of successful missions, but the USSR maintains its lead in weight of payloads orbited. Both countries give substantial promise of more complex and challenging projects for the near future. Certainly the hiatus in Soviet manned space activity during 1966 is no basis for complacency on our part as their preparations for future flights appear to be ambitious and the resources being devoted to space competence and performance are absolutely and relatively impressive.

SUMMARY

In addition to the various sessions held, the Council directly and through its staff engaged in a broad range of policy, coordinating, and informational activities. Among these were:

a. Supervised and edited the President's Annual Report to the Congress on Aeronautics and Space Activities for 1966.

b. Submitted regular reports to the President on significant space activities and plans.

c. Increased public understanding of the national space program through numerous speeches, articles, correspondence, and other public contacts.

d. Participated in analysis of and made recommendations concerning the FY 1968 budgets for space and aeronautics.

e. Examined the problems and alternative solutions regarding the implementation and development of space rescue capabilities.

f. Continued to coordinate for the President the issues and decisions involved in the launching of nuclear power units in spacecraft.

g. Participated in the development of policy recommendations relative to the growth of communication satellite systems and the export of related technology.

h. Examined the status and potential of navigational satellite utilization.

i. Surveyed the development of on-board space power supply alternatives.

j. Furnished briefing materials, including space photographs, for appropriate use in connection with visits to Washington of high officials of other nations.

k. Participated in the planning for aeronautical and space exhibits abroad.

l. Examined need for legislative changes affecting space and aeronautics.

m. Maintained liaison with the technological and aerospace management communities.

n. Contributed to the planning for foreign visits of U. S. astronauts.

o. Reviewed the status of meteorological satellite projects.

p. Visited space installations, examined facilities, and engaged in inter-agency as well as Government-industry meetings and briefings on new developments in aeronautics, space technology, and space benefits.

q. Analyzed the impact of our national space program at home and abroad.

r. Maintained a current record of U. S. and Soviet space launches, developed comparisons between U. S. and USSR space activities, and reviewed space accomplishments and potentials of other nations.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CHAPTER III

INTRODUCTION

Nineteen sixty-six was a year of continued accomplishment for the National Aeronautics and Space Administration.

Five successful GEMINI flights, which demonstrated our capability for extravehicular activity, rendezvous and docking, station keeping, and orbital plane changes, brought this phase of the manned space flight program to a close. Three test flights in the APOLLO SATURN series were also completed with satisfactory results.

Space sciences and applications programs made significant contributions to our knowledge of the moon, the sun, and interplanetary space. Two LUNAR ORBITER spacecraft sent back a remarkable series of pictures of the lunar surface, and SURVEYOR I soft landed on the moon and televised pictures of its surroundings to earth. The two types of views of the potential landing sites for manned spacecraft have given scientists unprecedented information about the nature of the surface of the moon and the lunar environment. In addition, launches were made in the ORBITING ASTRONOMICAL OBSERVATORY, APPLICATIONS TECHNOLOGY SATELLITE, and BIOSATELLITE programs.

Advanced research and technology programs continued to provide the new technology to support aeronautics and space research. The three X-15 research airplanes were used for a broad spectrum of aeronautical and space flight experiments; extensive investigations were made on problems relating to vertical and short take-off and landing aircraft; and the XB-70 was assigned to collect data on sonic boom for the National Supersonic Transport program. A 260-inch solid motor developed over 3.5 million pounds of thrust in a successful 2-minute test firing early in the year.

In the nuclear power generation program, the first power conversion system (breadboard) began operating, and components and subassemblies of the SNAP-27 generator were being delivered. Also, two major tests, associated with the NERVA reactor and engine system efforts, were conducted, and work was continuing on the facilities for testing of ground experimental engines.

Other NASA programs continued to provide the support necessary to advance the Agency's major activities.

MANNED SPACE FLIGHT

NASA's manned space flight program overcame a succession of problems and achieved its most significant successes during the year. These achievements included the final five manned GEMINI missions and the first three APOLLO unmanned missions. Additionally, the Agency made very substantial progress in providing the broad-based national capability for future manned space flights. This capability will be effectively demonstrated through the lunar mission planned for the 1968-69 time period.

GEMINI Program

Five manned missions brought the GEMINI program to a successful completion in 1966. All program objectives were accomplished.

The acceleration of the GEMINI schedule, begun in 1965, permitted completion two months earlier than planned.

Altogether, 10 two-man missions were conducted. The astronauts returned safely each time. The program provided 1940 man-hours of space flight experience, including about 12 hours of activity outside the GEMINI spacecraft.

Participating in GEMINI were more than 25,000 people of the industry and universities, including 50 major contractors, more than 150 subcontractors, and numerous vendors and suppliers. Within the government, the program was supported by the Departments of Defense; State; Health, Education and Welfare; and Commerce, as well as the Atomic Energy Commission. Department of Defense participants included the Space Systems Division of the Air Force Systems Command, the National Range Division of the Air Force, and the recovery forces of the Navy. Tracking and other types of support were provided by six foreign countries--United Kingdom, Australia, Malagasy, Mexico, Nigeria and Spain.

The principal objectives of GEMINI were to gain experience in long duration flight, in rendezvous and docking, in the use of the docked vehicles to pioneer new frontiers of flight, in extravehicular activity, in controlled reentry from orbit, and in the conduct of experiments.

GEMINI long-duration flights were completed in December 1965, when Astronauts Frank Borman and James A. Lovell, Jr. carried out the GEMINI 7 mission lasting 13 days, 18 hours and 35 minutes--almost twice the duration of a flight to the moon and back.

Rendezvous was accomplished on all five GEMINI missions of 1966 and docking on four of the five. Different means of achieving rendezvous were employed on each flight to amass a body of knowledge about such maneuvers.

Astronauts Neil A. Armstrong and David R. Scott performed the first docking in space when they joined their spacecraft with the AGENA target in the GEMINI 8 mission on March 16, 1966. Also successful in docking with the AGENA were Astronauts John W. Young and Michael Collins on GEMINI 10, July 18; Charles Conrad, Jr. and Richard F. Gordon on GEMINI 11, September 12; and Lovell and Edwin E. Aldrin on GEMINI 12, November 11. On the GEMINI 9-A mission, June 3, Astronauts Thomas P. Stafford and Eugene Cernan performed rendezvous with their Augmented Target Docking Adapter but were unable to dock because a protective shroud had failed to separate from the vehicle as planned.

The most advanced of the five 1966 rendezvous maneuvers was on GEMINI 11, when Conrad and Gordon joined with the AGENA target vehicle on the first revolution of the earth, one hour and 34 minutes after liftoff.

A noteworthy event of 1966 was the space emergency that occurred during the GEMINI 8 mission. Twenty-seven minutes after Armstrong and Scott confirmed the docking, the spacecraft/AGENA combination encountered unexpected roll and yaw motion. They reduced the rates sufficiently to undock from the AGENA, and began trouble-shooting to determine the cause of the problem. During this activity, the unexpected roll rates increased to a peak of about 50 revolutions per minute. Subsequently, the crew activated and used the Reentry Control System to stop the motion.

In accordance with previously developed rules, it was decided to terminate the mission during the seventh revolution, after 10 hours and 42 minutes of a scheduled three-day mission. The spacecraft was returned to the Western Pacific instead of to the Atlantic Ocean. Aircraft stationed in the area observed the touchdown and recovery was made by the USS Mason, three hours and 14 minutes later. Data analysis showed that the problem resulted from a short-circuit in the electrical wiring of a thruster of the GEMINI spacecraft.

Of the 16 United States manned space flight missions, GEMINI 8 was the only one to experience an emergency significant enough to cause the mission to be terminated earlier than planned. The success of the efforts to overcome this emergency, combined with the satisfactory accomplishment of plans on other missions, illustrates the value of the comprehensive testing, mission preparations, and contingency planning that have characterized the MERCURY and GEMINI programs.

On two GEMINI missions of 1966, U.S. astronauts employed the AGENA as a propulsion unit to fly higher and faster than man had ever flown before. On GEMINI 10, Young and Collins reached a speed of 17,700 statute miles an hour and an altitude of 475 miles. On GEMINI 11, Conrad and Gordon achieved a speed of 17,943 miles an hour and an altitude of 851 miles.

Four astronauts ventured outside their GEMINI spacecraft during 1966, bringing to five the number of Americans who have engaged in such activity. Problems were encountered on the first three 1966 flights. Cernan on GEMINI 9-A and Gordon on GEMINI 11 had difficulties with extravehicular tasks. EVA was curtailed when GEMINI 10 ran short of spacecraft fuel. These problems indicated that extravehicular activity is somewhat more difficult than had been anticipated by some. On the GEMINI 12 mission, Aldrin employed body tethers and other hand and foot holds. He obtained a quantity of baseline data, through performance of basic tasks with electrical and fluid connectors, hook-and-ring combinations, plastic strips, and fixed and removable bolts. He was in space on three occasions--twice standing in his cockpit and once attached with a tether--for a total of five hours and 37 minutes, and accomplished all extravehicular objectives. His physiological responses were good throughout.

Except for GEMINI 8, which landed within a few miles of the contingency area, all 1966 GEMINI missions returned to earth within a few miles of the center of the primary recovery area and were visible from the carrier. On the year's first three missions, reentry was performed under the manual control of the astronauts. On GEMINI 11 and 12, control was automatically performed through the spacecraft computer after initiation by the astronauts. Through the use of the EARLY BIRD communications satellite, carrier recovery operations were seen by television viewers in the United States and elsewhere.

Numerous scientific, technological and operational experiments were performed on the GEMINI missions, demonstrating the utility of man as an experimenter in space. One of the most significant took place on the GEMINI 12 mission on November 12, when Lovell and Aldrin photographed a total eclipse of the sun as they approached the west coast of South America.

Results of medical experiments performed during the 1966 missions indicated that man can perform satisfactorily and without ill effect on all of the operations conducted.

APOLLO Program

Substantial progress was made in the APOLLO program during 1966. Despite problems in testing and qualification of some of the flight hardware, the overall program continued on its schedule leading to the manned lunar landing and safe return before the decade is out. The APOLLO mission milestones serve as a focus for achievement and a demonstration of broad-based national capability in manned space flight, which is the program objective.

The first major flight phase -- the all-systems-up unmanned flight testing of the command and service modules of the spacecraft and the uprated SATURN I launch vehicle -- was completed according to plan. Preparations neared completion for the beginning of APOLLO-uprated SATURN I manned flights. Arrangements were well advanced for the beginning of unmanned flights of the lunar module and of the APOLLO-SATURN V, the vehicle that will be employed on the lunar missions.

A schedule of seven major phases was established for the APOLLO flight operations. The first phase was that of unmanned flights of the APOLLO-uprated SATURN I vehicle, previously called SATURN IB, completed in 1966. Other phases and their scheduled dates are as follows:

Manned APOLLO-uprated SATURN I flights (Block I Command and Service Modules)	1967
Unmanned Lunar Module-SATURN I flights	1967
Manned dual missions (Block II Command and Service Modules, Lunar Module) both launched by an uprated SATURN I	1967 or 1968
Unmanned APOLLO-SATURN V flights, all systems up	1967

Manned APOLLO-SATURN V flights, simulating lunar mission in earth orbit	1968
Manned missions, open ended, with equipment capable of lunar mission	1969

APOLLO-uprated SATURN I -- A series of three unmanned flights was completed successfully in the qualification of the APOLLO-uprated SATURN I vehicle for three-man earth-orbital flights of the command and service modules.

Two of the three flights carried the spacecraft on suborbital trajectories to certify the structural integrity and compatibility of the launch vehicle and spacecraft, the operation of spacecraft systems under flight conditions and the performance of the heat shield during entry to the atmosphere. The other was an orbital test of the uprated SATURN I second stage--which is the same as the third stage of the SATURN V-- to verify system performance and operation and to provide information on the behavior and management of its fuel, liquid hydrogen, in earth orbit. This latter information was needed because the lunar mission calls for a restart of the SATURN V third stage following a coasting phase in earth orbit. Following is a listing of the three flights and their highlights.

APOLLO RESULTS 1966

Mission	Date	Mission Highlights
AS-201	February 26	Suborbital flight from Cape Kennedy to South Atlantic; unmanned; demonstrated compatibility and structural integrity of launch vehicle-spacecraft combination, evaluated heat shield performance; at high heat rate entry, spacecraft recovered.
AS-203	July 5	Second stage (S-IVB) of uprated SATURN I placed in orbit for evaluation of separation from instrument unit, storage of liquid hydrogen and liquid oxygen at zero gravity, vent and restart capability; pressure and structural test conducted to destruction on fourth orbit.
AS-202	August 25	Flight from Cape Kennedy to Western Pacific; unmanned; test of Command and Service Module subsystems and space vehicle structural integrity and compatibility; evaluated heat shield performance at high heat lead entry; spacecraft recovered.

The thrust of the H-1 engine employed in the uprated SATURN I first stage was uprated to 205,000, thus increasing the total thrust of the eight-engine stage from 1,600,000 to 1,640,000 pounds. Engine qualification was completed. The thrust of the second-stage J-2 engine was increased from 225,000 to 230,000 pounds and its requalification was completed.

Comprehensive ground tests were completed in qualifying the APOLLO-uprated SATURN I vehicle for manned flight. A major milestone was the successful manned test of a ground-test spacecraft under simulated space conditions in the thermal-vacuum chamber at the Manned Spacecraft Center, Houston, Texas.

The principal problem in qualifying this vehicle resulted from the discovery that the titanium material of the Service Module fuel tanks was weakened when exposed under pressure to anhydrous methyl alcohol, a fluid employed to test their ability to withstand high pressure. Replacement was made of all tanks exposed to methyl alcohol and distilled water was substituted for pressure tests.

At year's end, checkout was in progress at Cape Kennedy on the vehicle for the first manned flight, designated APOLLO-uprated SATURN 204 (AS-204). The launch vehicle was erected at Launch Complex 34 and the spacecraft was undergoing final tests prior to placement atop the launch vehicle. A principal phase of these tests was a series of manned runs in the Kennedy Space Center vacuum chamber.

During the first vacuum chamber tests in October, difficulties were encountered with the spacecraft Environmental Control Unit. Among the problems were those in the operation of a water boiler, impaired by the clogging of a porous distribution plate, and the failure of an oxygen regulator because of improper valve design. The faulty equipment was replaced, and an extended qualification program was instituted to substantiate the adequacy of design and manufacturing changes.

For the first mission, the trajectory was established, the flight and experiments plan was completed, and the Mission Control Center-Houston was reconfigured for APOLLO. The assigned astronauts are Virgil I. Grissom, Edward H. White III, and Roger B. Chaffee. The backup crew consists of Walter M. Schirra, Jr., Donn F. Eisele and Walter Cunningham. The mission is planned as open ended, up to 14 days in duration.

LUNAR MODULE -- The peak effort was reached in the testing and qualification of the LUNAR MODULE--the two-stage, two-manned spacecraft that will descend from lunar orbit to the moon and then return to rendezvous and dock with the COMMAND and SERVICE MODULES in lunar orbit. The LUNAR MODULE is the first manned spacecraft designed to operate exclusively outside the earth's atmosphere. The first unmanned flight of this vehicle, designated APOLLO-SATURN 206 (AS-206), is planned to follow the AS-204 mission.

Problems in the development of the LUNAR MODULE have focused on its overall weight, the performance of its ascent and descent engines, and the sensitivity of its titanium tanks to the liquid oxidizer, nitrogen tetroxide.

A program was conducted to exercise tight control of the LUNAR MODULE weight, resulting in a reduction well below the control weight. This now permits the vehicle to accommodate nominal increases if necessary or to load additional propellant for mission flexibility.

Qualification of design was completed for the descent engine to be employed in the first two flights and engines were manufactured in accordance with an improved design for later flights. Modifications of the ascent engine injector design were completed during the year and found satisfactory. Testing of ascent and descent engines proceeded satisfactorily at the White Sands Test Facility, N. Mex.

Just as in the SERVICE MODULE, the compatibility of fluids with the titanium tank materials has been a problem in the LUNAR MODULE. A test program during 1966 verified that a small amount of nitric oxide added to nitrogen tetroxide inhibits the corrosion due to this fluid.

A step contributing to program progress was the successful performance of the radar on the SURVEYOR I unmanned spacecraft, which is similar to that in the LUNAR MODULE.

At the end of 1966, the launch vehicle for the AS-206 mission was accepted for delivery to the Kennedy Space Center and the preparations neared completion at the manufacturer's plant for the shipment of the LUNAR MODULE to KSC. Launch will be from Complex 37B.

Dual Mission -- Plans were established for the first of a series of dual APOLLO-uprated SATURN I missions, in which the COMMAND and SERVICE MODULES rendezvous and dock with the LUNAR MODULE in earth orbit to provide for manned flight of the spacecraft in its lunar mission configuration. The mission is designated APOLLO-SATURN 205/208. The AS-205 vehicle consists of an uprated SATURN I launch vehicle with COMMAND and SERVICE MODULES of the Block II design to be used on the lunar missions. The AS-208 vehicle consists of an uprated SATURN I launch vehicle and a LUNAR MODULE.

The mission plan calls for manned launch of the AS-205 vehicle, followed a day later by unmanned launch of AS-208 with rendezvous, docking, and operation of the combined spacecraft in earth orbit.

APOLLO-SATURN V -- Significant progress was made in the testing and qualification of the three-stage SATURN V launch vehicle in preparation for the beginning of all-systems-up flight tests. The Mississippi Test Facility reached operational status for acceptance tests of the second stage. Launch Complex 39 at the Kennedy Space Center reached operational status for vehicle assembly and checkout. The first and third stages and the instrument unit for the first flight test were assembled with a dummy second stage on the mobile launch stand within the Vehicle Assembly Building at KSC.

On the first stage, the most powerful assembly of rocket engines yet produced by the United States, component qualification was essentially completed and the thrust of the F-1 engine was uprated from 1,500,000 to 1,522,000 pounds. Thus the five-engine stage generates total thrust of 7,610,000 pounds. Acceptance test firings were completed on the first three flight vehicles. The third was the first produced by the contractor at the Michoud Assembly Facility, New Orleans, La.

The first flight second-stage acceptance test firings were underway at Mississippi Test Facility. Uprating of the J-2 engine increases the thrust of this five-engine stage from 1,125,000 to 1,150,000 pounds effective on the fourth flight vehicle.

For the third stage and instrument unit, which are the same as the second stage and instrument unit of the uprated SATURN I, ground qualification tests were complete and the units performed satisfactorily in the 1966 flights.

The major problems in the development of the SATURN V launch vehicle have been in the second stage (S-II). Two test vehicles have been destroyed in ground tests, one in 1965 and one in 1966. The vehicle lost in 1965 was intended for dynamic tests. In May 1966, an All Systems test vehicle was lost at Mississippi Test Facility as the result of inadvertent over-pressurization of the liquid hydrogen tank with gaseous helium in a leak test. This occurred at a time when seven-eights of the planned static firing program had been completed in preparation for the acceptance firing of the flight stages. The loss of these stages forced rescheduling of the test program and plans for use of remaining hardware.

Another problem consisted of cracks in the liquid hydrogen tanks, and leaks in the liquid oxygen tanks, caused by stresses resulting from forming and assembly operations, and brittleness of the aluminum. Actions taken were repair, reinforcement, and application of sealing material to tanks in early flight vehicles, followed by design modifications in later vehicles.

The NASA spaceport at Merritt Island, north of Cape Kennedy, became operational during 1966. A ground version of the APOLLO-SATURN V vehicle was erected on the Launch Umbilical Tower within the Vehicle Assembly Building to test the facilities. On May 25, the crawler-transporter carried the tower and the vehicle out the building's door and onto the specially constructed roadway, where it traveled in a vertical position more than three miles to Pad A. Later in the year, the transporter and tower were returned to the Assembly Building, the test vehicle was disassembled, and assembly and checkout of the first APOLLO-SATURN V flight vehicle were begun.

At least two unmanned orbital flights of the APOLLO-SATURN V are scheduled for 1967. When the dual missions of the APOLLO-uprated SATURN I and the unmanned flights of the APOLLO-SATURN V are completed successfully, the program will proceed to the phase of manned earth-orbital flights of the APOLLO-SATURN V.

Planning also progressed during 1966 for the actual manned lunar missions. Essential information of the moon's surface was supplied from the unmanned SURVEYOR I and LUNAR ORBITER I and II flights. Detailed arrangements, including computer programs, were established for the stay on the lunar surface--lasting 18 hours on the first APOLLO lunar mission. Qualification of components of the lunar spacesuit was completed, and qualification of the complete spacesuit system was well advanced. Test hardware was being produced for the APOLLO Lunar Surface Experiment Package (ALSEP), which will be deployed on the moon 300 feet from the landing site, to transmit information to earth after the astronauts' departure. The USS Vanguard, first of three instrumentation ships designed for APOLLO tracking and data acquisition, was delivered and underwent limited use on the GEMINI 12 mission. The first of eight APOLLO instrumentation aircraft was also employed on GEMINI 12. Two of the remaining aircraft were delivered.

APPOLO Applications

The definition of the first phases of a program to follow the APOLLO program moved forward in 1966. This program will employ APOLLO space flight hardware and capabilities to meet other objectives than those previously planned for the lunar missions.

Planning moved ahead in two interesting areas. One is an airlock attached to the empty hydrogen tank of the second stage of the SATURN I to convert the stage to a habitable space structure. Astronauts will be able to enter the tank through the airlock after rendezvous and docking with an APOLLO spacecraft. The spent SATURN I stage equipped with a life support system and used in this manner will be called an Orbital Workshop.

Another is the APOLLO Telescope Mount, a major set of observational equipment consisting of a group of telescopes and other instruments mounted on a rack attached to the LUNAR MODULE.

SPACE SCIENCE AND APPLICATIONS

Continuing a trend toward the development of observatory-type spacecraft as a marked advance over the smaller EXPLORER class of geophysical satellites, NASA launched its first ORBITING ASTRONOMICAL OBSERVATORY and a third ORBITING GEOPHYSICAL OBSERVATORY this year. Sounding rockets also continued to play an important part in the unmanned space science program.

To take full advantage of the unique role of astronauts as sensors, manipulators, evaluators, and investigators in space and on lunar and planetary surfaces, the Agency planned numerous experiments and other tasks for them during future manned missions.

In other substantial accomplishments in the field of scientific investigations in space, two LUNAR ORBITER photographic laboratories and a SURVEYOR spacecraft transmitted thousands of high-resolution pictures of the moon's surface to pinpoint landing sites for astronauts and provide invaluable lunar data.

Also, during 1966, an improved, completely-instrumented NIMBUS spacecraft was orbited making more accurate weather forecasts possible, and the national operational meteorological satellite system was inaugurated with the orbiting of ESSA I and II in February. In addition, NASA launched a second communications satellite for the Communications Satellite Corporation--the first over the Pacific Ocean. And, to round out 12 months of noteworthy progress, the Agency launched its first APPLICATIONS TECHNOLOGY SATELLITE and its first BIOSATELLITE--an orbiting biological laboratory--in December.

Orbiting Observatories

On April 8 NASA launched its first ORBITING ASTRONOMICAL OBSERVATORY (OAO-1) into a nearly circular orbit at a height of about 500 miles. The 3,900-pound spacecraft was able to point to a star with an accuracy of one minute of arc. It carried instruments weighing 1,000 pounds, but on its second day a faulty circuit component ended its operation before any data could be transmitted by them.

OGO-III, an ORBITING GEOPHYSICAL OBSERVATORY, was launched on June 6. This observatory was placed into a highly elliptical orbit (183 to 75,874 miles) reaching beyond the boundary of earth's magnetic field. OGO-III is a 1,135-pound box with several booms carrying 21 experiments for a well-rounded program of measurements in the space environment.

The ORBITING GEOPHYSICAL OBSERVATORIES are designed to achieve three-axes stabilization with one surface facing the earth. OGO-III was the first to be stabilized in this manner for the full planned 30-day period. It maintained this type of stabilization for 46 days, and, when ordered on July 25 into the alternate scheduled spin, continued to provide data from its experiments.

EXPLORER Satellites

The atmospheric EXPLORER XXXII--a 35-inch stainless steel sphere weighing 495 pounds--was positioned into an orbit ranging from 173 to 1,629 miles above the earth. This satellite uses mass spectrometry to detect neutral, un-ionized atoms and molecules of hydrogen, helium, nitrogen, and oxygen; density gauges to determine neutral particle density; and mass spectrometry with electrostatic probes to detect atomic ions of hydrogen, helium, nitrogen, and oxygen and to measure low-energy electrons. EXPLORER XXXII's orbit greatly exceeded the planned one. For this reason it spent a larger part of its time at greater distances than scheduled, but its instruments were reprogrammed permitting all experiments to return data.

Another EXPLORER (XXXIII) was launched on July 1, an INTERPLANETARY MONITORING EXPLORER (IMP), the spacecraft was designed to reach deep into space to search for hazards to manned flight caused by energetic particles. The satellite went into an earth orbit ranging from 25,350 miles to a maximum of 295,920 miles. Its experiments measure magnetic fields, low energy particles in the solar wind, and solar cosmic rays.

PIONEER

PIONEER VII was orbited about the sun on August 17 to measure the interplanetary magnetic field, cosmic rays, and the total electron content in space, and to investigate the solar wind. Data from PIONEER VI (launched December 16, 1965) has provided information on the streaming of particles ejected by the sun in the solar wind and as cosmic rays. The 210-foot radio telescope at Goldstone, Calif., greatly extends the distances to which these probes can be followed.

SURVEYOR

The first SURVEYOR spacecraft was launched on May 30 and made a soft landing on the lunar surface about 63 and 1/2 hours later. The spacecraft performed almost flawlessly both during a 234,200-mile flight to the moon and as it carried out complex operations on its surface. During the first lunar day (two earth weeks), SURVEYOR I sent back 10,338 high-quality photographs showing details as small as .02 of an inch. After hibernating through the two-week lunar night, it was again turned on during the second lunar day and took 899 additional photographs.

SURVEYOR I accomplished and exceeded all planned mission objectives, transmitting data on soft-landing systems and the nature of the moon's surface which will contribute greatly toward the national goal of a manned lunar landing during this decade.

On September 20 SURVEYOR II was successfully launched on a similar mission, but at the midcourse correction thrust phase one of the three vernier engines failed to ignite. This resulted in severe tumbling of the spacecraft and the loss of the spacecraft. The cause of this malfunction is being investigated.

Five flights remain in the SURVEYOR program--the next scheduled for early in 1967. In addition to an engineering payload, SURVEYORS C and D will carry a surface sampler to determine the physical properties of the lunar surface and subsurface, and SURVEYORS E, F, and G will carry an alpha-scatter measuring instrument for determining the relative abundance of chemical elements in this surface.

LUNAR ORBITER

The first in a series of five LUNAR ORBITER spacecraft was launched in August, and, after a 91-hour flight, placed in a close-in orbit about the moon, to become the first U.S. satellite to orbit a planetary body other than the earth. LUNAR ORBITER photographed nine selected potential sites for the manned landings of Project APOLLO, seven other areas within the APOLLO zone of interest, an area on the east limb of the moon, and eleven different areas on its far side. The spacecraft also provided the first pictures of the earth taken from the immediate vicinity of the moon.

The 850-pound satellite supplied information on micrometeoroid flux and levels of radiation in the near-lunar environment, as well as data on the moon's gravitational field.

A second LUNAR ORBITER spacecraft launched in November photographed thirteen other selected potential APOLLO landing sites, as well as thirteen secondary areas of interest on the front side and four on the back. The three remaining LUNAR ORBITER flights are scheduled for 1967.

MARINER

MARINER IV (launched in November 1964) continued in orbit about the sun after successfully completing its flyby within 6,118 miles of Mars in July 1965. NASA's new 210-foot diameter antenna at Goldstone, Calif., received tracking data from the spacecraft at a range of 219 million miles. And as it passed behind the sun, MARINER IV transmitted coherent radio-frequency energy through the solar corona which was monitored by earth-based receiving stations.

A MARINER spacecraft, built as a back-up for MARINER IV, was modified to fly past Venus in mid-1967. The spacecraft is designed to obtain information on the origin and nature of Venus and its environment, complementing and extending data provided by the Venus flyby of MARINER II in 1962. This MARINER will also provide engineering experience in converting and operating a spacecraft designed for flight to Mars into one to be flown to Venus, and supply data on the interplanetary environment during a period of increasing solar activity. It will carry an ultraviolet photometer, occultation experiments, trapped radiation detector, magnetometer, and plasma probe to supply data on the dense atmosphere surrounding the planet and possibly information on the planet's surface temperature.

The spacecraft is scheduled to pass within 2,000 miles of the planet's surface. (MARINER II's closest approach was 21,600 miles.) Its scientific components were delivered to the test facility for inclusion with spacecraft tests; spacecraft fabrication, assembly, and testing progressed satisfactorily.

NASA also approved two MARINER flybys of Mars during 1969 as an intermediate step between MARINER IV and VOYAGER scheduled for a 1973 launch. These missions will make exploratory investigations of Mars to set the stage for future experiments, particularly searches for extraterrestrial life. Each spacecraft will carry an ultraviolet spectrometer, infrared spectrometer, infrared radiometer, and two TV cameras designed for high and low resolution pictures of the Martian surface as they pass three times closer to the planet than did MARINER IV.

During 1966, designs of these MARINER to Mars spacecraft systems were established, their missions defined, and subcontractors selected to perform the detailed design and fabrication of all flight hardware.

VOYAGER

Funding limitations have caused the first VOYAGER flights to Mars to be postponed from 1971 to 1973. These flights will include orbiter and survivable landing missions.

During this year overall mission design and conceptual design studies of the landing capsule were emphasized. Preliminary design of the orbiting spacecraft was completed in January. Mission and capsule studies indicate that using a single SATURN V to launch two VOYAGER planetary vehicles (each vehicle consisting of an orbiting spacecraft and a landing capsule) is feasible and can assure a substantial number of scientific experiments.

These capsule design studies also established that the design and development of a soft-landing delivery system for the 1973 mission is feasible, and that a clean interface could be obtained between the soft-landing delivery system and the landed payload. This will permit the design and development of a soft-landing delivery system for several Martian missions while the landed payload is changed from one to another. The capsule design studies have paved the way for the preliminary design of the capsule system.

Manned Space Science

In September Project GEMINI astronauts took pictures from their spacecraft revealing, for the first time, that there were absorption lines of iron and magnesium in the ultraviolet light of the stars as well as in the ultraviolet light of the sun. The stars photographed were in the constellations Orion, Scorpius, and Carina.

Planning for future astronauts to carry out other scientific investigations in space, the Agency approved an APOLLO TELESCOPE MOUNT (ATM).

APOLLO Lunar Surface Experiments Package -- System tests of the engineering model of the APOLLO Lunar Surface Experiments Package (ALSEP) began in November. A part of the program of experiments to be conducted and activated on the lunar surface by astronauts, the experiments will be carried to the moon aboard the APOLLO LUNAR MODULE (LM). This geophysical station is being designed to obtain scientific data and telemeter it to the earth for a year. Its experiments will provide information on the changing and residual magnetic fields of the moon; the lunar interior, thickness, and density; the charged particle environment of the moon; and the pressure and composition of ions in the atmosphere.

The complete ALSEP system is made up of eight experiments (five to six to be carried on each APOLLO flight), a central station to receive commands and transmit data to the earth, and the SNAP-27 Radioisotope Thermoelectric Generator providing nuclear power to operate it. Three ALSEPs will operate simultaneously at different lunar locations.

Sounding Rockets

Fifty sounding rockets were launched by NASA into the region about 100 miles above the earth to continue studies in ultraviolet and X-ray astronomy. Scientists at Goddard Space Flight Center have developed a stabilizer for these rockets which allows astronomers to point their instruments at the planets and the stars with much greater accuracy.

BIOSCIENCE PROGRAMS

Biosatellites

NASA's first BIOSATELLITE, launched on a three-day flight on December 14, was designed to carry experiments to study the effects of weightlessness on various life forms, and of weightlessness combined with an on-board source of gamma radiation. This marked the first flight of a new recoverable orbiting spacecraft with a natural atmosphere life support system and programmed remote control of complex biological experiments. The satellite could not be recovered on December 17 as planned, possibly because the retro-rocket failed to fire. It continues in orbit.

Environmental Biology

Recent studies show that the regular changes in physiological functions in biological organisms occurring in about 24-hour cycles can break down completely and result in illness or death. The 24-hour rhythmic activities of rodents exposed to complete darkness shifted greatly, but disintegrated in continuous light. When exposed to continuous darkness and then to constant light, the rodents rhythmic activities broke up into disconnected components. These experiments indicate that astronauts may need to be kept on a regular light-dark schedule.

Exobiology

Scientists have identified certain molecules as "fossils" to extend their knowledge of the history of life on earth. They used high-resolution mass spectrometry to analyze ancient sediments, discovering biological chemicals that showed life definitely existed 3.1 billion years ago. Fossil remains of certain micro-organisms 2.7 billion years old were also discovered. Identification of these molecular "fossils" led bioscientists to recommend that a planet's fossil remains be investigated as possible clues to its biology.

Micro-organisms (mold spores and virus phage) survived six hours of exposure outside the spacecraft during the GEMINI 9 flight in June. These organisms also survived two months when exposed to the vacuum and radiation of space aboard the orbiting AGENA Target Vehicle.

SPACE APPLICATIONS PROGRAMS

Communications

APPLICATIONS TECHNOLOGY SATELLITE -- The first spin-stabilized version of the APPLICATIONS TECHNOLOGY SATELLITE (ATS) was launched on December 6 and placed into a near geostationary orbit on the following day. The satellite, weighing about 1,550 pounds at launch, will conduct experiments in communications, meteorology, and geophysics.

The prototype of the 6,000-mile orbit, gravity gradient-stabilized spacecraft (scheduled for flight in mid-1967) was also completed.

INTELSAT -- On October 26 NASA launched the first INTELSAT-II satellite for the Communications Satellite Corporation. It is operating normally over the Pacific, even though it did not achieve the desired geostationary orbit. The world's first commercial communications satellite INTELSAT-I (EARLY BIRD) launched by NASA for the Corporation in April 1965, continues to function satisfactorily in its geostationary orbit over the Atlantic with no noticeable signs of degradation.

Plans call for two more INTELSAT-II satellites to be positioned in geostationary orbits--one over the Atlantic, the other, the Pacific. More than twice as powerful as the first INTELSAT, these satellites will increase greatly the present coverage. The Pacific satellite will link Asia and Australia with North America, and the Atlantic satellite will link South America and Africa, also expanding the current capacity between North America and Europe.

Each satellite will satisfy some of the communications requirements of the APOLLO lunar program and provide additional commercial service.

Gravity Gradient Test Satellite (GGTS) -- On June 16 a two-axes stabilized satellite, using a gravity gradient system made up of 52-foot long booms, was successfully launched from Cape Kennedy. A TITAN III-C rocket injected the GGTS into a nearly synchronous, equatorial orbit, and it was demonstrated that the earth's gravitational pull can stabilize spacecraft in high orbits.

Meteorology

TIROS -- The nation's operational meteorological satellite system was inaugurated with the launchings of ESSA I and II (TIROS OT-3 and OT-2) on February 3 and 28. Based on the TIROS IX design, these satellites provided, on a daily basis, global daytime cloud cover data to national users as well as local cloud pictures to Automatic Picture Transmission (APT) users throughout the world. ESSA III (TOS-A) launched October 2 is the first of the TIROS Operational Satellites to use the improved remote camera system developed and flight tested on NIMBUS I and II.

TIROS VII continued to set new records for longevity. It has furnished more than 111,000 useable pictures in over three and one-half years of operation. This satellite, together with TIROS IX and X, provides engineering data and cloud cover information.

NIMBUS -- NIMBUS II (the second NIMBUS) was orbited on May 15. The satellite carries Automatic Picture Transmission, an Advanced Vidicon Camera System, and a High Resolution Infrared Radiometer (HRIR) similar to sensors on the NIMBUS I flight. The HRIR also provides local nighttime cloud-cover information to ground stations modified to receive these data, and, for the first time, a Medium Resolution Infrared Radiometer to measure the heat balance of the entire earth daily.

Hardware for the third NIMBUS (NIMBUS B) was being developed and the engineering model of the spacecraft and its flight experiments completed and tested. In addition to several new sensors to measure the earth's radiation, including the ultraviolet and infrared regions, the satellite will carry a meteorological data collection system to gather information on a global scale. NIMBUS B will also carry a radioisotope thermoelectric generator (SNAP-19) to determine the feasibility of using this power source for meteorological satellites. Development of the NIMBUS D spacecraft was begun and its flight experiments were selected. Improvements will be incorporated primarily into its control system and in its data handling and transmission system. The 11 flight experiments of this spacecraft will be more advanced than those flown on NIMBUS B and provide more quantitative measurements of the earth's atmosphere on a global scale through infrared sounding and extensive earth platform interrogation.

Meteorological Sounding Rockets -- NASA launched 53 research meteorological rockets carrying experiments to heights of 60 miles. The experiments (acoustic grenade firings, sodium releases, and pitot-static tube measurements) were carried out in the upper atmosphere to measure wind, temperature, and density.

Geodesy

The GEOS-I geodetic satellite, orbited November 6, 1965, continues to supply data to 110 stations located around the world. The information is sent to the Geodetic Satellites Data Service, National Space Science Data Center, at Goddard Space Flight Center. GEOS-B (the next geodetic satellite) is scheduled for a 1967 launch.

PAGEOS (a Passive Geodetic Earth-Orbiting Satellite) is a 100-foot diameter mylar and aluminum sphere which was successfully launched on June 23. Worldwide ground stations photograph the satellite, which carries no instruments, to help determine the location of continents, land masses, islands and other geographic points for a unified global geodetic control reference system.

Earth Resources Survey

Spacecraft-acquired data applied to agriculture, forestry, and mineral, water, cultural, and marine resources cover the wide range of the Earth Resources Survey Program. The Departments of Agriculture, Interior, Commerce, and other agencies are considering how such data can be beneficial.

During this year the scientific phenomena to be measured, instruments to be used, and possible missions to be flown were determined. And prototypes of instruments to be carried aboard spacecraft were flown by aircraft over carefully selected test sites gathering earth resources survey data to help scientists demonstrate the feasibility of such measurements.

LIGHT AND MEDIUM LAUNCH VEHICLES

During the year SCOUT, THOR-DELTA, THOR-AGENA, ATLAS-AGENA, and ATLAS-CENTAUR launch vehicles were used for the Agency's unmanned missions.

The four-stage solid propellant SCOUT vehicle launched nine spacecraft--chalking up a record of 22 consecutive successful launches.

THOR-DELTA orbited three meteorological satellites for the Weather Bureau and a communications spacecraft for the Communications Satellite Corporation. Also, THOR-DELTA launched four satellites in NASA's Space Science and Applications Program, including the first BIOSATELLITE, to perform successfully in 40 of 43 launch attempts.

AGENA successfully supported seven unmanned missions, with ATLAS-AGENA launches of the first ORBITING ASTRONOMICAL OBSERVATORY, the first APPLICATIONS TECHNOLOGY SATELLITE, two LUNAR ORBITERS, and an ORBITING GEOPHYSICAL OBSERVATORY; THOR-AGENA launched a NIMBUS weather satellite and PAGEOS, a passive geodetic satellite.

The seventh ATLAS-CENTAUR development vehicle (launched April 8 to simulate a two-burn SURVEYOR mission to the moon) did not achieve a nominal CENTAUR second burn but remained in an earth-parking orbit instead. The eighth flight (May 30) was the first direct ascent production flight of the CENTAUR vehicle, which placed the SURVEYOR I spacecraft into a lunar transfer trajectory to soft land it on the moon. The ninth flight placed the SURVEYOR II spacecraft into its desired lunar transfer trajectory on September 20, but spacecraft problems prevented a successful soft landing on the moon. The tenth and last development flight was on October 26, at which time all program objectives were achieved. Four ATLAS-CENTAUR vehicles are scheduled to launch SURVEYOR spacecraft to the moon in 1967.

ADVANCED RESEARCH AND TECHNOLOGY

This area of activity, which is the source of the new technology needed for present research and future leadership in aeronautics and space, continued to move forward on a broad front.

Basic and Applied Research

Fluid Physics -- Progress was made in determining, for the first time, the radiative properties of air at temperatures exceeding 15,000° F. This information is essential in designing the configuration and heat protection systems of post-APOLLO spacecraft since radiation energy transfer is the dominant heating mechanism for bodies returning from interplanetary flights. Data obtained in ballistic ranges, shock tubes, and constricted arcs showed relatively good agreement with each other and with various theories and additional work was under way to determine self-absorption effects and the detailed contributions from different parts of the spectrum.

The state of the thin layer of air adjacent to the surface of a supersonic body strongly affects the friction drag and heating of the body and is most important in the aerodynamic design of aircraft and spacecraft. A new theory was developed which sheds more light on how this layer of air turns from a laminar into a turbulent state. An experiment validated the theory at Mach 4.5 and confirmed the existence of the two processes predicted by the theory.

A theoretical program originated to predict molecular states through quantum mechanical analyses made it possible to predict and to detect experimentally the Nitrofluorine molecule, which had been searched for unsuccessfully in laboratories all over the world. This was the first time that a molecule was discovered experimentally as a result of the prediction of its stability and configuration by theoretical chemistry.

Applied Mathematics -- Research necessary for planning a Mars Orbiter was completed. Using a new mathematical approach, investigators found that lifetimes for orbits at heights between 150 and 5,000 km in three different possible atmosphere models ranged from about a week to 200 years.

Electrophysics -- A laboratory investigation was instituted to determine whether electrostatic forces are important in the formation of tornadoes. In this research, the premise is that the tornado cloud derives its high angular momentum from an electrostatic motor type action, i.e., two nearby cloud regions each containing oppositely charged water droplets with positively charged droplets moving to the negatively charged cloud and vice versa to produce a circulatory motion of water droplets. Moving charged droplets simulating the rotary motion of tornado clouds were obtained on a small scale, and work was continuing to improve the laboratory equipment. This research may provide an understanding of the causes of tornadoes and may enable man to control them or to minimize their destructiveness.

Materials -- A very small solid state battery, about the size of a pea, was developed by researchers at the Jet Propulsion Laboratory. An aromatic hydro carbon mixed with a halogen and placed between magnesium and carbon electrodes was found to be capable of delivering useful electrical power. Such 2.5 volt solid state batteries, which have a short circuit current of 20 to 30 milliamps and can be encapsulated, are promising power sources since they should be insensitive to radiation, sterilizable, and capable of being made even smaller.

After several years of development, NASA now has an operational large (240,000 joules) ruby laser system, suitable for drilling, cutting, and welding of space components. With it, 1/8 inch aluminum has been welded and 1/4 inch aluminum has been penetrated. Work continued to improve the device and increase its useful operational life.

A special laboratory fatigue machine was developed that will closely simulate the fatigue conditions (loads, temperatures, and corrosive environment) that a Mach 2.7 SST will experience in many flights over its full design-life. The ground-to-air load, realistic gust-loads, normal maneuver loads, and thermal stresses will be applied to test specimens just as the actual airplane will encounter them from take-off to equilibrium cruise conditions. Simultaneously, the temperature of the specimens will be raised to correspond to the airframe temperature during climb while the corrosive environment of an ocean-side jetport is imposed. Then the corresponding sequence of loads and temperature associated with let-down and landing will be applied. The cycle will be applied in real time, so that any unexpected time-dependent effects will be revealed.

The facility can test sixty specimens at a time, permitting the accumulation of reliable data on the ability of the airframe to stand up under many years of use by the SST goes into service. This facility will support the SST program by verifying the design theory, by disclosing errors and unforeseen problems, and by contributin to the reliability and safety of the first SST.

Columbium and tantalum base alloys which can hold boiling potassium metal for several thousand hours at temperatures above 2,000° F. were developed and evaluated. Data were collected on the effect small amounts of impurities have on the ability of these alloys to withstand such extreme conditions and on how to control impurities. This development is important in relation to the more advanced spacecraft concepts in which the electrical power for interplanetary missions would be derived from turbines driven by boiling metals and for potential commercial applications.

Aeronautics

Aircraft Aerodynamics -- A study was made of drastically modified airfoil shapes to determine and evaluate an aerodynamically and structurally near-ideal wing for flight close to the speed of sound (660 mph). Using a specially shaped fuselage on which was mounted a swept-back wing with greater span and thicker sections than those of the current jets (supercritical airfoils), investigators found that this advanced configuration could be operated at about 10 percent higher speeds with appreciably less power than the most recent jet transports with conventional wings and fuselages. Research is continuing to explore the potentialities of this concept.

Structures -- Models embodying lightweight structural concepts which may be practical for a future hypersonic-cruise-aircraft fuselage were constructed and were being subjected to the load and temperature tests representative of hypersonic flight to obtain basic engineering information on structural behavior and characteristics and to identify specific fabrication and design problems. Analytical studies of various possible designs of the hypersonic aircraft wing were made. And fatigue tests of structural box beams representative of supersonic aircraft design indicated that crack propagation rates in fusion-welded beams were slightly higher than in spot-welded beams.

Air Breathing Propulsion -- Research on propulsion systems for supersonic aircraft concentrated on advanced engine component concepts, such as application of advanced flow control technology to the design and operation of the individual compressor blades, which will increase performance and reduce system weight. In addition, competitive studies indicated the feasibility and high performance potential of a hypersonic research engine capable of operating with supersonic combustion to a Mach number of 8, and a contractor was selected to design and develop this engine.

Aircraft Operating Problems -- In an investigation of cornering forces under heavy braking conditions with the aircraft yawed on the runway, tests conducted on the Langley Research Center Landing Loads Track indicated that maximum cornering forces can be developed only for non-skid conditions, that brakes should be released when a skid develops in order to retain directional control, and that one wheel on each landing gear truck might be left unbraked to develop cornering forces for control.

A basic flight test handling qualities evaluation of the characteristics of seven general aviation aircraft was completed by the Flight Research Center. The study showed that all aircraft tested were acceptable for good weather operations in the hands of alert, experienced pilots, but that there was a general deficiency in the aircraft characteristics necessary for safe instrument flight operations.

The Naval Air Engineering Center, Philadelphia, under contract to NASA completed construction of spin test pits for studying the mechanism of compressor and turbine section failures and means of containing the fragments. The pits can test turbine sections up to the size of those proposed for the SST type engine.

NASA continued basic research on the fundamentals of aircraft engine noise generation, and joining other Government agencies in an inter-agency aircraft noise abatement program, expanded its research to include studies of the noise generation characteristics and potential for noise reduction of full-scale engine components. The engines on the X-21 aircraft were converted to permit an inflight study of the effectiveness of inlet choking as a noise reduction system.

X-15 Research Aircraft -- The three X-15 research airplanes continued in use as sources of basic information on manned maneuverable flight at hypersonic speeds, making a total of 20 flights. These flights were devoted to aeronautical and space flight experiments which use the unique speed, altitude, and recoverability capabilities of the X-15 aircraft. Research programs underway during the year included the University of Wisconsin stellar ultraviolet photography experiment, an aerodynamic base-drag study; an Air Force-sponsored high-altitude atmospheric density experiment, the Project APOLLO horizon scanner equipment development; a micrometeorite collection program for the Air Force; a horizontal-tail loads investigation; boundary-layer noise measurements; heat transfer measurements; the JPL solar spectrum experiment; the functional checkout of a new pilot's cockpit display panel, utilizing tapes instead of round dials; new inertial flight data system; and the alternate pitot static system required for future Mach 8 flights. In addition, all three aircraft were updated and modified for these various test-bed experiments.

Two flights of the X-15-2 were made with the large external propellant tanks which will be required for the Mach 8 flights to be flown in support of the hypersonic ramjet research engine experiment. The first flight with full external tanks was on July 1. Launch weight for this flight was 52,000 pounds, in contrast with the X-15's normal gross weight of 34,000 pounds. An error in the telemetry system led to an emergency landing at Mud Lake, Nev., an uprange dry-lake bed; the landing was without incident. The second full-external-tank flight, on November 18, was successful. Data were obtained on aircraft handling characteristics with full external tanks; tank jettison and separation characteristics; test of ablative materials being developed for programmed Mach 8 flights; and several test bed experiments. This flight resulted in the fastest speed to date in the X-15 program: 4,233 mph; Mach 6.33.

Supersonic Transport -- NASA assigned technical personnel to the Federal Aviation Agency Source Selection Evalutation Group for evaluation of contractor proposals for construction of the Phase III prototype supersonic transport. In addition, the agency made wind tunnel tests of the contractors' designs to assist in the evaluation and provided other types of requested technical relatively minor changes in the shape of a large airplane like the SST can alleviate appreciably the sonic boom overpressure and impulse on the ground. It was also found that the same changes can be used in the design of a smaller, shorter-range SST to minimize sonic boom generation over domestic routes.

V/STOL Aircraft -- The second NASA Conference on V/STOL aircraft, held at the Ames Research Center in April, was attended by about 500 engineers and scientists from industry, universities, and the Government. Reports were made on the progress of NASA research on vertical and short take-off and landing aircraft and on studies of the feasibility of using V/STOL concepts for improved short-haul commercial transports.

A program was initiated to solve operational problems encountered in landing a jet fighter VTOL airplane in poor visibility weather conditions; contracts were awarded for studies of the possibility of modifying a conventional jet airplane to incorporate VTOL features desired for this research. In experimental research studies conducted during the year, the rotating-cylinder flap and augmentor wing concepts for providing more efficient short take-off and landing capability, and the hingeless-rotor and jet-flap rotor for improving or extending the flight capability of the helicopter seemed to have special potential value.

NASA-USAF XB-70 Flight Research Program -- The initial phase of this program was almost completed by June 8, 1966, when one of the aircraft was destroyed following a midair collision with an F-104 chase airplane. At the time of this loss, the two XB-70s had made 95 flights totaling 186 hours and 23 minutes of flight time. After the loss of the XB-70 Number 2, the entire program was replanned around the XB-70 Number 1, which had to be modified by installing additional research instrumentation and updating the airplane structure, landing gear, and several subsystems. This work was completed by early November, and the first flight in the joint NASA-USAF program was made on November 3. Priority research areas for the XB-70 program include sonic boom (at least nine flights are scheduled in the first two months to obtain sonic boom data required for the national supersonic transport program); dynamic loads; stability, control and handling qualities; engine-inlet performance; and general aircraft performance.

Chemical Propulsion

Liquid Propulsion Systems -- Components of the 1,500,000 pound thrust M-1 rocket engine were tested during the phaseout of this development project. The main combustion chamber was tested successfully, yielding design specification performance values, other components were tested, and 62 reports on the project's technological advances were published.

In the advanced cryogenic rocket engine project, a jointly planned NASA-USAF effort to demonstrate two different advanced launch vehicle rocket engine concepts, work was started on toroidal combustion chamber dynamics and testing of high pressure cryogenic pumps.

In spacecraft propulsion research, significant data were collected on the performance and cooling capabilities of the space-storable class of propellants. Good performance was obtained from the liquefied petroleum gases reacting with fluorine-oxygen mixtures and also from the oxygen difluoride-diborane propellant combination.

Design criteria were completed for small monopropellant hydrazine auxiliary rockets with thrust ranging from 1/2 to 50 pounds. These single propellant engines have a long service life, simplify propellant storage, and are useful for a number of attitude control, extravehicular activity, and hot gas source applications. A low-thrust auxiliary propulsion system using high energy advanced cryogenic propellants was being defined, and several components were designed and tested.

Research on materials for liquid propulsion spacecraft engines stressed new manufacturing processes, with major advances in the pyroceramic and ablative rocket engine chamber fields. New methods were developed for processing pyroceramic materials such as pyrolytic graphite and compounds such as zirconium carbide and hafnium carbide, yielding noticeably superior products. Improved materials for ablative rocket engine chambers included a new synthesized resin that is easy to process, light in weight, resistant to salt water and many other chemicals, and has good compressive strength. It appears to be adaptable to such uses as surgical heart valves, oceanographic and naval structures, and syntactic foams for flotation gear materials.

Solid Propulsion Technology -- Research in materials, propellants, combustion phenomena, environmental effects, test techniques and improved correlation of experimental data with theoretical predictions continues to provide the long-range basis for the NASA solid propulsion motor needs. During this year, significant results were achieved in identifying and understanding solid propellant combustion phenomena including the effects of metal particles in oxygen-containing propellants. The relation of various types of acoustic losses in a solid motor to other losses was clarified. These efforts will provide better assurance in achieving combustion stability for large solid motors than would otherwise be obtained in an experimental demonstration program.

Large Solid Motor Program -- The large solid motor program progressed with the successful testing of the second 260" diameter solid rocket motor in February. This motor, identical to the first, developed a maximum thrust of over 3.5 million pounds and burned for about 2 minutes; test results were exceptionally close to the pre-firing predictions. Based on the success of the two test firings a follow-on contract was negotiated for the firing in mid-1967 of a third motor with a thrust level of over 5 million pounds. Launch vehicle design analyses indicated that a 260" diameter motor with a thrust of over 7 million pounds combined with the second stage of the SATURN IB can place about 100,000 pounds in orbit for an unusually low cost, and plans for a test of such a high thrust motor were initiated.

Programs were underway to optimize the materials used in the fabrication of large motors, particularly the case and nozzle, and components, such as a failure warning system, devices for thrust termination, and motor steering systems, for a solid rocket motor vehicle stage were being analyzed and developed. Analyses indicated that the payload performance of small launch vehicles such as THOR and ATLAS can be improved significantly if high energy and controllable solid rocket motors are used as final stages, and planning was underway for demonstration tests of such motors.

Biotechnology and Human Research

Cardiovascular Research -- NASA-supported research on decreased oxygen in the blood during prolonged high g conditions revealed that the decrease in brain performance during high g is due not only to a decreased blood supply to the brain, but also to the fact that the blood which is supplied has less oxygen. In other research, a device was developed for measuring vibrations of the heart (an indication of heart work) and relating them to the heart's electrical or conducting system. This device is new, and perhaps provides a more sensitive method for measuring changes in heart activity. A system incorporating several devices for measuring cardiovascular parameters was incorporated into a single chair, permitting an electrocardiogram, phonocardiogram, pulse rate, and respiration rate to be obtained from a fully clothed individual who simply sits in the chair.

Respiratory Research -- NASA continued work on the problem of providing a suitable and safe atmospheric environment for astronauts. A summer study group on respiratory physiology sponsored by NASA, and conducted by the Space Science Board of the National Academy of Sciences, defined critical respiratory research needs for future extended manned space flights in 16 areas ranging from oxygen toxicity to the action of drugs and medication on the respiratory tract.

Investigations of oxygen toxicity led to a discovery that may affect research on emphysema, a progressive and usually fatal lung disease whose exact cause is unknown and for which no curative treatment is known. Research on emphysema has been hampered because only people get the disease, and it could not be induced in laboratory animals. In NASA's studies of the toxic effects of pure oxygen on mammals, rats and larger animals breathing pure oxygen at 14.7 psi (sea level pressure) for extended periods developed lung lesions very similar to true emphysematous lesions. This finding may serve as the basis for research on the treatment and perhaps cure of human emphysema.

Studies conducted with the Navy and the Air Force to determine the best diluent for oxygen when a two-gas spacecraft system becomes feasible showed helium to be safe for as long as 57 days.

Noise -- Studies were underway on the effects of high-intensity sound in the 1-100 cycles per second range on the inner ear sensory hair cells, and on three psychophysiological problems related to the sonic boom: (1) the arousal effects of sonic booms upon sleeping persons, (2) the startling effect on people who are awake, and (3) the relation between the audibility of sonic booms and the physical characteristics of their acoustic waveforms.

Life Support Systems -- The advanced closed cycle system which requires resupply every 90 days while in orbit was tested at the Langley Research Center with limited manned runs. Concurrent with this system test program, new life support system concepts were being developed. Progress was made in the development of an electrochemical carbon dioxide concentrator, of solid electrolyte techniques for reclaiming oxygen from carbon dioxide, and of expulsion techniques for subcritical cryogenic oxygen using electric fields to replace the gravity field.

Hard Suit Development -- Studies of the hard suit concept produced a radical arm and joint design, utilizing the principle of a constant volume joint applied to two conic or cone-like sections so that they interface to form a rotating seal. After testing, the best features of the Ames Experiment hard suit and of the earlier series can be incorporated into an operational suit.

Underwater Simulation -- Astronauts participated in studies of water immersion to simulate the effects of reduced gravity on human performance. Astronaut Cernan simulated several of the EVA tasks which were involved in the GT-9 flight, and experienced problems indicating the need for redesign of footholds. Astronaut Aldrin received training on the complete sequence of the GT-12 EVA in the underwater simulation facility. Using a time chart for each activity, he rehearsed the EVA tasks underwater on three different occasions, resulting in some modifications to the EVA procedures, and late in October he went through a final complete EVA sequence. He returned to the underwater simulation facility on November 30, after his space flight, to compare its effects with the water immersion simulation of zero g.

Aerosol Particle Analyzer -- The instrument to measure dust particles in the cabin atmosphere was fabricated, qualified for flight, and assigned to the flight of the SATURN APOLLO 204 spacecraft. The finished hardware is a 3 1/2" x 4" x 5", self-contained, portable unit which replaces the standard one or two racks of heavy electronics normally required.

Flight Experiments -- The Orbital Otolith experiment to provide basic physiological information on how the otolith functions in the zero g environment made considerable progress. Flight hardware was designed, fabricated, and flight qualified, baseline data were obtained in the laboratory on the otolith response in the 1 g environment, and techniques to implant and support microelectrodes during the launch were perfected. The experiment was scheduled for flight on the SATURN APOLLO 205 vehicle, which was cancelled. The experiment was being considered for rescheduling on as early a flight as possible.

For the primate experiment, 35 companies were invited to submit proposals for a hardware definition study, the responses were evaluated, and recommendations were made for the contract award. Concurrently, laboratory research was conducted on the problems of diet, animal confinement, animal instrumentation, performance measurements, and experiment techniques. Problems uncovered, such as diet deficiencies, were being researched.

Space Vehicle Systems

Aerothermodynamics -- The reentry V Experiment returned highly significant data on the performance of a promising heat shield material. The second NASA lifting-body vehicle, the HL-10, was delivered and was being readied for initial flight tests. The first vehicle, the M-2, delivered last year, was flown in the subsonic flight regime and landed several times to determine pilot handling qualities and vehicle landing characteristics. Flight research was being conducted to determine the deployment and performance characteristics of parachutes for use on the VOYAGER program. The parachutes are carried to high altitudes by balloons and rockets and deployed so as to simulate flight in the very low density Martian atmosphere. One such experiment with an 85-foot parachute was successfully completed. Research also continued on advanced lifting parachutes capable of landing APOLLO-type spacecraft on land and of being steered to chosen landing sites.

Structures -- Analytical studies demonstrated the feasibility of constructing and deploying in space a very large (about one mile in diameter), extremely lightweight radio telescope antenna to detect electromagnetic waves from stellar sources in the very low frequency range. The antenna would be made of an open grid work of fine wire or ribbon relatively insensitive to damage caused by meteoroid penetrations. Dynamic modeling technology for large boosters demonstrated its value through dynamic tests of models of the TITAN III, which was developed and flown successfully with its structural dynamic qualities determined solely by modeling techniques without the full-scale ground tests characteristic of other large launch vehicles. The same economical technique was used to test models of the SATURN V.

An analog computer program was developed to investigate the effects of rough terrain and low gravitational restoring force on a vehicle traversing the lunar surface. The same program, because of its generality, can also be used to predict the response characteristics of earth vehicles.

Environmental Factors -- Analytical techniques which can be used to calculate the transmission of electrons through shield materials, the production of secondary radiations within the material and their subsequent penetration through the shield, were developed and checked experimentally. Data from this program were being used to assess the radiation doses received by astronauts in manned space flights.

The three large PEGASUS spacecraft, launched in 1965 by uprated SATURN I vehicles to count meteoroid penetrations in metallic skins, continued to furnish significant data. These data, with those obtained by EXPLORER XXIII, resulted in revisions to the APOLLO meteoroid design criteria. Artificial meteor observations yielded data used in analyzing natural meteor observational data and in determining the meteoroid hazard to spacecraft.

Data from the Lewis Research Center zero-gravity program were the basis for the design of the propellant management systems used in the CENTAUR and S-1VB stages. Feasibility of the system was demonstrated by a liquid-slosh experiment in ballistic flight, and its adequacy was confirmed by successful flights of the CENTAUR and S-IVB stages.

Test procedures used to determine the degradation of thermal control coatings exposed to the space environment were improved by measuring degradation without exposure to the atmosphere. Results obtained in such tests resulted in modification of coatings on the LUNAR ORBITER spacecraft.

Design Criteria -- The program to develop design criteria to insure the flightworthiness of NASA space vehicles was strengthened through the assignment of specific responsibility to NASA Centers: Langley for structures; Lewis for chemical propulsion; Electronics Research Center for stability, guidance, and control; and Goddard for the Environment area. Contractual and in-house efforts were continued to formulate suitable criteria.

Electronics and Control

Project Scanner -- This program was initiated to measure the radiance characteristics of the earth's horizon as a basis for the development of highly accurate navigation and attitude control sensors. The first flight of a sub-orbital probe in August produced more than 250 good horizon crossings and data which revealed close correlation between theoretical predictions and the experimental data. In addition, the experiment indicated that the 14-16 micron region is relatively free of cold cloud effects which were major contributors to the failure of the OGO-II spacecraft. A second sub-orbital probe was launched on December 10 to acquire additional data under different seasonal conditions and further verify the theoretical calculations.

Laser Gyro -- NASA began development of a three-axes ring laser gyro system for evaluation in a strapdown inertial platform, thereby eliminating complex and costly gimbal systems currently employed as reference platforms in spacecraft and aircraft. Studies indicated that this system will exceed the performance of conventional gyros in a strapped-down mode (0.1° per hour drift rate) by a factor of 10 and will also be simpler and less costly.

Control Systems -- Results of research on new or advanced concepts for spacecraft and aircraft control included a manual control backup capability for the APOLLO SATURN V launch vehicle upper stages; a control moment gyro system applied in the APOLLO Telescope Mount project for precise pointing of a solar telescope by attitude control of an APOLLO vehicle; an aircraft autopilot using fluidics or fluid devices exclusively and offering potential low cost, high reliability, and long life; and indirect viewing optical devices to give pilots of lifting body reentry vehicles adequate visibility for landing.

Optical Technology -- High resolution space telescopes for optical astronomy and communications may be developed by using segmented optics which could be assembled and aligned in space. A mirror figure sensor determines which segments are out of alignment and to what extent and provides electrical signals to correction actuators located behind the mirror. A 24-inch diameter 3-segment mirror feasibility model was tested to evaluate this technique with encouraging results. If this concept proves workable, it will mean significant advances in optical technology for space astronomy, communications, earth orbital geological surveys, mapping, and navigation.

Vibrating Diaphragm Pressure Transducer -- An instrument was developed for measuring aerodynamic pressure on small models used in hypersonic tunnels and shock tubes. It is capable of operating from 1/10,000 to 1,000 mm pressure with an accuracy of about 1 percent. Its operating principle is based on sensing the damping of a vibrating metal diaphragm which is immersed in the gas whose pressure is to be measured; the higher the surrounding gas pressure, the larger is the damping effect on the membrane. The device lends itself well to automatic operation because of its simplicity.

Angleometer -- Another device was designed to give very precise model alignment with gas flow direction required in testing with small models. It can measure angular inclination with a precision of plus or minus $.02^{\circ}$ over a range of 60°. The device, which weighs 4 ounces and is 1 7/8" x 1 3/32" x 5/8" in size. The sensor is extremely linear and insensitive to temperature effects, and its critical sensing element is free from wear.

Adaptive Telemetry -- In research on methods of increasing the efficiency of telemetered data from spacecraft, on-board adaptive telemetry techniques were developed which remove redundant information bits and reduce the volume of data transmitted to earth. The method conserves transmitting power and reduces ground processing.

NUCLEAR SYSTEMS AND SPACE POWER

In the field of nuclear systems and space power, further research and development gains were achieved with nuclear power generation, solar and chemical power research, and electric thrustors.

Nuclear Power Generation

The SNAP-8 project is aimed at developing a 35 kilowatt power system capable of reliable space operation for 10,000 hours. In 1966, the first power conversion system, in a breadboarded configuration, began operating, and a self-sustaining electrical output of 33 KWe was achieved.

Work on the SNAP-19 isotope generator continued. Ames Research Center and the AEC's Lawrence Radiation Laboratory, working together and using an isotopically fueled SNAP-19 generator, mapped its radiation field to determine its suitability for other satellites that may carry extensive scientific equipment.

The SNAP-27 generator begun last year under AEC sponsorship for the APOLLO Lunar Surface Experiment Package (ALSEP) entered the hardware delivery stage. Components and subassemblies of actual equiment were delivered and were undergoing tests. Many of the problems encountered during design and manufacture were attacked and solved. Difficulties in meeting the weight restrictions were being overcome, and the contractor is expected to meet the completion schedule.

The advanced nuclear electric power program continued to give major emphasis to three energy conversion concepts: the Rankine and Brayton cycle turbogenerator systems and the thermionic direct conversion system.

The alkali metal Rankine turbogenerator program attained major milestones in the technologies of the system materials and components. A 2100°F liquid sodium-to-boiling potassium loop, with walls constructed of an advanced columbium alloy, and with sample stator blades of advanced molybdenum alloy in the circuit, completed a 5000-hour endurance test. The loop showed only negligible evidence of corrosion.

A 200-kilowatt two-stage turbine, operating with slightly wet potassium vapor, successfully completed a 5000-hour performance-and-endurance test. There was little or no evidence of erosion of the blades, and the turbine operated steadily and efficiently.

Results of a design study indicated that a tenfold reduction in the weights of conventional electromagnetic pumps is attainable. Such pumps have no moving parts, require no lubrication and have zero leakage. Their use substantially increases the reliability of dynamic space power systems.

The reactor powered thermionic direct conversion system program continued to make significant progress in providing new data on some of the problems involved in the design of a long-life lightweight system. The principal efforts included reactor fuel property research and out-of-reactor life-testing of high performance converters. The fuel investigations were still in progress at the end of the year. The (stable performance) operating life of the out-of-pile converters continued to improve, although the life achieved from converter-to-converter remains erratic.

Numerous research programs relating to detailed thermionic component problem areas were also continued. A typical one concerned the effects of reactor radiation upon the electrical properties of insulators. Another was addressed to the matter of the chemical compatibility of various insulator and braze materials with high temperature cesium vapor. A third was concerned with the high temperature stability of the crystal orientation of various emitter materials. And a fourth was involved with finding improved methods of protecting vapor depositing refractory elements and alloys.

The Brayton cycle power conversion work was focused on the 5 to 10KWe power range typical of the needs of early manned orbiting space station missions. The high cycle efficiency of the Brayton system at these low power levels makes it attractive for use with a radioisotope heat source. "Cold" flow performance tests (efficiency, pressure ratios, etc.) were substantially completed on the radial flow turbine and compressor components, and "hot" flow tests on the gas bearing mounted turbocompressor package were in progress. Preliminary tests were encouraging. The gas bearings operated successfully at their design temperature and speed. However, facility limitations made it necessary to operate the turbocompressor package at less than its design temperature. Design point operation (about 1550°F turbine inlet temperature) is the prime objective of the test series that will begin shortly.

The performance achieved on the small research turbines and compressors led to a more compact single-shaft radial flow unit typical of a 5.5KWe power system. This unit, now in preliminary design, will combine the turbine, the alternator, and the compressor.

Solar and Chemical Power

The extension of solar power system capabilities to multi-kilowatt levels was given increased emphasis during 1966, with the initiation of a technology program directed toward the test of a deployment model of a 12.5 kilowatt solar panel assembly. Four such panel assemblies grouped around the spacecraft would be capable of providing a 50-kilowatt output, providing a 50-fold advancement in the power generating capacity of solar cell arrays with a 2 to 1 reduction in weight over present technology.

Significant reduction in the solar cell's sensitivity to radiation hazards of the space environment is believed possible, based on 1966 research results. Short duration tests to date of lithium-doped silicon solar cells indicate a 50-to-100-fold increase in radiation tolerance over comparable solar cells made by the best conventional processes. Long duration tests are needed before determining the suitability of these cells for use.

Developmental circuit techniques were demonstrated for the parallel operation and synchronization of low-input voltage converters.

The low-input voltage conversion technology benefitted also through the development of experimental silicon power transistors having collector saturation resistance comparable to the best presently available germanium devices. The silicon units also have advantages of reduced switching time and higher breakdown voltages. Of even more importance, the allowable junction temperature for silicon is about 60 percent higher than for germanium, thus markedly reducing sensitivity to the operating environment.

Electric Thrustors

The attainment of thrustor components capable of achieving long life at high performance has long been a major goal of the NASA effort in electric rocket propulsion. Endurance tests of ion thrustors and their associated propellant feed systems during the past year, the most notable being a single engine test of over 8000 hours, provided confidence that this goal can be met. The results led to a decision to prepare a second flight in the SERT (Space Electric Rocket Test) program.

The successful sub-orbital SERT I flight in July of 1964 demonstrated that ion engines can operate in the space environment. The primary objective of this second flight will be to verify long-term thrustor performance in space. Launch is planned to take place in the first half of 1969. Initial studies evaluating the usefulness of such engine systems in combination with light weight solar arrays for prime or mid-course propulsion of planetary probes indicated that such an approach has potential merit.

Progress was also made in developing the small electric thrustor systems intended for spacecraft auxiliary propulsion. A resistojet system was installed as an experiment aboard the ATS-B satellite. Other systems were being prepared for flight on later spacecraft. Advanced research efforts were continued on ion, plasma, and electrothermal systems.

THE NUCLEAR ROCKET PROGRAM

During 1966, the major emphasis in the joint NASA/AEC Nuclear Rocket Program was on the continued development of graphite reactor and engine system technology.

As in previous years, work also continued at a low level of effort on the alternate solid core reactors, using tungsten instead of graphite as the primary structural material, and on various advanced cavity reactor concepts offering promise of greater performance.

Technology work on an 1100 megawatt reactor and engine system was being performed under the NERVA project and is an outgrowth of the reactor technology developed by the Los Alamos Scientific Laboratory earlier in the program. In addition, work was also underway to develop a large NERVA engine with a thrust of 200,000 to 250,000 pounds and a nominal reactor power of about 5000 megawatts. The technology for this effort is being provided through the PHOEBUS program.

Advanced graphite reactor technology work is being carried out through the PHOEBUS effort. KIWI-sized reactors, called PHOEBUS 1 and incorporating a variety of experiments, were being tested to explore some of the operating characteristics and design features planned for a larger PHOEBUS 2 reactor of approximately 5000 megawatts.

NERVA Reactors and Systems

Two major test series were conducted during the past year as part of the NERVA reactor and engine system technology effort. The first was designed to increase the existing knowledge and understanding of nuclear rocket engines which previously had been studied only under cold flow conditions. The test article used was a 55,000 pound thrust "breadboard" engine called the NRX/EST (NERVA Reactor Experiment/Engine System Test). The second test, involving the use of a NERVA technology reactor called the NRX-A5, was designed to provide further data on reactor operation under extended test durations.

The "breadboard" engine system test series was initiated in December of last year; power testing was initiated in February of this year and extended into March. The test series differed from reactor tests previously conducted in that it involved the use of several major components not previously operated with a reactor: a turbopump, a turbine power control valve, and a nozzle with a hot-bleed port located in its convergent section. These components were functionally arranged on a modified reactor test car to provide the flow and pumping arrangement to be used in a flight system and, therefore, system characteristics representative of a flight engine. The NRX/EST was thus markedly different from a test system used when only a reactor is being tested.

The objectives in the "breadboard" engine test program were to demonstrate the hot bleed cycle nuclear rocket engine, to determine the ability of the engine to start up without any separate supply of starting energy (the so-called bootstrap start), to provide data on steady state and transient operation of the engine, and to examine various control modes. All of these objectives were achieved.

After cold flow tests on this engine, a series of power tests was conducted. In all there were ten startups to power. During these startups, the pressure in the propellant dewar and the temperature of the reactor's reflector were varied to determine their effects on the bootstrap start characteristics. In the several tests, numerous closed loop and open loop control modes were investigated and numerous experiments were conducted to determine the response of a system to pressure, temperature, and power transients. A total of 110 minutes of power operation was accumulated, including more than 28 minutes at full power.

As a result of this test series, it was possible to conclude that the hot bleed system is stable over a very wide range. Such a conclusion means, in addition to its general significance, that the system can be throttled at full specific impulse, that several start techniques are feasible, and that any one of several control modes can be used. It was also found that cold flow tests can be used very effectively to check out the hardware prior to power operation.

The NERVA NRX-A5 reactor was first successfully operated at full power for 15-1/2 minutes and then restarted and operated for an additional 14-1/2 minutes on June 23, 1966. The objective of the test program was to explore the corrosion behavior of the reactor under closely-controlled sustained operating conditions.

With the completion of the NRX-A5 test program, more than one and three quarters hours of reactor operation at or near full power had been accumulated in the technology program. Particularly noteworthy was the fact that there had now been a string of seven successive reactor tests, including the breadboard engine system, without a reactor failure. This fact indicated that nuclear rockets have a potential for high reliability through a reasonable development program.

To complement the reactor and engine system technology efforts which continued throughout the year, work also continued on the design, construction, and/or modification of the facilities required to carry out the next phase of work under the engine system technology effort -- the testing of ground experimental engines (XE).

The testing of ground experimental engines, XE, scheduled to begin in mid-1967, is to be carried out in Engine Test Stand 1 at the Nuclear Rocket Development Station. At year's end, this test stand was being activated. Reactor testing will be conducted in Test Cell "C" which was being modified to accommodate the higher powered NERVA and PHOEBUS 1 technology reactors.

The development testing of the large NERVA engine (200,000 to 250,000 pounds of thrust) will be accomplished in a new test facility called Engine/State Test Stands 2 and 3, now in the preliminary design phase.

PHOEBUS Reactors

In the PHOEBUS reactor program, major activity during 1966 was in preparing for the upcoming PHOEBUS 1-B power reactor tests. Work also continued to develop the nonreactor components (exhaust nozzle and facility feed system) for conducting the PHOEBUS 2 power reactor experiments.

The development of the exhaust nozzle for the PHOEBUS 2 was being accomplished under contract. The nozzle design is similar to the U-tube nozzle used for NRX reactor testing, except that Hastelloy X material is being used instead of stainless steel to accommodate the higher PHOEBUS 2 temperatures and heat fluxes. Fabrication of the basic nozzle hardware and activation and demonstration of the nozzle test stand (using an uncooled nozzle) were completed during 1966. The first cooled nozzle also was moved in the final stages of fabrication and is nearing completion.

Development of the feed system for the PHOEBUS 2 has been underway now for the past four years. Basically, this system is an outgrowth of the pump-turbine system developed for reactor testing in the Los Alamos KIWI program at NRDS. In the PHOEBUS 2 feed system, two of these pump-turbine units were being combined in a parallel arrangement to provide the higher flow rates required.

In addition, the pumps were being developed to deliver fluid at higher pressures than were required for the KIWI tests. A single pump-turbine unit of this system was installed at Test Cell C; it is to be used for the PHOEBUS 1-B test scheduled to be conducted early in 1967.

Tungsten Reactors

Research on the tungsten systems has shown that tungsten reactors are feasible and that their performance in terms of specific impulse probably approaches that of the graphite system. This research also has shown that tungsten reactors can operate for long durations. However, the missions currently envisioned for nuclear rockets do not require operating durations longer than appear to be attainable with graphite. Therefore, all work on tungsten nuclear reactors was discontinued at the end of FY 66.

Advanced Concepts

The advanced concept work conducted under the nuclear rocket program consists primarily of basic studies on the liquid and gaseous fuel reactor concepts to explore some of the known problems that may be associated with establishing their feasibility and performance potential. The work includes basic research into the phenomena of co-axial and vortex gas flows involving two or more gaseous components, calculations of fluid properties at extremely high temperatures and pressures, analysis of radiation heat transfer processes, and research on the properties of molten metal-carbide mixtures.

TRACKING AND DATA ACQUISITION

The Tracking and Data Acquisition Program continued to play a highly successful part in support of NASA missions -- both manned and unmanned. In addition to the operational support provided, basic network facilities and equipment were modified and augmented to meet the requirements of NASA's future programs.

Manned Space Flight Network

The Manned Space Flight Network, an outgrowth of the original Mercury Network, successfully completed its support of the second phase of the Nation's Manned Space Flight Program -- GEMINI -- and is currently supporting the APOLLO Program.

From the first GEMINI launch, in April 1964, through the final flight, in November 1966, the Network repeatedly demonstrated its support capability and recorded many "firsts" in space accomplishments. In 1966, the Network supported the first dual launch and docking with an AGENA vehicle, GEMINI 8, and controlled the first docked vehicle maneuvers, GEMINI 10. The GEMINI 11 support was highlighted by the precision of the technical operations which enabled the spacecraft, during its first orbit of earth, to catch and dock with the AGENA vehicle after a chase of 18,000 miles in space. Proof of such precision operations was necessary since future astronauts will require similar support during the APOLLO Program.

Further proof of these precision operations was obtained during the GEMINI 12 mission. From lift-off to splash-down, the Network constantly monitored the flight, relaying necessary information and commands to the astronauts. Precise orbit predictions and computer calculations enabled the spacecraft to rendezvous and dock with an AGENA target vehicle that had been fired aloft 99 minutes before the GEMINI launch. The accuracy of the "splash-down" was another example of the precision the Network has developed during the GEMINI Program. For the fourth straight time, a GEMINI spacecraft landed close enough to its recovery ship to permit television coverage of the descent and splash-down via the EARLY BIRD satellite to an estimated 50 million Americans.

In addition to performing its primary function, support of NASA's Manned Space Flight Programs, the Network provides similar support for other NASA and Department of Defense programs on a noninterference basis to the manned program. Some of the programs so supported during 1966 were the ORBITING ASTRONOMICAL OBSERVATORY, the SURVEYOR, the TITAN III C, and the ORBITING GEOPHYSICAL OBSERVATORY.

During calendar year 1966, existing GEMINI network systems supported the final GEMINI flights and early APOLLO/SATURN IB missions concurrently with major augmentation of the Network for support of the more complex missions of the later

APOLLO Program. This year five GEMINI support stations, three new land stations, and one of the five APOLLO Instrumentation Ships achieved operational capability for support of these later missions. During calendar year 1967, all remaining stations required for APOLLO Program support, including eight APOLLO/Range Instrumentation Aircraft (A/RIA), will achieve initial operational capability.

Effective September 1, 1966, management of the GLOTRAC Station at Gibbs Hill, Bermuda, was transferred to NASA from DOD. The DOD reimburses NASA for the operational costs of the GLOTRAC Station, and, in turn, NASA provides support for all programs requiring coverage by this station. The transfer was in accordance with the NASA/DOD agreement concerning the operations of land-based tracking, data acquisition, and communications facilities.

The conclusion of the GEMINI Program eliminated NASA's requirement for its tracking station at Kano, Nigeria. The station was established in October 1960, for support of Project MERCURY, and was continued for GEMINI. With the reconfiguration of the Network for APOLLO support, the Kano station is no longer needed.

Satellite Network

The Satellite Network supports NASA's unmanned scientific and applications satellites. The Network also supports space projects of other Government agencies (the Department of Defense and the Environmental Science Services Administration) and industry (the Communications Satellite Corporation). The Network provides this support through the electronic Space Tracking and Data Acquisition Network (STADAN) stations and the Smithsonian Astrophysical Observatory (SAO) optical tracking stations.

Two of the veteran STADAN stations -- East Grand Forks, Minnesota, and Blossom Point, Maryland -- were deactivated during the year. Although these stations were invaluable for support of early programs, the large unmanned satellites now being launched follow orbital paths which are better served by stations at other locations.

Also, two consolidations of equipment and capabilities were accomplished, resulting in reduced operating costs. Equipment previously located at Woomera, Australia, was relocated and consolidated with the STADAN station at Canberra; and Minitrack and telemetry operations at College, Alaska, were consolidated with the STADAN facilities at Fairbanks.

Support requirements for the Applications Technology Satellite (ATS) Program necessitated some additions to the Network. These include locating a transportable station at Toowoomba, Australia, and adding project-unique equipment at Rosman, North Carolina, and Goldstone, California, all of which were completed during 1966.

Forty-foot parabolic antennas were installed at Tananarive, Madagascar, and Fairbanks, Alaska, to meet the increasing workload. The increase in workload is due primarily to the volume of data received from the large Observatory-type satellites.

Another vital addition to the Network during 1966 was the Network Test and Training Facility, located at the Goddard Space Flight Center, Greenbelt, Maryland. This facility is used as an engineering test-bed for the checkout of new and standard equipment prior to installation at the operational stations.

Deep Space Network

The Deep Space Network supports NASA's unmanned lunar and planetary space flight missions. During the year, three Network stations -- located in Australia, Spain, and California -- were being modified and equipped to provide joint support to the Manned Space Flight Network for the lunar phase of the APOLLO Program. These stations are approximately 120° apart in longitude, and allow continuous viewing of a lunar mission from at least one of the ground stations.

During the year, the Network supported six major flight missions: PIONEER VI and VII, SURVEYOR I and II, and LUNAR ORBITER I and II. The Network also provided limited support to the MARINER IV mission and to two ATLAS-CENTAUR vehicle development tests, AC-8 and AC-9. With the exception of PIONEER VI and MARINER IV, all the missions were launched in 1966.

The support given the SURVEYOR I mission -- one of the most significant and successful lunar flights to date -- was outstanding. The SURVEYOR I mission provided the first opportunity for the Network to demonstrate its capability to control a spacecraft from launch to lunar soft-landing and lunar based operations. The successful accomplishment of this feat required that over 100,000 commands be sent to the spacecraft, and resulted in the receipt of over 10,000 pictures from the lunar surface.

The Network again demonstrated its support capability during the LUNAR ORBITER I and II missions. Although the high resolution camera aboard ORBITER I functioned marginally, the Network provided flawless support throughout the entire mission. The ORBITER II mission was also provided this level of support, and the pictures received at the Network stations were excellent. These high-quality pictures are vital in determining the APOLLO landing sites on the moon.

A significant addition to the Network in 1966 was the 210-foot diameter parabolic antenna at Goldstone, California. Dedicated in April 1966, the antenna is the United States' largest fully steerable antenna and the world's largest built for research by spacecraft. This giant structure -- it stands 240 feet tall and weighs abut 16 million pounds -- provides an overall tenfold improvement in telecommunications support over that of the standard 85-foot diameter antenna. This increased capability permitted solar corona experiments to be conducted with the MARINER IV spacecraft, and provided the first measurements of radio transmissions through the solar plasma. It is estimated that using this antenna station to support the PIONEER VI and VII flight missions will extend the useful life of these missions a minimum of one year.

Network Communications

The NASA Communications Network (NASCOM) is the interconnecting link between the network stations and control centers. The NASCOM was extremely successful in meeting the communications requirements of NASA and other agencies during the period.

In addition to meeting the operational requirements the NASCOM was being prepared for the APOLLO Program. The APOLLO Program will impose by far the most stringent communications requirements of any program to date. Last year it became evident -- from studies conducted with the National Communications System (NCS) -- that these requirements could not be met by conventional systems alone but could be met through the addition of a communications satellite system.

Accordingly, NASA contracted for communications services via the INTELSAT communications satellites. The primary use of these circuits will be in support of the APOLLO Program to provide communications between remote instrumentation ships and stations and the United States. The stations using the satellite services are located at Carnarvon, Australia; the Canary Islands; and Ascension Island. The three APOLLO instrumentation ships, providing coverage for the insertion/injection phase and equipped with communications satellite terminals, will be stationed in the Atlantic, Indian, and Pacific Oceans. These satellite communications services will provide necessary communications with sufficient reliability and quality to allow real-time mission direction from the Mission Control Center, Houston, Texas.

UNIVERSITY PROGRAMS

The NASA Sustaining University Program has elements related to predoctoral training, special purpose multidisciplinary research, and to construction of laboratory facilities. All elements contribute to broadening the base of university participation in the space program.

One hundred and fifty-two colleges and universities, including at least one institution in each state, now hold training grants. In September 1966, the total number of students in the program rose to 3,681, as 1,335 new students began their training in space-related sciences and engineering. By September 1, 1966, 334 doctorates had been awarded at 75 universities in 34 states and the District of Columbia. Students are now participating in this program in every state.

NASA-supported multidisciplinary research and the encouragement of new research were provided through 57 research grants at 55 universities.

Progress continued in expanding research facilities at universities. Two new facilities grants were made to universities, and eight facilities begun under previous grants were completed, providing an added capability of 283,000 square feet of university laboratory area for space related investigations.

INTERNATIONAL AFFAIRS

NASA again extended its international cooperative space and atmospheric research projects, as well as support activities, and laid the groundwork for new ones.

Satellite Projects

The successful Canadian satellites ALOUETTE I and ALOUETTE II (launched by NASA in 1962 and 1965, respectively) continued probing the ionosphere as the sun passed its quiet period. The two satellites are part of an eleven-year long, five-satellite series to cover an entire solar activity cycle. The next three in the series are scheduled for launching by NASA in 1967, 1968 and 1969.

The first satellite launched in cooperation with France (FR-1) passed its first year in space on December 6. Satellite instrumentation and telemetry have functioned effectively, and at year's end U. S. and French scientists were reducing and analyzing the data received from the spacecraft.

In May, NASA and the French National Center for Space Studies (CNES) concluded an agreement on a new experimental project. This project is expected to demonstrate the scientific value and technical feasibility of collecting global weather data from constant-level instrumented balloons by means of an earth-orbiting satellite (EOLE/FR-2).

In September, NASA and the German Ministry for Scientific Research agreed in principle that the second joint US/German satellite project will be an aeronomy research spacecraft. This spacecraft is to be placed in orbit in 1970, during the solar maximum period, to study effects of solar radiation on the upper ionosphere. Development of the first German satellite, programmed for launching in 1968 to study the earth's radiation belts, progressed according to plan. A basis for negotiating a third project, a joint U. S. /German space probe to the sun, was established.

Nearing launching readiness at year's end were the first ESRO (European Space Research Organization) spacecraft, the third British satellite (first to be constructed entirely in the U. K.) and Italy's SAN MARCO II. All three are scheduled for launching on NASA Scout vehicles early in 1967, the first two from the U. S. Western Test Range and the latter to be the first orbital launching from an Italian Texas Tower-type platform positioned off the east African coast near the equator.

During 1966, the total of foreign experiments selected for flight on NASA satellites reached nineteen. These include experiments from the U. K., France, Italy, the Netherlands, and, for the first time, Israel.

Of particular interest among the experiments suggested by the international scientific community are 69 proposals received from six countries for studies of samples of the lunar surface to be returned to earth by the APOLLO astronauts. These proposals are being evaluated by NASA along with those submitted by U. S. scientists.

Sounding Rockets

This year, for the first time, Spain and Greece entered into agreements with NASA for cooperative sounding rocket programs, bringing to 19 the total of countries having such arrangements with the United States. Rockets launched by NASA from Greece helped the world scientific community study the May 20 solar eclipse. On October 15, Spain launched the first of a series of meteorological rockets under one of two new cooperative projects with NASA. In addition, new sounding rocket projects were negotiated with Argentina, Brazil, Germany, Japan, and the Netherlands.

Under agreements with Argentina and Brazil, twenty-seven sounding rocket launchings were conducted during the total solar eclipse of November 12. Agreement was reached with Germany and Brazil providing for the test flight in Brazil on a NASA rocket of German scientific instrumentation; this instrumentation is expected to be included in the cooperative U. S. /German radiation belt satellite. NASA and the Japanese Science and Technology Agency agreed on coordinated test flights of Japanese and U. S. meteorological sounding rocket systems from Wallops Island, Virginia. The Netherlands Laboratory for Space Research and NASA reached an agreement to include Dutch-built experiments as part of a solar physics package flown on a NASA sounding rocket from White Sands, New Mexico.

The Interamerican Experimental Meteorological Rocket Network (Exametnet), established in 1965 by agreement with Brazil and Argentina, began active operations with fifty-three meteorological rocket launchings in 1966. Data was being exchanged through a central clearing house arrangement at NASA's Wallops Station.

Other cooperative international sounding rocket projects continued under existing arrangements with Canada, Denmark, India, France, the Netherlands, Norway, Pakistan, Sweden, and the United Kingdom.

Additional International Projects

In the first arrangement of its kind, a Memorandum of Understanding was concluded between the European Space Research Organization (ESRO) and NASA, providing for purchase of launchings from the United States for ESRO spacecraft.

The number of countries benefiting from the U. S. weather satellite program continued to grow. By the end of 1966, 31 countries had installed automatic picture transmission (APT) facilities which enable them to obtain directly, from a satellite overhead, cloud-cover pictures of local and adjacent areas.

NASA continued to provide to the export control offices of the Departments of State and Commerce technical advice concerning the propriety of licensing the export of equipment and technology in the aerospace field.

U. S. -Soviet Cooperation

Experimental two-way transmissions of satellite weather data over a special shared-cost facsimile link between Suitland, Maryland, and Moscow began in September, when Soviet satellite data, including both cloud-cover photographs and nephanalyses, became available. In the meantime, reciprocal exchange of conventional meteorological data between the U. S. and the U. S. S. R. continued.

Tracking Station Network

Approvals were obtained from the United Kingdom for the establishment of tracking stations in Antigua and Grand Bahamas to support Project APOLLO, and negotiations for intergovernmental agreements covering the stations were in process. The agreement with the United Kingdom for operation of a tracking station at Winkfield, England, for support of scientific satellites was extended to December 31, 1967, as an interim measure pending completion of a new agreement. An agreement was reached with Spain, continuing the existing NASA tracking station in the Canary Islands and expanding it to support Project APOLLO. The manned flight station at Kano, Nigeria, was closed in December following completion of Project GEMINI, since it will not be required under the network reconfiguration for Project APOLLO.

The ESRO/Alaska Station

On November 28, an agreement was signed between the United States and ESRO for the establishment and operation of an ESRO telemetry/command station near Fairbanks, Alaska. The station is expected to be operational by the summer of 1967. The President had earlier (February 2, 1966) signed legislation making ESRO eligible to receive the benefits of the International Organizations Immunities Act in connection with its activities in the United States.

The National Geodetic Satellite Program (NGSP)

Denmark, Norway, Italy, Japan, Portugal, Iran, and the Netherlands agreed to the stationing of temporary geodetic satellite observation camera teams on their territory as part of the first phase of the National Geodetic Satellite Program.

Personnel Exchanges

One hundred fifteen scientists from 28 countries participated in postdoctoral theoretical and experimental research programs at NASA centers. During academic year 1965, 53 NASA international fellows were enrolled in U.S. universities. Sixteen of this group continued their studies into the September 1966 term; at that time, 29 newly enrolled students began their studies. All were co-sponsored and supported by their national or regional space committees.

NASA and national or regional space committees also co-sponsored 11 foreign students who attended summer institutes in the United States (The Summer Institute in Space Physics, Columbia University; The Environmental and Planetary Science Summer School, University of Miami; and The Bio-Space Technology Training Program, University of Virginia).

Some 130 scientists, engineers, and technicians from six countries and ESRO were trained at NASA centers in payload engineering, telemetry, tracking, radar, meteorology, launch procedures, and range safety operations. During the year about 5000 foreign visitors -- representing scientific and technical organizations, government and overseas news media -- toured NASA Headquarters and the Agency's field installations.

NASA-DOD Cooperation

During the past year, the Aeronautics and Astronautics Coordinating Board (AACB) continued coordinating matters of mutual NASA-DOD interest. New NASA-DOD Interagency coordinating bodies established during the year include the Manned Space Flight Policy Committee, the Manned Space Flight Experiments Board, and the Space Applications Coordinating Committee for technical monitoring of NASA's Earth Resources Survey Program.

The AACB coordinated FY 1967 facilities budgets for NASA and DOD after reviewing planned construction of new facilities and expansion of existing facilities for both agencies. Areas of unwarranted duplication of aeronautical and space facilities were identified and eliminated.

The supporting Space Research and Technology Panel and the Launch Vehicle Panel of the AACB completed their reviews of advanced space propulsion systems. The large liquid fuel engine program was reoriented to develop and demonstrate both NASA and DOD engine concepts at a common thrust level. In order to preserve a capability in large solid motor technology, the two agencies are carrying on level-of-effort programs that supplement each other. The continuation of the long-life space power systems was endorsed, with special emphasis on further development of the SNAP-8 system.

A study was completed on reusable launch vehicle technology. This study provided valuable guidance to both Agencies for future technology programs relating to reusable launch vehicles and maneuvering re-entry spacecraft. Additional studies to provide more specific guidelines for developing the most meaningful technology will be made.

Procedures were also established to provide for the efficient use of secondary payload space on the launch vehicles and spacecraft of both Agencies by cataloging and advertising available space.

The Joint Navigation Satellite Committee Report, setting forth national requirements, future guidelines, relative costs, and technical merits of navigational satellite systems, was accepted by all member agencies (NASA, DOD, FAA, Commerce and Treasury).

The Manned Space Flight Policy Committee considered policy matters related to the MANNED ORBITING LABORATORY, refurbishment of the GEMINI spacecraft, and cost-effectiveness comparisons of the TITAN IIIC and the SATURN I launch vehicles for future NASA missions.

Arrangements were made for NASA to assist the Air Force Systems Command in its study of Fundamental Space Principles, Applications, and Doctrine (Project SPAD). NASA is to provide this assistance by furnishing copies of reports on appropriate studies of future space systems and by providing informal consultative assistance to the AFSC Planning Group.

Through NASA's Technology Utilization Program, steps were taken to make sure the Department of Defense would receive all applicable information or innovative ideas in all areas of space technology such as materials, propulsion, electronics, power sources fuels, etc., of potential value to DOD, are made available.

NASA and the Department of the Air Force entered into an agreement wherein the Air Force will provide supply support for NASA's propellants and pressurants needs. Under the agreement, the Air Force Logistics Command will serve as single manager for propellants and pressurants where it is considered in the best interest of the Government.

NASA and the Department of the Army completed arrangements for the Army Audit Agency to perform audits on that portion of NASA's Construction Program performed by the Corps of Engineers. Under this agreement the Army Audit Agency provides NASA with reports of its regularly scheduled cyclical audits and performs special audits as requested by NASA.

NASA and the Defense Contract Administration Service (DCAS) developed a coordinated training course; through this course, DCAS instructors, trained by NASA, provided field training in NASA quality requirements to about 1,000 DOD quality assurance personnel who perform quality assurance functions on NASA contracts.

To promote the exchange of technical data resulting from ground tests and flight experiences, NASA has joined with the DOD services in support and management of the Interagency Data Exchange Program (IDEP). NASA also took action to support the Navy's Failure Rate Data Program (FARADA).

NASA and the DOD continued their coordination in the X-15 and XB-70 Research Aircraft programs. The efforts were aimed at validating theory and wind tunnel data, and obtaining information on design, materials, and operational techniques applicable to future supersonic military and transport aircraft.

The exchange of military and civilian personnel between NASA and the Department of Defense continued, with the major portion of the flow being to assist NASA. For example, fifteen of the nineteen new NASA astronauts came from the military services. However, several NASA employees were detailed for tours of duty with the Air Force Systems Command in connection with the MOL and other programs and additional requests for the detail of NASA employees to the Air Force and the Navy were being processed.

Following the recent passage of the Marine Resources and Engineering Development Act, the Administrator of NASA was designated as an observer on the National Council on Marine Resources and Engineering Development. NASA's participation in the Council and in the activities of the Interagency Committee on Oceanography should advance the application of space technology to the National Oceanographic Program.

Close cooperation between NASA and DOD in the field of aeronautical research continued. Fourteen aircraft on loan from the Armed Forces were being used as research and test-bed vehicles at NASA Research Centers. The DOD increased its use of NASA wind tunnels during the year.

Other agreements entered into during the period with the Department of Defense or one of the individual Military Services included procedures for the funding and operating APOLLO Range Ships and Instrumentation Aircraft; detailing Navy and Marine Corps officers to NASA; loaning research aircraft; extraterrestrial mapping, charting, and geodesy support; and jointly investigating space program accidents.

ORGANIZATIONAL IMPROVEMENTS

NASA's Office of Space Science and Applications (OSSA) was reorganized to make better use of its developing manned flight capabilities: The Manned Space Science Office was redesignated the Manned Flight Experiments Office/OSSA. The new office serves as the principal interface between OSSA and NASA's Office of Manned Space Flight. An Advanced Mission Staff was established to improve coordination in advanced studies, supporting research and technology, and other efforts related to intermediate and long range planning.

Also, the Communications and Navigation Programs Office and the Meteorological Program Office were consolidated into a new Space Applications Programs Office. The consolidation provides an improved focus for the growing number of relationships between NASA and other Government agencies in space applications programs.

Major organizational elements of the Kennedy Space Center were realigned to improve functional and program supervision. A second deputy position was established to strengthen top management, and an Executive Staff was established to handle executive communication processes and management review. Separate focal points were established for management systems and resources management; design engineering and development; technical support, and general housekeeping functions.

A Medical Research and Operations Directorate was established at the Manned Spacecraft Center (MSC) to consolidate the diversified but interrelated medical activities. This Directorate is responsible for identifying medical problems associated with manned space flight operations, and for directing the research to solve those problems. Also at MSC, a Science and Applications Directorate was established to handle the Manned Spacecraft Center's emerging science and applications-related responsibilities.

The Western Operations Office was closed and its functions were realigned under two component field activities reporting to the Headquarters Office of Industry Affairs. One of the components -- designated Western Support Office --provide administrative, technical, and related services to NASA programs and projects in Southern California and Nevada. The other component -- NASA Office, Downey -- will provide overall NASA representation at North American Aviation, Inc., and support field installation projects at the contractor's site.

A NASA Resident Office at the Jet Propulsion Laboratory was formally organized and personnel of the former Western Operations Office's Contract Division were relocated at that Office. This realignment provides direct governmental capability and responsibility for the procurement of the VOYAGER spacecraft and capsule systems.

INDUSTRY AFFAIRS

NASA's policies, procedures, and practices involving the use of incentive contracts continue to mature in an orderly manner. The use of incentive contracting showed a three-fold increase during 1966, and NASA now has over 200 incentive contracts under administration, amounting to over $6 billion. This year, for the first time in NASA, incentive contract awards exceeded those made on a cost plus fixed fee basis.

NASA further broadened its use of contract administration services available through DOD offices which are in the proximity of NASA contractors, or within the contractor's plant itself. By this arrangement, NASA contracts receive on-site attention by specialists intimately familiar with the contractor's operations. An agreement was reached with DOD, simplifying procedures to be used for reimbursing DOD for services performed.

NASA and DOD have entered into an agreement whereby DOD will conduct contractor compliance reviews and complaint investigations for NASA under the Equal Employment Opportunity Program.

After a trial perod, full implementation of the Contractor Performance Evaluation (CPE) System in NASA was approved by NASA management. A CPE Review Group was established, and NASA contracts were being screened by the group for recommended inclusion in the system.

During 1966, NASA continued to improve its government quality assurance activities. At contractor's plants, quality assurance functions are normally carried out for NASA by DOD field personnel. NASA published a Handbook providing direction and guidance for its field installations on improved management of these functions.

The Headquarters Reliability and Quality Assurance Office began a formal program to evaluate the reliability and quality assurance activities of its field installations relative to procurement.

The NASA internal cost reduction program resulted in savings of $200 million. The Agency's major contractors, voluntarily participating in the contractor cost reduction program, reported savings of $280 million during 1966 for a total savings of $480 million.

NASA experienced a notable decrease in labor disputes leading to work stoppages during the year. Increased efforts in preventive labor relations management, particularly at the John F. Kennedy Space Center, have resulted in reduction of work stoppages. While time lost during calendar year 1965 was 67, 815 man days, this figure was reduced during 1966 to 31, 423 man days. The Agency is actively seeking labor-management cooperation to ease the transition from construction projects to predominantly "industrial"-type labor relations. Most NASA facilities are now developing into the latter phase and the change appears to be developing as planned.

TECHNOLOGY UTILIZATION

NASA continued expanding dissemination of knowledge gained from aerospace work and to experiment with new approaches to transfer aerospace technology. In the past year, the Agency entered into joint programs with the Office of State Technical Services of the Department of Commerce, the Atomic Energy Commission, the Vocational Rehabilitation Administration, the Office of Law Enforcement Assistance in the Justice Department, and the Small Business Administration. Preliminary stages of exploration toward joint efforts were reached with the Bureau of Mines.

The Department of Commerce's Office of State Technical Services (OSTS) has launched an effort to bring to all states, through state-designated agencies, scientific and technological information to fill the needs of business, commerce, and industry. After thoroughly reviewing the capabilities of the established NASA-sponsored Regional Dissemination Centers (RDCs), the OSTS recommended to all the designated state agencies "increased cooperation" with the RDCs based upon "the early and consistent success of the NASA/RDC program."

To increase the store of scientific and technological information available for dissemination, the Atomic Energy Commission entered a cooperative program with NASA. Through this program, the Argonne National Laboratory (and, eventually, other AEC laboratories) will report innovations deriving from their research endeavors. Such reports will be published and disseminated in the form of AEC-NASA Tech Briefs. This activity is modeled after NASA's Tech Brief program, established in 1964, which has reached a volume in published Briefs of over 1, 300 -- a 100 percent increase in this year's effort compared to that of two previous years.

NASA's Technology Utilization program also assisted in medical advancement through two new programs. Biomedical Application Teams were established to improve the exchange between NASA and the biomedical community by direct communication of new concepts to biomedical researchers. Additionally, these Teams and NASA information dissemination personnel began work with the Vocational Rehabilitation Administration under a formal agreement to apply space technology to the rehabilitation needs of disabled persons.

The NASA Office of Technology Utilization and the Small Business Administration jointly began seeking a means of bringing aerospace knowledge to small industrial businesses to assist them in keeping abreast of technological changes.

In an effort to bring NASA-generated scientific discoveries to the educational field, the Office of Technology Utilization in cooperation with the Oklahoma State University launched an experimental pilot program. The aim is to review, select, and prepare significant technical material stemming from NASA's R&D activity for incorporation in graduate engineering and physical sciences courses. In addition, a computer programs dissemination service was started at the University of Georgia. This service will make NASA computer programs more quickly available to the non-aerospace community.

DEPARTMENT OF DEFENSE

CHAPTER IV

INTRODUCTION

Three major actions and events highlighted the Department of Defense space and aeronautical activity during 1966. (1) A single TITAN IIIC successfully placed seven communications satellite repeaters and one experimental satellite into equatorial, near-synchronous orbit. This is the initial step toward orbital establishment of the space segment of a defense satellite communications system designed to meet unique and vital communications needs in support of national objectives. (2) A second TITAN IIIC was used to launch eleven DOD experiments and a modified GEMINI spacecraft. The experiments and spacecraft provided test data in support of the MOL program, the communications program, and the Aerospace Research Support Program. (3) Development of the world's largest military cargo aircraft, the C-5A, continued on schedule.

SPACE DEVELOPMENT ACTIVITIES

MANNED ORBITING LABORATORY (MOL)

The MANNED ORBITING LABORATORY (MOL) is being developed to meet the following program objectives:

a. Learn more about what man is able to do in space and how that ability can be used for defense purposes.

b. Develop technology and equipment which will help advance manned and unmanned space flight.

c. Experiment with this technology and equipment.

Management of the MOL Program is being conducted under streamlined organizational structure in which the Director, MOL, reports directly to the Secretary of the Air Force.

The past year has been devoted to the Contract Definition Phase in which sufficient technical data and costing information have been developed to specify in detail the optimum program. Engineering definition has been completed, the baseline configuration has been established, the development and flight schedule has been refined, procurement of developmental hardware has been initiated, and the program is moving progressively toward meeting the established objectives.

Twelve aerospace research pilots have been assigned to the MOL Program. In addition to preparation for their flight duties, they are each assigned special areas on systems engineering and test operations as members of the MOL development team.

In one of the series of TITAN III development flights from the Eastern Test Range, test data useful to MOL was obtained on the TITAN structure integrity and control capability, and on a modified GEMINI spacecraft.

DOD and NASA will continue to coordinate fully their manned space flight efforts. Where feasible the Air Force will accommodate, on a minimum interference basis, such NASA experiments of a general scientific and technological interest as may be economically and effectively conducted.

TITAN III Program

The TITAN IIIC flight test program involved three flights in 1966. The mission of the first of these was to place seven Defense Communication Satellites and one Gravity Gradient Experiment in a near-synchronous orbit of 18, 200 nautical miles. It was one of the most complex earth orbital flights ever attempted. The eight satellites were placed in the exact orbit desired and are operating satisfactorily.

The second flight plan was identical to the first. In this case the payload consisted of eight Defense Communication Satellites. After some 79 seconds of flawless performance in flight, the payload fairing suddenly failed, leading to subsequent self destruction of the vehicle. Although the exact reasons for this lack of success could not be absolutely determined, it is believed that the payload fairing experienced structural failure. As a result, a metal fairing in lieu of the original fiberglass honeycomb fairing will be used for the next Defense Communication Satellite mission and all subsequent TITAN IIIC flights.

One objective of the third flight of the year was the test of a modified GEMINI heat shield. In addition, a series of scientific experiments was carried. The test was successful in every respect. The definition phase of the modified TITAN III, known as the TITAN IIIM, was completed and long lead time procurement was initiated for the development phase. This configuration of the TITAN III will be used to boost the MANNED ORBITING LABORATORY (MOL).

Also during this year the TITAN IIIB development program was completed on schedule in July 1966 by the successful R&D launch of the first vehicle from Vandenberg AFB. The TITAN IIIB vehicle, which consists of the first two liquid stages of the basic TITAN III plus an AGENA upper stage, was developed to meet polar orbit mission requirements.

DOD Satellite Communications Activities

To provide the prompt, reliable, secure, and flexible communications vital to the United States in support of its global responsibilities, to command its forces, and to control its weapons, the DOD has continued its efforts to exploit the demonstrated ability of orbiting satellite radiowave repeaters together with appropriately designed surface terminals to provide such communications.

Defense Communications Satellite Program (DCSP)

The objectives of the Defense Communications Satellite Program are to conduct necessary satellite communications research and development, and to establish an operational long haul point-to-point satellite communications system in a timely manner. The DCSP is carried out by the three Military Departments with the Defense Communications Agency providing management and operational direction to coordinate the Departmental efforts.

To accomplish these objectives, the DCSP is divided into three broad efforts as follows:

a. SYNCOM

b. Initial Defense Communications Satellite Project (IDCSP)

c. The Operational Defense Satellite Communications System (DSCS)

SYNCOM

SYNCOM II and SYNCOM III, developed and orbited by the National Aeronautics and Space Administration, were used with various DOD terminals in 1966 for experimental system test activities and for passing operational communications. The SYNCOM system was converted to operational status in July 1966 and is currently being employed as an alternate to cable and high frequency radio circuits between land terminals in Hawaii, Philippines, and Southeast Asia; a shipboard terminal installed on the USS ANNAPOLIS is also being used in this system. The SYNCOM system will be used for the remaining life of the satellites -- currently estimated to be about two years for SYNCOM II and five years for SYNCOM III.

Initial Defense Communications Satellite Project (IDCSP)

This project is designed both to provide an in-being research and development satellite communications system to demonstrate system feasibility on a world-wide network basis and to provide an early, though limited, operational capability to supplement the essential command and control communications system of the DOD.

The first spacecraft-repeaters were successfully launched in June 1966. A single development model TITAN IIIC performed in near-perfect fashion to inject seven satellites and one gravity gradient stabilized test satellite into circular, equatorial orbit at a near-synchronous altitude of approximately 18,000 nautical miles. The satellites were sequentially injected into orbit and each was given a small increase in velocity with respect to the preceding satellite to cause a "random" dispersion of the satellites around the orbit. A second launch attempted in August 1966 failed and the DOD is examining possible reasons for the failure, including the protective fairing surrounding the satellites.

The IDCSP surface subsystem consists of newly developed ground and shipboard terminals. During 1966 ground terminals were established for world-wide communication -- on the east and west coasts of the United States, and in Germany, Hawaii, and the Philippines. The first shipboard terminal was tested aboard the USS PROVIDENCE, flagship of the First Fleet, in October 1966. As the year came to an end, terminals were being installed and checked out in Southeast Asia to support operations in that area. Development of a smaller, lighter ground terminal, transportable in a single aircraft, continued throughout 1966 with system testing beginning in November 1966.

The Operational Defense Satellite Communications System (DSCS)

During 1966 the DOD continued planning and preparation for acquiring a truly operational satellite communications system which will take full advantage of our experience with the SYNCOM and IDCSP circuits and of advances in communications, spacecraft and rocket technology. System definition studies were completed and implementing direction was prepared.

Tactical Satellite Communications (TacSatCom) Program

Operational advances in such areas as strategic and tactical weaponry, transportation, and combat surveillance -- both in our forces and those of potential enemies -- place a related demand on improving our means for commanding the operating forces, providing them promptly with adequate intelligence and controlling their weapon systems. Often, tactical combat forces are restrained from exploiting the full potential of their fire power and maneuver capabilities because of limitations on the means provided for command, control and communications. Recent Military Department studies have confirmed that important tactical communications requirements could be met by sensibly designed satellite communication equipments and networks. Also, rapid national progress in the development of economical space boosters and sophisticated spacecraft in recent years suggest that properly designed orbiting repeaters, used in concert with appropriate surface and near surface equipments, could go far toward meeting military tactical communication needs.

The program is directed toward meeting the needs of the highly mobile, lower echelon land, sea and air forces using very small, lightweight and relatively less costly tactical equipment in networks characterized by great flexibility and minimum control. During 1966, the Military Departments formed a Tri-Service Executive Steering Group (TSEG) to manage a joint research and development program with the following objectives: (a) to develop and test experimental space and surface satellite communications hardware, (b) to develop operational concepts for the confident military use in large scale communication networks, and (c) to demonstrate and test those concepts in an operational environment.

The Army has the primary responsibility for the development of the experimental ground equipments; the Navy, the seaborne terminals; and the Air Force, the airborne terminals. The Air Force also has the responsibility for developing and launching the spacecraft/repeaters which the Services agree will meet their needs. Joint development projects ensure that only a minimum number of surface equipment types will be developed. A joint test program will be devised and implemented.

Initial experiments are keyed to the launch of an Air Force-MIT UHF repeater by a developmental TITAN IIIC booster early in 1967. During 1966, the Military Departments developed, fabricated and installed suitable terminals in combat vehicles, ships and aircraft in line with the joint test program to be implemented during 1967. Contractual action was also initiated in 1966 for a second satellite, one specifically designed to meet the goals of this program, for launch in 1968 using a developmental TITAN IIIC booster. By then, suitably designed surface terminals will be installed in a sufficient number of tactical vehicles, operational aircraft and Navy combat surface ships and submarines to permit adequate technical and operational testing in simulated and real tactical environments. The development of an actual operational tactical satellite communication system will depend on the results of the 1967-1968 experimental program.

Experimental Communications Satellites

Two experimental satellites, designed and built by the MIT-Lincoln Laboratory under DOD sponsorship, were placed in orbit in December 1965 by a TITAN IIIC. These satellites, LES-3 and LES-4, were placed into a elliptical orbit rather than the planned circular, near-synchronous orbit; however, planned experiments were successfully conducted during 1966. LES-3 included a UHF transmitter and was used to make accurate measurements of UHF propagation phenomena. LES-4 operating at SHF, demonstrated the feasibility of using sensors to select, from a number of antennas, the one antenna pointing most directly toward earth so that the energy radiated by the satellites is directed to the earth. LES-4 also yielded valuable data on electron density throughout the orbital path. The Laboratory continued the design and fabrication of LES-5, a larger UHF satellite to be launched in 1967.

International Satellite Communications Discussions

During 1966 the DOD held a number of discussions with friendly nations to acquaint them with the DCSP; initial reaction indicates considerable interest in the potential of satellite communications for military purposes. A Memorandum of Understanding was concluded with the United Kingdom for their participation in the research and development phase of the IDCSP. Arrangements were also made for Canadian participation in IDCSP research and development.

The United States Ambassador to the North Atlantic Treaty Organization proposed a cooperative program to provide the NATO an early operational satellite communications capability.

Spaceborne Nuclear Detection (VELA)

Development of a satellite based nuclear detection capability for events occurring on the earth's surface to the outer reaches of deep space has been the design of the VELA Satellite Program. Originally a research and development program of the Advanced Research Projects Agency, it is conducted jointly by the USAF and AEC.

There are six VELA satellites presently in orbit. The satellites were launched in pairs in 1963, 1964 and 1965. All six are still providing valuable data on the radiation environment in space and on the operation of nuclear detection sensors in space. The VELA program is providing an interim monitoring capability for detecting nuclear explosions occurring in the region from the earth's surface to deep space. Future launches are planned to maintain the present system, in addition to continued research on advanced space detection techniques.

VELA satellites are launched from Cape Kennedy into near-circular orbits about 60,000 nautical miles from earth. The radiation background data has and is making valuable contributions in techniques of solar storm forecasting. The VELA program also provided a real-time radiation cover to the GEMINI manned space flights.

VELA satellites will continue to provide this important radiation detection service for future manned spacecraft flights.

Space Object Identification

The Air Force and Advanced Research Projects Agency are cooperating on a continuing research program to determine the best means by which the physical characteristics of uncooperating objects in earth orbit can be obtained through observations by ground-based radar. The advanced techniques will be of value in obtaining diagnostic information on our own satellites in orbit and will serve as a prime source of technology for improving the capabilities of the Space Surveillance and Detection Tracking System (SPADATS). Plans are being made for transfer of the ARPA research efforts in this area to Air Force management.

Geodetic Satellite

The Department of Defense continued its active participation in the National Geodetic Satellite Program during 1966. The NASA's EXPLORER XXIX satellite (GEOS A), launched November 6, 1965, is being observed on a world-wide basis by DOD as well as other participating Government agencies. EXPLORER XXIX carries an Army SECOR transponder, a NASA Range-Range Rate transponder and LASER reflector, an Air Force optical beacon, and a Navy Doppler beacon.

The NASA's PAGEOS A satellite launched in a 2000 nautical mile orbit in June 1966 is currently being observed by DOD and the Coast and Geodetic Survey for establishing a world-wide Geometric net of 43 stations. PAGEOS is a reflective 100' inflatable sphere observed simultaneously against a star background from at least two ground stations.

These projects will continue to provide more precise information about the earth's size, shape, mass and variations in gravity and precise determinations of locations for accurate mapping, charting, and geodesy.

The Army Corps of Engineers has extended a continuous geodetic network from Japan to Hawaii using the SECOR (Sequential Collation of Range) satellite system. Three SECOR satellites, VI, VII, and VIII, with a newly developed high altitude performance capability, were successfully orbited in 1966. Of the three, the SECOR transponder in VII is functioning favorably, and it is anticipated greater distances between stations will soon be possible. Operations will begin in the near future on a 30-station globe-circling network designed to link all major geodetic datums, provide a new determination of the earth's equatorial radius, and provide scale to the PAGEOS satellite triangulation network.

During 1966, the Navy determined from Doppler observations, the positions of 21 world-wide stations to an accuracy of $\pm$ 25 meters with respect to the earth's center of mass. Additionally, the Doppler data was used to determine the harmonic coefficients of the earth's gravitational potential. Coefficients through the eighth order have been published. The Doppler beacons in the Navy Navigation Satellites, NASA's Beacon B, Beacon C and GEOS A are being used for gathering the Doppler data.

In 1966, the Air Force completed two programs using the PC-1000 geodetic stellar cameras. Trinidad has been related geodetically to Cape Kennedy for the Eastern Test Range with an accuracy of 10 meters (1σ). In the U.S., the PC-1000 cameras were used to provide comparative data with the SECOR and Doppler systems. The three systems, in turn, were checked against the Coast and Geodetic Survey's super accurate base line. Favorable results were obtained. Currently, the Air Force is engaged in establishing eighteen stations world-wide for defining the GEOS orbits more precisely and to assist in verifying major datums of the world.

Navy Navigation Satellite System

The Navy Navigation Satellite System has been in operation since 1964. Receivers are installed in all Fleet Ballistic Missile submarines and all attack carriers deployed to Southeast Asia to up-date the ships' inertial navigators and to insert data into the inertial navigators of aircraft prior to launch from the carriers.

During 1966 the use of the Navigation Satellite System for up-dating an aircraft's inertial system was found feasible. Flight tests were performed using shipboard equipments with an existing inertial navigator and an interconnection system that was considerably less than optimum. Now that the feasibility of the technique has been shown, a receiver designed specifically for the aircraft application will be developed and tested to determine the potentials of its operational use in military aircraft.

Also during 1966 the accuracy of the system was improved by the use of more detailed and accurate knowledge of the earth's gravity field with a consequent improvement in predictability of a satellite's position. The system is also now being used by oceanographic and range instrumentation ships as a primary source of accurate, all-weather position data.

To give artillery units the capabilities of locating themselves accurately in relation to one another, a 50 lb. navigation satellite receiver suitable for carrying as a back-pack was developed. Accuracies equivalent to those obtained by surveying can be obtained by one satellite pass without the necessity for laborious, time-consuming and sometimes dangerous conventional 4th order survey techniques. Further development work will be done to make this receiver suitable to actual field conditions. Both the Marine Corps and Army plan to exploit the technique if it proves operationally feasible.

Meteorological Systems

The first NASA TIROS Operational System satellite with a direct readout capability was launched in 1966. Concurrently Navy attack carriers deploying to Southeast Asia were provided with equipment for utilizing this technique. Thereby, for the first time the task force commander or captain of a ship was able to determine in real time the actual cloud conditions in the Task Force area of operations with a single overhead pass of the satellite.

SPACE GROUND SUPPORT

DOD National Ranges

The realignment of the National Range complex continues as program support requires change. On the Eastern Test Range, the San Salvador Station was deactivated and both Advanced Range Instrumentation Ships were moved to the Pacific Ocean. On the Western Test Range, Vandenberg Air Force Base was expanded with the acquisition of Sudden Ranch. Several older launch complexes at Vandenberg AFB are being modified to accommodate the newer versions of THOR and TITAN space boosters.

Instrumentation improvements on the Department of Defense Ranges were limited by available funding. The major modifications now underway are directed at improving radar accuracies and converting the telemetry systems from the Very High Frequency (VHF) spectrum to the Ultra High Frequency (UHF) band. This latter is a directed action to relieve some of the congestion in the 200 to 400 megacycle spectrum. Instrumentation improvements for re-entry and terminal measurements have been initiated and must continue next year to meet the needs of ballistic missile systems which will be flying on the Eastern and Western Test Ranges.

The instrumentation system for the first APOLLO ship (the VANGUARD) has been completed and this ship is now undergoing engineering tests. The second of these five range ships (the REDSTONE) is nearing completion and will be delivered about February 1967 for testing and operational shake-down. The first two of eight APOLLO range instrumentation aircraft were delivered in November 1966.

Conversion of the Satellite Control Facility to the Ultra High Frequency spectrum passed a significant milestone on 13 October 1966 with the successful flight test of the Space Ground Link Subsystem. Two tracking stations were equipped with prototype hardware to support this and subsequent flight tests. Production is now underway to equip the entire network with this system which permits transmission of more than a million bits of data per second between space vehicles and ground terminals. A new UHF antenna is now being installed at the Hawaiian Tracking Station and work has been initiated to install a similar high gain antenna at the Guam Tracking Station.

TITAN III Facilities at WTR - MOL Launch Complex

Site preparation for the TITAN III launch facility at WTR was completed in August 1966. This work included land grading and installation of access roads and utilities. The next phase of facility construction, including items specifically associated with MOL, has been approved, and construction will commence in the early part of 1967.

Space Detection and Tracking System (SPADATS)

SPADATS operation is under the control of the North American Air Defense Command (NORAD). It consists of detection and tracking radar systems assigned to the Air Force (SPACETRACK) and the Navy (SPASUR). SPADATS is responsible for the detection and tracking of all foreign and friendly earth orbiting objects. Support of Service and NASA space programs such as GEMINI, APOLLO and the MANNED ORBITAL LABORATORY (MOL) is also a function of SPADATS. The SPADATS capabilities are constantly being evaluated for possible improvements in operation and for required equipment modifications and additions. Advances have been made in the capability to provide more precise predictions of satellite orbital positions and determine space object decay times and locations. Such improvements are enabling the U. S. to advance our knowledge of the earth's atmosphere, shape and of various extra terrestrial effects upon orbital flights.

AERONAUTICS DEVELOPMENT ACTIVITY

C-5A Heavy Logistics Transport Aircraft

The airframe/system integrating contractor began on schedule, in August, the manufacture of what will be the world's largest military cargo aircraft. Final assembly of the first aircraft will begin in November 1967. Roll-out is scheduled to occur in February 1968. First flight is planned in June 1968. Some major technological advances in design are: high by-pass ratio turbofan engines (TF-39) featuring very low specific fuel consumption; an in-flight electronic "trouble shooter" for flight safety and reduction in ground time; a straight-through loading feature, made possible by large cargo doors in both nose and tail, for fast ground turn-around time; and a landing gear with high flotation to permit the massive aircraft to tread softly over relatively unprepared fields and with a "kneeling" feature to facilitate cargo loading.

A B-52E will serve as the flight test bed for the TF-39 turbofan engines and was made available to the engine contractor in October. First flight with the test engine is planned in April 1967. The TF-39 engine is in the 41,000 pound thrust class and the installed dimensions (with cowling) will be 8.5 feet in diameter and 26.0 feet in length.

Working with the airframe/system integrating contractor is a team of subcontractors spread across the United States, who will produce 60 percent of the C-5A by aircraft weight.

The Air Force began designing some new facilities to support testing of the C-5A. In order to ensure sufficient cold air for accomplishing the cold weather tests of the high bypass engine, the Climatic Laboratory at Eglin AFB, Florida, will be modified to increase the amount of cold air so as to permit a cold soak period and engine run up at -65°F. At Edwards AFB, California, where the aircraft will undergo flight tests, a large hangar and engineering office is being designed. The large size of the C-5A requires a new hangar and modification to several other smaller facilities in order to support the test program.

F-111

The F-111 System Program was marked by satisfactory progress as well as a significant increase in program activity during the past year. By the end of the period, the F-111A flight envelope was extended to its maximum speed and altitude and a total of six separate versions of the F-111 aircraft were under development.

As of 4 October 1966, thirteen F-111A aircraft and four F-111B aircraft had been delivered to the flight test program. Contractor Category I testing was in progress at Fort Worth, Texas, Eglin AFB, Florida, and Peconic River, Long Island, New York Air Force Category II Testing was also initiated at Edwards AFB, California, during the year. Over 992 flights and 1,634 flight test hours were accumulated by the end of the reported period. Of these, 359 flights were supersonic and 95 flights were in excess of Mach 2.0.

To take full advantage of advancements in avionic system development since the F-111A was initially conceived, an improved avionics system package has been selected for production installation in the F-111A aircraft. This Mark II Avionics equipment is designed to provide increased reliability and increased air-to-ground and increased air-to-air weapon delivery capability through use of improved navigation and radar equipment.

Development of a RF-111A reconnaissance version of the F-111A was approved on 28 October 1965. The configuration of the RF-111A will be based on maximum commonality with the basic F-111A. Reconnaissance sensors will be located in the weapons bay on a removable pallet type structure. Photographic, radar, thermal, and electronic sensors will be carried.

Congressional approval was obtained and development of a Strategic Bomber version of the F-111 was initiated in February 1966. The FB-111 utilizes the basic F-111A design but has improved avionics and structural improvements for long range, high payload missions. The FB-111 will be capable of delivering nuclear weapons, short range attack missiles (SRAM) or conventional bombs over long ranges with great accuracy.

The F-111 Cooperative Logistics Arrangement between the U.S. and the U.K. dated 5 April 1965 was implemented by a sales order for 50 F-111 aircraft on 12 March 1966. The U.K. F-111 Program is being managed in the Air Force by the F-111 System Program Office (SPO) in the same manner as the Air Force F-111 Program. RAF personnel are assigned to the SPO to assist the System Program Director and provide the necessary technical management interface between the two countries. The U.K. F-111 configuration will have design features of both the F-111A and the FB-111 aircraft, and include British furnished equipment as well.

Royal Australian Air Force (RAAF) liaison activities relative to their order for F-111A aircraft continued to increase during the year.

Advanced Tactical Fighter

The Air Force is studying an advanced tactical fighter (FX) for introduction into the Tactical Air Command. The weapon system is to replace F-104 aircraft and the F-4. Based on the results of contractor studies and additional DOD examination, the Air Force will recommend acquisition of this new fighter. As presently envisioned, the Aircraft will have performance superior to the projected threat.

The Navy has indicated a requirement for a multi-mission carrier based fighter-attack aircraft (VFAX). The requirements of the Navy and Air Force for this new aircraft are in many respects similar, and the Services are studying the possibility of meeting their joint requirements with a common aircraft.

A-7 Light Attack Aircraft

The Navy A-7A is a turbo-fan powered, single place, visual attack aircraft. Replacing the A-4 light attack plane, the A-7A has a more versatile ordnance carrying capacity, an improved weapons delivery accuracy capability and an increase range. Design and engineering concepts have emphasized simplicity of systems to maximize reliability, maintainability and operability at minimum cost. The first operational A-7A's were delivered to Navy Fleet Training Squadron VA-174 at Cecil Field on 13 October 1966.

The program for the Air Force A-7D version of the Navy A-7A is progressing on schedule. The aircraft will be equipped with the Allison TF-41 engine which is under development and will be in production by early 1968.

XB-70

A total of two XB-70 aircraft were built. The first flight of the Number 1 airplane occurred on September 21, 1964, and the first flight of Number 2 occurred on July 17, 1965.

The Number 2 airplane was more sophisticated than the Number 1 airplane. It was equipped with more test instrumentation than was provided in the Number 1 airplane, and it contained some improved systems components.

Both airplanes were used in a Flight Test Program from the first flight of the first airplane until the Number 2 airplane was lost in an accident on June 8, 1966. Objectives of that program were to establish airworthiness of the airplanes, invesigate the design feasibility, determine handling qualities, and demonstrate Mach 3 flight for 30 minutes. Those objectives were met. A total of 186 hours were flown in the program.

The second phase of the XB-70 program consists of a joint AF/NASA program directed toward some 23 flight test objectives and 76 flights, top priority being on sonic boom test. The joint program was to have begun on 16 June 1966. The project was delayed, however, pending an investigation of the June 8 accident and modification to the remaining XB-70.

On 3 November the Number 1 aircraft resumed its flights. It is planned that 75 more flights will be made during an 18 month period in order to meet the flight test objectives. If all the flights are not made, however, it appears that a sufficient number can be made to meet a high percent of the test objectives.

COIN Aircraft

The first flight of a COIN OV-10A aircraft was on July 16, 1965. Engineering problems affecting aircraft performance have delayed some aspects of the development; however, the production delivery date for USAF and Marine Corps aircraft is not expected to slip more than a month or two.

The Navy conducted early evaluation testing of the OV-10A. The first phase of the Navy Preliminary Evaluation (NPE) program was completed on 21 March 1966. Several deficiencies were discovered and the Navy/Contractor team immediately initiated a vigorous "get well" effort. The corrective action was successful and a contract for 185 production aircraft (109 USAF and 70 USMC) was released on 15 October 1966. The most significant changes to the aircraft configuration included an increase in wing span and up-rating of the turboprop engines.

The OV-10A is a twin engine turboprop aircraft wish short takeoff and landing performance from unimproved fields, roads and aircraft carriers without using arresting gear. In addition to weapon delivery missions, the aircraft may be used for light logistic duty carrying five paratroopers or 3000 pounds of cargo. Variants of the OV-10 are presently under study for USAF strike reconnaissance and light transport missions.

This aircraft may replace USAF O-1's, T-28's, and A-1E's. Marines plan to use the OV-10A in the helicopter escort and reconnaissance role.

Helicopter

The Department of Defense is developing helicopters which will have significantly improved operating characteristics and effectiveness over those now in operation. This need has been accentuated by the Army's recently adopted airmobile concept which places almost complete reliance on helicopters for battlefield mobility.

Engineering development of the AH-56A (Advanced Aerial Fire Support System) was initiated by the Army. The design of this helicopter will integrate armament, avionics and fire control subsystems into a weapons platform capable of effectively employing various combinations of point and area fire weapons in support of ground combat operations. The Army has contracted for ten prototype AH-56A helicopters.

Pending availability of the optimized AH-56A, and in response to an urgent operational requirement for an interim improved armed helicopter in Vietnam, the Army is procuring the AH-1G (COBRA) helicopter. This helicopter is a streamlined version of the UH-1 helicopter. The AH-1G armament includes a flexible chin turret and wing-mounted pods which are capable of employing machine guns, rockets and grenade launchers. First flight of the Army AH-10 prototype was made on 15 October 1966. Flight test reports are highly favorable. Production deliveries of the AH-1G will begin in the spring of 1967.

During 1966 the Air Force used the HH-3E helicopter as its primary Combat Aircrew Recovery Vehicle. Reprogramming approval was obtained to procure eight air refuelable HH-53B's. These helicopters will provide a substantial improvement in hover ceiling and speed over the HH-3E now in use. To improve further its capability to recover downed airmen from enemy territory, the Air Force is conducting a continuing evaluation programof various VTOL and advanced helicopter designs that are capable of quick reaction and increased performance in hover and range.

V/STOL Development

The Army XV-5A (Fan-in-Wing) research program was completed in September 1966. The two test aircraft accumulated over 150 hours flying time in approximately 350 flights. One aircraft crashed on 21 April 1965 as a result of a control malfunction; the other completed the Army program and was undergoing a follow-on Navy and Air Force sea air rescue evaluation when it crashed during rescue simulation in October 1966 -- the cause not yet determined. Plans for developing a fan-in-wing aircraft are therefore indefinite.

During CY 66 the three Services successfully conducted individual operational evaluations of the XV-6A (P. 1127) aircraft to perform missions relatedto their specific areas of interest. The XB-6A diverted thrust aircraft completed the tripartite (US, UK, FRG) V/STOL operational concept evaluation in England during 1965. U.S. National Trials of the six research aircraft -- all built in England -- were conducted by the U.S. Army, Navy and Air Force from April through July 1966.

Major objectives of the overall program, involving 1,196 flights, were to evaluate flight operating procedures, transition techniques, V/STOL aircraft suitability to operating environments, logistic implications, and the various modes of take-off and landing. Additional follow-on flights and studies are being conducted by NASA and the Air Force. Two aircraft are on loan to NASA for technological studies and four assigned to the Air Force at Edwards Air Force Base. The Air Force will conduct unilateral tests to study further the flight characteristics and handling qualities of the XV-6A. The aircraft will also be used to check out additional pilots to build up experience in V/STOL aircraft for future development programs.

Members of the XC-142A Tri-Service Test Force at Edwards Air Force Base have operated this tilt-wing V/STOL transport aircraft from unprepared terrain (barren desert), semi-prepared surfaces (sod, gravel, sand, plastic membrane, metal pads) and normal runways. Take-offs and landings were accomplished in the STOL (Short Take-Off and Landing) and hover modes to ascertain operational suitability. On 18 May 1966 an XC-142A investigated initial aircraft carrier compatibility when 41 take-offs and landings were made on the USS BENNINGTON off the coast of California. Several methods of cargo air drop have also been demonstrated, the most demanding of which was the dropping of 4100 pound load while hovering ten feet above the ground. The rescue potential of the XC-142A was investigated and culminated in the hoisting of a man from a life raft into the XC-142A which was hovering 100 feet overhead. The Army is preparing an operational plan to conduct an evaluation of the XC-142A's ability to operate from an Army field environment. The operational evaluation is scheduled for April-August 1967. Configuration studies for a follow-on version of the C-142 tilt-wing turbo prop aircraft were completed in September by the USAF. A decision on the purchase of additional C-142's is pending.

The X-22 rotating ducted-propeller aircraft program suffered a serious setback in August 1966 when one of the two test aircraft experienced hydraulic systems failures and crashed at Buffalo, New York. While minor design changes in the hydraulic systems controlling ducted-propeller orientation will correct this particular problem on the remaining aircraft, the program is being re-evaluated to determine the re-adjustments necessary to complete this program.

Contract definition of the V/STOL Assault Transport (previously referred to as the CX-6) was deferred pending the results of several on-going studies which should determine the requirements for a transport of this size. The program originally envisioned an aircraft with a 17.5 ton payload to replace the C-130 in the mid 1970's. Design studies had configured the aircraft as a fan-in-wing type V/STOL vehicle.

X-15 Research Aircraft Program

The three X-15 aircraft are being used primarily as test beds to carry a series of experimental payloads in support of environmental studies, the development of improved components for future aerospace vehicles, and basic aerothermodynamic research.

The X-15's were designed to achieve speeds of up to Mach 6. Following an accident in November 1962, X-15 Number 2 was rebuilt and modified to achieve Mach 8. Development (primarily of ablative material) leading to expansion of the flight envelope from Mach 6 to Mach 8 is continuing.

Highest speed attained to date is Mach 6.1 and highest altitude 67 miles. These high speed and altitude capabilities, along with the high degree of reliability attained, make the X-15 ideally suited for its missions.

The USAF sponsored X-15 experiments are scheduled to be completed in December 1967. The experiments planned by the NASA in the CY 1968 - 73 time period include a scramjet engine, high temperature structures, and a delta wing.

SUPPORTING RESEARCH AND TECHNOLOGY

Over-the-Horizon Radar

The Department of Defense developed OTH radars, using the ionospheric reflection of radar energy technique, have demonstrated a capability to detect missiles and aircraft beyond the radar or line-of-sight horizon. Instead of being limited to detection ranges of several hundreds of miles, the OTH technique provide ranges of several thousands of miles. Laboratory and field evaluations are continuing with the objectives of improving our missile early warning capabilities and operational aircraft movement observations and for possible application to air traffic control operations.

Spacecraft Technology and Advanced Re-entry Tests (START)

The START program consists of four hardware oriented projects:

ASSET. (Aerothermoelastic Structural Systems Environmental Tests) consisted of six THOR boosted flights from the Eastern Test Range. The last of these radiatively cooled vehicles was flown in 1965.

PRIME. (Precision Recovery Including Maneuvering Entry) encompasses four flights of a small unmanned ablatively cooled lifting body from the Western Test Range. These vehicles, which can be maneuvered by means of aerodynamic controls, will test the speed range from hypersonic re-entry to approximately Mach 2.0 where they will be recovered by parachute.

PILOT. (PIloted LOw-speed Tests) will be flown at Edwards Air Force Base by a joint AF/NASA test force. This single piloted vehicle will be launched from B-52 aircraft to investigate the trisonic velocity spectrum from Mach 2.0 to horizontal landing.

RMS. (Re-usable Multipurpose Spacecraft) is in the early stages of study. In-house Air Force studies have been completed and follow-on contractor studies are underway. These studies will serve as a basis for vehicle selection and will insure a least cost approach to Air Force requirements.

The four PRIME flights will be flown in the period from December 1966 through June 1967. Flight testing of the PILOT vehicle will start in October 1967 and continue into 1970.

Space Power Equipment

The DOD continued to develop various concepts for meeting anticipated electrical power requirements of future satellites. The accomplishments of 1966 include further development of fuel cells for unmanned satellites and fabrication of a prototype window shade solar cell array.

The fuel cell is an electrochemical device which converts hydrogen and oxygen to useful electricity, heat and water. Present unmanned short life vehicles use primary batteries. Successful completion of this program will increase power and life over current missions, increase payload weight through power supply weight reduction and, in general, allow missions which are presently impossible.

Solar cells in conjunction with rechargeable batteries have been used to provide electricity in the majority of long duration space vehicles to date. Flexible solar cell arrays presently under development have great potential for weight and volume reduction combined with simple reliable deployment and retraction. The latter advancement will reduce vulnerability and increase maneuverability of space vehicles. Arrays are stored in a rolled up window shade configuration; arrays are deployed and retracted with the aid of extendable rods.

Rocket Propulsion Technology

The three Military Departments maintain exploratory and supporting research and technology programs in rocket and missile propulsion which are designed to provide the technological base for advanced rocket-propelled weapon systems for tactical, defensive, strategic, and space missions. The technical content of these programs is coordinated among the three Services and with NASA to give priority to the missions of greatest interest to each agency and to avoid redundant effort, except by design. These exploratory development programs initiate, evaluate, and selectively develop new propellants, novel propulsion concepts, and advanced componentry. They in turn generate advanced development programs which consolidate selected exploratory development advances and demonstrate them in the form of integrated prototype engines for specified missions.

Thus, the exploratory development program of the Air Force us currently supporting five advanced development programs. One of these is a modular storable high-pressure liquid engine of sufficiently improved performance to make possible a one-stage intercontinental ballistic missile. Another program is developing two competing concepts employing the hydrogen-oxygen propellant system for high-energy booster stages. This program which will demonstrate a 250,000 pound thrust modular engine for a variety of space applications is being closely coordinated with NASA by a Subpanel of the Aeronautics and Astronautics Coordinating Board on Advanced Cryogenic Rocket Engines. A newly started advanced development program will demonstrate a hydrogen-fluorine engine with deep throttling and multiple restart capabilities for satellite inspection and intercept missions requiring great versatility and the maximum in velocity increment. This engine demonstration will bring to fruition 20 years of exploratory development in the technology of hydrogen-fluorine rocket engines. In the tactical field, the Air Force is mounting an advanced development program in air-launched rocket propulsion. This program is designed to develop and demonstrate three desired attributes of air-to-air and air-to-ground propulsion system: great ruggedness and resistance to environmental extremes; command-controlled thrust magnitude variation for choice of trajectory and end-game maneuvering; and use of air-augmentation for extended range in volume-limited systems. Closely related to the air-augmentation programs is an advanced development effort in the area of supersonic combustion ramjet propulsion. This program is of interest in connection with the ultimate development of a composite scramjet rocket engine capable of operating efficiently at sea level, in the upper atmosphere and in space. It represents a potential propulsion system for reusable spacecraft and reusable launch vehicles.

The Army in cooperation with the Advanced Research Projects Agency is developing the technology of high-acceleration solid rockets for advanced missile interceptors, requiring extremely short reaction times and the ability to perform high-G and high-Q maneuvers. This has involved the development of high-burning rate propellants and novel means of achieving thrust vector control through external burning. The Army is also sponsoring the development of smokeless propellants for tactical field missiles.

The Navy is pursuing an advanced development program to realistically demonstrate the performance gains that can be realized by employing ram air to augment the thrust of solid rocket motors for both tactical and strategic weapon applications. This program will culminate in flight demonstrations of five prototype missiles, and these data will serve the thrust augmentation interests of all three Services. The Navy is also developing the technology of advanced throttleable prepackaged liquid rocket motors, which may operate interchangeably in a ramjet mode by command control.

Gravity Gradient Stabilization for Satellites

A two-axis gravity gradient stabilized satellite was placed in equatorial, near-synchronous orbit in June 1966 as a part of the first launch of the Defense Communications Satellite Program. While not entirely successful, this experiment did demonstrate that gravitational forces at an altitude of about 18,000 nautical miles are useful in stabilizing a satellite to point toward the earth.

Following several experimental gravity gradient satellites launched over the past few years the Navy utilizes 2-axis gravity gradient stabilization on all navigation satellites.

The Department of Defense Gravity Gradient Experiment (DODGE) will attempt to use simple extendable booms and magnetic damping techniques to stabilize a satellite in 3 axes at near-synchronous altitude.

In addition, a multi-purpose Gravity Gradient Experiment (DODGE-M) will be capable of carrying a number of technology experiments to synchronous altitude.

Despun Satellite Antenna (DATS)

An experimental electronically despun communications antenna was fabricated during 1966 and was undergoing tests at the end of the year prior to being launched on an experimental satellite early in 1967. The despun antenna will improve the efficiency of satellite communications repeaters by directing radiated energy toward the earth rather than dissipating a large portion of this energy into space, and by offering a larger absorption cross section for transmissions directed toward it from the earth.

Project HARP

The joint U. S. -Canada high altitude research program (Project HARP) continued to develop techniques for probing the upper atmosphere with gun-launched sensors. The preliminary research launcher is a modified, smoothbore, 16-inch gun with a 119-foot barrel, installed on Barbados in the West Indies. Fiberglass plastic rocket bodies have been successfully developed and tested. Rocket grains, rocket components and hardened telemetry components have withstood the 10,000 g acceleration associated with a gun launch. An improved powder ignition system has produced higher muzzle velocities.

During 1966 an extended 16-inch modified gun was installed at the Highwater Test Facility in Canada for horizontal test firings of rocket and guidance control systems. Another extended 16-inch gun has been installed at the Yuma Proving Grounds in Arizona to vertically fire recoverable rocket guidance components and to collect upper atmospheric wind information over this desert testing range.

During 1966 there were approximately 50 vertical firings with the 16-inch gun to gather upper air wind and electron density measurements and to test the engineering design. The vertical soundings, taken to a maximum height of 475,000 feet, revealed upper atmospheric winds in excess of 200 knots. The hourly measurements made showed very marked wind changes in speed and direction over short time intervals. This phenomena had hitherto been undetected.

Solar Radiation Monitoring Program

SOLRAD VIII was launched on a NASA Scout in November 1965 continuing a series of solar X-ray monitors begun by the Naval Research Laboratory in 1960. The observations during 1966 suggest that the coming solar maximum, 1968-69, will equal or exceed the level of activity reached at the previous maximum, 1957-58. Accumulated evidence indicates that an increase in background solar X-ray emission can be interpreted as a precursor of flare activity and the subsequent disruption of radio communications and may provide early warning of energetic particle fluxes hazardous to manned operations in space.

X-ray astronomy is the most rapidly developing category of space astronomy. It shows all the ingredients of a fundamental new discovery that has characterized radio astronomy for the past quarter century. Further observations are planned to reveal the energy production mechanisms of the most powerful cosmic sources.

Turbojet Engines

This area of research and development effort has made considerable progress during the year. Four new aircraft engines are in the initial stages of development.

C-5A Engine. This engine has entered the development stage. It is in the 41,000 lb. class and is scheduled for completion of qualification tests in September 1968.

Vertical Take-Off Aircraft Lift Engine. This engine is being developed as a joint U. S. /U. K. development program. Government to Government and contractor to contractor agreements have been signed. The development program started in mid 1966.

Vertical Take-Off Aircraft Lift-Cruise Engine. This advanced engine will have a vectoring device so that the thrust may be used for either lift or cruise. Three contractors are in competition for this program. A single contractor will be selected and system development will begin about July 1967.

Advanced Strategic Aircraft Engine. The Air Force presently is conducting a program to do the initial development of an engine which could be used for strategic aircraft in the future. This engine is unique in that it is designed to operate more efficiently over a wider range of speeds and altitudes than has been possible previously. The demonstration phase is planned to be completed in July 1967.

Instrument for Mass Measurement Under Weightless Conditions

During 1965, the Air Force undertook a development effort to devise a method for accurately making mass measurements in a weightless flight environment. The Aerospace Medical Division has produced such a device which is considered to be a major accomplishment in support of manned space flight.

The present configuration consists of a 6" x 8" x 9" package which weighs approximately 15 pounds. It has the capability to determine accurately the masses of items from 25 grams (0.1 pound) to 500 grams. By merely changing the platform, the same package can be used for items from one-half to 100 plus kilograms. The present accuracy ranges from .03 of 1% at lower masses to .01 of 1% at masses in excess of one pound. Using the principle of the linear spring/mass pendulum, the device is more accurate in the weightless environment as has been demonstrated in "zero-g" aircraft flight trajectories.

The necessity to measure weight changes during space flight and to be able to assess as a function of elapsed time the body fluid changes which occur have been considered as a major requirement of the U.S. space flight program by the Medical and Bio-Sciences community. The ability for accurate determination of input and output from astronauts in space flight in order to determine body fluid balance and body weight changes is now possible.

Airborne Warning and Control System

The Airborne Warning and Control System (AWACS) is being considered for overland operation in support of the Air Defense Command and Tactical Air Forces deployed world-wide. In December of last year three separate configuration studies were completed by different contractors and reviewed by the Air Force. The studies had been initiated to determine if an effective AWACS was within the state-of-the-art. Each of the three study contractors concluded that an effective AWACS could be built and delivered in the early 1970's. Also in December, and as a result of these studies, DDR&E directed the Air Force to proceed with the development of a prototype system (two aircraft for flight test) in a timely and orderly manner.

The Air Force has responded during the past year by organizing a system program office to manage the development, planning a sound development program and engaging a number of contractors to carry out the first phase of the program. This first phase, called concept formulation, will be completed by May of next year and will ensure, through studies and preliminary designs, that we continue development of a system that can be built and can do the job that we want it to do.

The study contracts let this year fall into three general groupings. First, there are four radar contractors making preliminary design studies of radars that will have the ability to detect and track aircraft against a background of ground returns. Second, two contractor teams are examining the command, control and communications problems entailed in providing communications, data processing and displays. Significantly, these studies are defining what must be done to make AWACS compatible with the other services and our allies. Finally, two aircraft system contractors are reviewing the above mentioned studies and other factors which affect the proposed aircraft. The result of the system studies will be a cost-effectiveness trade-off analysis which will be used to validate the concept formulation and to support the contract definition phase.

COOPERATION WITH OTHER GOVERNMENT AGENCIES

Coordination and cooperation with other governmental activities, particularly NASA, continues at a high level. These include very frequent informal discussions at all levels of the respective agencies, scheduled meetings of formal coordinating panels and boards, and direct support o NASA.

Aeronautics-Astronautics Coordinating Board

The Board held five meetings during CY 1966. Examples of its activities are: reusable launch vehicle studies, coordination of planning of new facilities, examination of advanced large liquid fuel engine, and use of navigation satellites.

Manned Space Flight Policy Committee

DOD and NASA, by agreement of January 1966, established a "Manned Space Flight Policy Committee" as a means of expediting coordination at a policy level the manned space flight programs of the two agencies. Three meetings of the Committee were held during 1966.

DOD Participation in the GEMINI Program

This program, consisting of fifteen separate experiments, has been directed towards enhancing the DOD manned space flight experience level by conducting and evaluating techniques and equipment on the NASA GEMINI missions.

During 1966, eleven DOD experiments were flown on four GEMINI missions. The early termination of the GEMINI 8 mission and Extra Vehicular Activity (EVA) curtailment due to some astronaut and operational difficulties on GEMINI missions 9, 10 and 11 precluded totally successful completion of all DOD experiments. However, rescheduling some of the early experiments that were not conducted to later missions permitted a substantial accomplishment of experiment objectives.

With the successful completion of the D-15 Night Image Intensification Experiment on GEMINI XI, the Navy concluded its series of experiments in the GEMINI program. The Navy's experiments included D-15, D-14 UHF/VHF Polarization Measurement and D-15 Astronaut Visibility; all experiments were successfully accomplished.

DOD Support of NASA

There are over 400 separately identifiable activities of DOD support of NASA, representing in magnitude a total value of effort over $500 million per year. Among the major items of support are the operation of the ranges for manned and unmanned spacecraft launches and host base support by the Air Force, major construction by the Army and operation of the recovery fleet by the Navy. In addition, there are many other activities of lesser magnitude. Selected examples are cited below:

Army

Construction Support. The Corps of Engineers supported NASA by providing real estate acquisition services, and design and construction of facilities at various locations, including the John F. Kennedy Space Center, Mississippi Test Facility, the Manned Spacecraft Center and the Electronics Research Center. The magnitude of this support exceeded $80 million.

Lunar Activities. The Army Map Service assisted NASA by developing lunar mapping techniques and lunar control networks. Maps are being produced at several scales using various source data, including RANGER, SURVEYOR and LUNAR ORBITER photographs.

The Corps of Engineers and the Army Materiel Command made a study of the feasibility of modifying an Army vehicle for use in exploration missions on the surface of the moon. The Army Materiel Command is conducting mobility tests on two versions of prototype lunar vehicles, designated as Mobility Test Articles. The Corps of Engineers is assisting NASA in evaluating engineering models of lunar drills.

Supporting Technology. The Army Materiel Command, through its laboratories and field commands, carried out a variety of research and development projects for NASA. These included: (1) Development of freeze-dried foods for space use and design of clothing for extended space missions -- Natick Laboratories; (2) Investigation of spacecraft contamination and sterilization -- Fort Dietrick; (3) R&D of post-operational destruction system for NERVA engine -- Picatinny Arsenal; (4) Development of safety and ignition device for spacecraft apogee motor and development of fluid logic techniques -- Harry Diamond Laboratories.

Navy

GEMINI. Operation of the recovery fleet for GEMINI flights. About 14 ships are involved in each operation. In addition to the ships, the Navy flew aircraft in excess of 1000 hours.

Medical Projects. Tests of vestibular function have been conducted in conjunction with GEMINI V and VII flights and similar test program is planned for APOLLO AS-204 and AS-205.

Construction Projects. Work performed for NASA under this category covers facilities design and construction together with inspection and contract administration. Types of facilities that have been constructed run from fabrication of facilities for space vehicles, and space tracking and data acquisition facilities to foundations for antenna structures and associated site and utility work.

Air Force

Range Support. The National Range Division provides support o NASA for manned and unmanned programs. This support included range support services, base support, and range ship support.

Launch Vehicles. The Medium Launch Vehicles Program Office has provided an average of approximately: (1) one booster delivery per month to the combined NASA AGENA and NASA DELTA programs over the past four years; and has provided launch services management of between two and three boosters per year for NASA AGENA.

The GEMINI Target Vehicle Program Office acts as the NASA contractor for six AGENA Target Vehicles used in the GEMINI rendezvous and docking experiments. This includes procurement of the basic AGENA D vehicle; development, test and procurement of the program peculiar equipment necessary to convert the AGENA D to a GEMINI Target Vehicle; development and procurement of Aerospace Ground Equipment; procurement of the ATLAS (SLV-3) boosters; and launch of both vehicles.

The SLV-3 Directorate is responsible for the management of the SLV-3 vehicle program. This responsibility includes technical direction, configuration magement, procurement and production of SLV-3 vehicles and supporting Aerospace ground equipment. For example, LUNAR ORBITER, from its inception as a requirement to its recent launch required 24 months of management, 6 months contractual lead-time and 18 months production time, during which close surveillance was required to insure its successful launch.

APOLLO Services Provided for Manned Spacecraft Center

a. LEM Ascent Engine Environmental Development. Thirty-eight firings were made in the period 14 January - 10 February 1966 to evaluate the effects of altitude and thermal environment on engine performance and structure and to investigate altitude start transients.

b. LEM Descent Engine Environmental Test. Objective was to conduct long duration mission duty cycle tests at simulated altitude of about 350,000 feet.

c. Service Module Propulsion Test. A continuing test program to establish the operating characteristics of the engine and determine whether it meets performance specifications in a simulated space environment.

d. Command Module. Von Karman Gas Dynamics Facility. Testing on models of the Command Module was accomplished to investigate flow interference problems encountered in previous tests.

e. Miscellaneous. Meteoroid impact test conducted by the Marshall Space Flight Center at Von Karman Gas Dynamics Facility Impact Ranges. This is a continuing test program to determine effects of hypervelocity projectile impacts into lined and unlined pressure vessels containing air or oxygen at various pressures.

Aerospace Rescue and Recovery prepositioned operating and support personnel to world-wide locations to support GEMINI 8 through 12 to recover astronauts and spacecraft and to recover the APOLLO SATURN 201 unmanned suborbital spacecraft near Ascension Island.

T-2 testing which evaluated the SURVEYOR lunar soft-landing vehicle was accomplished. This testing required over three years to complete.

ATOMIC ENERGY COMMISSION

CHAPTER V

INTRODUCTION

In the Atomic Energy Commission's space nuclear power program, 1966 was the year in which the joint NASA/AEC nuclear-rocket program progressed from a graphite reactor engine system technology program into a combined technology and engine system development program, and the space electric power program moved from the developmental to the applications stage. During the year, additional experimental data was accumulated on the high-performance capabilities of nuclear-rocket systems. Nuclear-rocket reactors were started, stopped, and restarted without difficulty and operated over a wide range of conditions. The nation's first nuclear-rocket engine was successfully tested in a "breadboard" configuration (flight-type components in a nonflight arrangement). Work also proceeded on the next phase of the engine system technology program -- to build and test ground experimental rocket engines which are more closely configured to a flight engine than the "breadboard" engine tested early this year.

The development of nuclear energy systems to provide the source of electrical energy in long-life space applications also progressed during 1966. A reactor-powered electric generating system completed one full year of continuous operation on the ground in a vacuum tank, and a growing list of requirements has developed for radioisotope electric generating systems.

NUCLEAR ROCKET PROPULSION

In the program to develop nuclear rocket propulsion systems, an altitude specific impulse of more than 750 seconds was experimentally demonstrated (assuming a nozzle area ratio of 40 to 1) for approximately 30 minutes at design power (1,100 megawatts) in each of two reactors. In addition, the ability to restart these systems, run them back to full power, and throttle them at full specific impulse was demonstrated. Laboratory experiments further indicated higher specific impulses of 850-900 seconds were potentially attainable. Laboratory experiments also indicated that extended operating duration was also attainable. The work done indicates that nuclear rockets will permit large gains in payload for the variety of space missions now being considered.

NERVA Reactors and Engine Systems

Significant advancements were made during 1966 in the development of the NERVA (Nuclear Engine for Rocket Vehicle Application) graphite engine reactor system capable of operating at full power of 1,100 thermal megawatts for approximately 60 minutes. These advancements were demonstrated in tests of the nation's first nuclear-rocket engine, a "breadboard" engine called NRX/EST (NERVA Reactor Experimental Engine System Test), and in tests of the NRX-A5 reactor.

The NRX/EST consisted of a flight-type reactor (the NRX-A4) mounted on a test car in an upside-down firing position and connected for the first time to an engine turbopump located on the test car, the turbine of which was driven by hot hydrogen bled from the reactor exhaust through a port in the nozzle wall (a hot-bleed port). The main differences between this system and that of an actual flight engine system were that the pump was not in its flight engine location (it was located on the test car), the engine fired upward rather than downward, and the exhaust gases discharged into the atmosphere rather than into an altitude simulation (vacuum) duct. The engine operating information obtained from tests of such a system, however, was indicative of and applicable to the design of a flight engine. The NRX/EST was subjected to five days of testing over a period of seven weeks and accumulated a total of 110 minutes of power operation, including about 29 minutes at full power. Analyses of test data are as yet incomplete, but it has been established that the hot-bleed nuclear-rocket engine system is stable over a wide range of operating conditions, and is capable of withstanding multiple starts, stops, and restarts, and of being controlled by several means. Only one of the engine components, a valve actuator, caused difficulty in the test program, and it was replaced early in the test series with an improved model which functioned well for the remainder of the test program.

On June 8, the NRX-A5 reactor was successfully test operated at full power for 15.5 minutes. On June 23 the same reactor was restarted without difficulty and run for an additional 14.5 minutes to gain a further understanding of its operation and life.

In addition to the NRX/EST and NRX-A5 tests, work also continued throughout the year on developing those components and facilities required to assemble and test ground-based experimental engines (XE's) -- the next phase of the engine system technology program. The XE's will resemble actual flight engines and will be the first systems to be tested in a down-firing position, at conditions partially simulating operation in space. The first XE is scheduled to begin power testing in 1967 to provide further data on engine startup, system interactions, and various control modes. This test program will also provide important needed data on the operation of the complex engine-test facility system.

PHOEBUS Reactors

The principal activity during 1966 in the PHOEBUS reactor program -- the designation given to the program to advance the KIWI/NERVA graphite reactor technology toward higher power and temperatures -- was the preparation for and conduct of the PHOEBUS-1B power reactor test program. The PHOEBUS-1 reactors are the same size as the KIWI/NERVA reactors and incorporate a variety of experiments to explore some of the operating characteristics and design features planned for the larger-diameter, higher-powered (5,000 thermal megawatts) PHOEBUS-2.

The development and fabrication of improved fuel elements, high-temperature materials, large hardware, and complex facilities which will allow testing of the PHOEBUS-2 reactor also continued throughout 1966.

The nuclear-rocket propulsion program has, to date, proven the feasibility of nuclear rockets and their high-performance capabilities. In addition, the program is well on the way toward establishing the technology base on which it will be possible to design and develop the specific flight hardware required for future missions.

SPACE ELECTRIC POWER

Space Radioisotope Power Systems

To supplement present technical management of the rapidly expanding space radioisotope power systems programs, the AEC in February 1966 selected its Sandia Laboratory and Albuquerque Operations Office, Albuquerque, N. Mex., to support the Space Nuclear Systems Division in the conduct of these programs.

The first fueling of a SNAP-11 thermoelectric generator with curium-242 was accomplished in July 1966 at the Oak Ridge National Laboratory in Tennessee. In October 1966, this fueled unit successfully completed a 90-day test under simulated lunar conditions. Electrically-heated SNAP-11 generators were delivered to NASA's Manned Spacecraft Center, Houston, Tex. and the Jet Propulsion Laboratory, Pasadena, Calif. late in the year. Testing of these generators will complete the planned SNAP-11 work.

Two prototype SNAP-19 generators, designed to provide approximately 50 watts of electrical power to the experiments on board the NIMBUS-B weather satellite while 200 watts electrical will be provided by the satellite's large solar cell paddles, were thermally tested on board a NIMBUS-B mockup in June 1966. An electrically heated system was delivered to NASA's spacecraft integration contractor in July 1966 for electrical compatibility testing with the spacecraft. Late in 1966 two prototype radioisotope-fueled generators were tested to flight system qualification levels.

The final design was completed, and hardware procurement and manufacturing initiated, for the 50 watt electrical SNAP-27 radioisotope thermoelectric generator. This plutonium-fueled generator, which is to be placed on the moon by an astronaut during an early APOLLO mission, will provide power for up to one year for experimental packages left there by the astronauts. Models of the complete SNAP-27 system -- including the generator, fuel capsule, and lunar excursion module shipping cask -- were delivered to NASA in January 1966 for system compatibility studies. The first electrically-heated engineering generators were placed on test in October 1966. In November 1966, delivery was made of the thermal test generator system mockups, and in December 1966 a prototype electrically-heated system was delivered to NASA's Manned Spacecraft Center for system compatibility testing with the APOLLO Lunar Surface Experiments Packages hardware.

The detailed design and subcomponents development phase of the SNAP-29 program was initiated in 1966. SNAP-29 is to be designed for fueling with polonium-210 and is to provide nominal power of 500 watts electrical for 150 days with a total system weight of about 500 pounds suitable for both manned and unmanned space applications.

Parallel six-month studies were also initiated in 1966 by three industrial contractors to determine the feasibility of designing radioisotope thermoelectric generators -- fueled with either plutonium-238 or, possibly, strontium-90 -- which would be capable of controlled re-entry into the earth's atmosphere from orbit in an intact condition. These studies will be used as the basis for possible follow-on work should the Department of Defense or NASA require long-lived radioisotope-powered generators for satellite operation in the few hundred watt power range.

Space Reactor Power Systems

SNAP-10A Ground Tests. A SNAP-10A flight-type system -- identical to the 500-watt SNAP-10A system which operated successfully in space for 43 days in 1965 before a faulty command within the spacecraft shut it down -- completed a record-making 10,000 hours (about 417 days) of continuous operation on the ground in a vacuum tank, simulating the space environment, and was then shut down. The unit has been disassembled and is now being examined to determine its status after operation.

SNAP-8. Funds to continue the development of the SNAP-8 reactor power conversion system (PCS) were re-instated, and the PCS has been assembled and is undergoing extended testing at NASA. The experimental version of the SNAP-8 reactor -- designated the SNAP-8 Experimental Reactor -- which was ground-tested for a total of 8,300 hours at thermal powers of 400 to 600 kilowatts before being shut down, was disassembled and found to have cladding cracks in most of the fuel elements. This problem, which is attributed to the combined effect of fuel swelling and fuel-clad embrittlement, is being evaluated and will be corrected before the fuel elements for the next reactor in the SNAP-8 series -- the SNAP-8 Developmental Reactor -- are fabricated.

SPACE-DIRECTED ADVANCED TECHNOLOGY DEVELOPMENT

Advanced Space Reactor Concepts

In order to meet future space power needs for very long-lived systems having electrical outputs in the hundreds and thousands of kilowatts, the AEC continues to support three basic advanced reactor concepts: (a) the liquid metal-cooled reactor, (b) the in-core thermionic reactor, and (c) the high-temperature advanced gas-cooled reactor. Further work on a fourth concept, the Medium Power Reactor Experiment (MPRE), was eliminated in 1966.

Major attention during the year on the liquid metal-cooled reactor concept was given to defining the reactor requirements, and by the end of the year the experimental portion of this program was evolving from exploratory materials research into a technology effort supporting the reference reactor designs.

Activities conducted on the thermionic reactor concept during 1966 consisted primarily of the in-pile (in-reactor) testing of fueled thermionic diodes to determine their capability of operating at temperatures above 3,000^{o}F. In view of the encouraging results obtained from these in-pile tests, the scope of the thermionic effort is being broadened to investigate overall reactor problems such as stability, control, and reliability.

Emphasis in 1966 in the development of high-temperature gas-cooled reactor technology was placed on dynamically testing full-size fuel elements at temperatures up to 3,000^{o}F, in-pile fuel testing, and on refining the reactor design. Because of reassessment of space program priorities, the development program is being reoriented from one which would involve the testing of a reactor core to one which will be limited for the time being to the development of fuel element technology.

Further work on the boiling potassium reactor (the MPRE) was eliminated during 1966 in order that effort and resources might be concentrated on the other three advanced reactor concepts.

Space Power Conversion Technology

To supplement prototype radioisotopic generator developments and studies, the AEC is supporting several industrial contractor organizations that are conducting programs to provide higher temperature, more efficient and/or lighter weight thermoelectric systems, and to demonstrate the capabilities of radioisotope-fueled thermionic power systems, to meet long-term requirements for future space applications. Among these programs are the Compact Thermoelectric Module Development program which looks toward the development of a compact space thermoelectric power converter of modular form which would use either radioisotopes or reactors as the heat source to produce one to 20 electrical kilowatts; the ISOTEC program which employs thermal radiation coupling between an isotope heat source and its surrounding flat-plate thermoelectric panels; and the Direct Radiating Thermoelectric program which has the purpose of upgrading the thermoelectric technology used in SNAP-10A so that higher efficiencies can be achieved with the SNAP-8 space reactor or with radioisotopes. Each of these programs progressed during 1966 through tests of thermoelectric elements in their operating environment. In addition, the design phase of a 100 watt thermionic module for use with radioisotope heat sources was initiated in 1966.

SPACE NUCLEAR SAFETY ACTIVITIES

On January 11, 1966 a modified SNAP-10A type reactor was deliberately destroyed in order to improve the predictive capability to determine the consequences that would follow an accidental excursion of a SNAP reactor system.

Additionally, safety studies were conducted on radioisotope fuel capsule impact and burial phenomena, system responses to propellant fires and explosions, re-entry phenomena, atmospheric dispersion of particles, and terrestrial contamination problems associated with radioisotope fuels.

SATELLITE-BASED DETECTION OF NUCLEAR EXPLOSIVES IN SPACE

The six AEC-instrumented VELA nuclear test detection satellites developed for the Department of Defense continued to perform their test ban monitoring functions in 1966. In addition, they relayed back to earth much new scientific information on the solar wind and its interaction with the earth's magnetosphere, including the earth's magnetospheric tail which is dragged out to distances of many earth radii on the dark side of the earth by the action of the solar wind. The six satellites were placed in orbit two at a time using ATLAS-AGENA booster systems, with the launches taking place in October 1963, July 1964, and July 1965. They are in widely space positions on a near circular orbit with coverage radius of about 60,000 nautical miles.

A fourth launch of two VELAs is planned for early 1967 and two more satellites are scheduled for a 1968 launch. The future launches will use a TITAN III-C booster system, and will place in orbit a new generation of twin spacecraft with increased nuclear test detection capabilities. The new satellites will have one axis earth oriented at all times, and will include new instrumentation for observing the optical and electromagnetic radiations from nuclear weapons tested in the atmosphere, in addition to improved versions of neutron, gamma-ray and X-ray detection systems for space surveillance.

DEPARTMENT OF STATE

CHAPTER VI

INTRODUCTION

The President's decision to seek increased cooperation with other technically advanced nations in advanced space exploration projects was greeted in Europe with great interest. United States embassies in Europe carefully briefed their host governments on the President's offer of cooperation. In February a NASA/Department of State team visited the major European capitals and space science centers to discuss the offer in detail. Senior officials also made a visit to Europe in September for additional discussions. This initiative toward increased cooperation in space exploration has stimulated interest in bilateral and multilateral cooperative projects and in the role of space programs in solving the problems of the technological gap.

A review of policy on the export of space technology has enabled the Department to inform European governments of U.S. willingness to increase its assistance to multinational development of a space launch capability.

The United Nations took several important decisions relating to outer space. The most significant was the agreement reached on the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies." The President has called this treaty "the most important arms control development since the limited test ban treaty of 1963." The treaty forbids the placing of weapons of mass destruction in outer space or on celestial bodies, restricts military activities on celestial bodies, bars claims of sovereignty and national appropriation, and contributes in a number of other ways to the establishment of a legal regime in outer space.

The General Assembly also approved recommendations of the Outer Space Committee for a United Nations conference on outer space to be held in Vienna in September 1967. The conference will focus on two basic subjects: practical benefits of space programs, with special reference to the needs of developing countries, and opportunities available for international cooperation in space programs. The U.N. Assembly also endorsed recommendations resulting from the work of the Scientific and Technical Subcommittee including one to establish a working group to consider the development of an international navigation-services satellite system.

The Department was pleased to forward through its science attaches and scientific affairs officers at missions overseas SURVEYOR I and LUNAR ORBITER I photographs for appraisal by foreign scientists. Our ambassadors were also provided with selected copies for presentation purposes.

The Department stimulated interest of foreign governments in the Automatic Picture Transmission (APT) system for receiving cloud-cover photographs from U.S.

weather satellites by having U.S. missions present information on the benefits and low cost of the system. The appreciation shown for the APT system has been encouraging. A number of countries have made up for their lack of funds to purchase commercial equipment by the ingenuity shown in building APT receiving sets from locally available materials.

The Department has continued to support the national space program by negotiating station agreements, assisting in contingency arrangements for astronaut recovery, and obtaining foreign cooperation and support for various aspects of the program. It has also taken an active part in encouraging broad participation in the development of a commercial global satellite communications system.

ACTIVITIES WITHIN THE UNITED NATIONS

A Working Group of the Committee on the Peaceful Uses of Outer Space met in New York January 18-25, and again September 6-9, to consider a proposal for a United Nations conference on Outer Space. It recommended a conference focused on two basic subjects: practical benefits of space programs, with special reference to the needs of developing countries, and opportunities available for international cooperation in space programs. A detailed agenda covering all aspects of these subjects was developed. The Working Group also recommended that the conference, which will not be empowered to make recommendations or decisions, be held in Vienna in September 1967.

The Scientific and Technical Subcommittee of the Outer Space Committee met April 18-27 at the European U.N. Headquarters in Geneva. The Subcommittee agreed on a number of recommendations, of which the most significant were:

a. five guidelines for evaluating requests for international support of training programs in the specialized field of space science.

b. a Space-Committee Working Group to consider the need, feasibility, and implementation of a navigation-services satellite system.

c. means to improve the usefulness and distribution of U.N. publications in the field of outer space.

The Space Committee's Legal Subcommittee met twice in 1966 -- July 12-August 4 and September 12-16 -- and its members conducted nearly continuous informal negotiations. On December 8, they announced agreement on a "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies." Work had begun shortly after May 7, when the President suggested a number of elements for such a treaty and asked the U.S. Ambassador to the United Nations to seek early discussions in the United Nations.

The Treaty forbids the placing of weapons of mass destruction in outer space or on celestial bodies -- thus incorporating the "no-bombs-in-orbit" U.N. resolution of 1963 -- and placed restrictions on military activities on the moon and other celestial bodies. To allow verification, open access to all areas on celestial bodies is guaranteed. The Treaty also contains a number of principles designed to establish a legal regime in outer space. Among the most important are the following:

a. freedom of exploration and use of outer space and celestial bodies for all States on a basis of equality.

b. activities in outer space and on celestial bodies are subject to international law, including the United Nations Charter.

c. claims of sovereignty and national appropriation are barred.

d. an unconditional obligation exists to help and to return astronauts promptly and safely if they land elsewhere than planned, and to exchange information relating to astronaut safety.

e. activities in outer space and other celestial bodies are to be reported to the Secretary-General of the United Nations to the greatest extent feasible and practicable.

f. provision is made for the avoidance of harmful contamination and for international consultation in connection with potentially harmful space experiments.

g. a launching state shall be internationally liable for damages caused by its space vehicles.

The Outer Space Committee endorsed the recommendations of the Scientific and Technical Subcommittee with little debate and noted the partial report of the Legal Subcommittee. The U. S. Ambassador to the United Nations drew attention to the broad opportunities for international cooperation available in our national space program.

On December 19, the U.N. General Assembly adopted by acclamation a resolution endorsing the draft treaty and asking the Outer Space Committee to begin study of related legal topics. The Assembly also adopted two other resolutions: one endorsed the recommendations of the Scientific and Technical Subcommittee; the other approved the holding of the U.N. space conference in 1967. All three of the Space Committee's major lines of action in 1966 thus culminated in General Assembly endorsement and approval.

TRACKING NETWORKS

NASA Facilities

Government-to-Government agreements by exchange of notes are in existence with the following countries covering the foreign portion of NASA's global tracking network: Australia, Canada, Chile, Ecuador, Malagasy Republic, Mexico, Nigeria, Peru, South Africa, Spain, and the United Kingdom. These facilities consist of stations supporting the manned space flight program, a tracking and telemetry network for scientific satellites, and deep-space antennae at four locations around the world. These are in addition to the U.S. Air Force's Eastern Test Range facilities which are also used by NASA.

During the past year the United States, through its embassies abroad, negotiated extensions and modifications of its agreements with Spain and the United Kingdom in preparation both for Project APOLLO and for new or expanding scientific satellite programs. After a NASA review of its tracking requirements determined that the facilities in Nigeria would no longer be required, negotiations were begun to close the station in Kano.

Cooperation with ESRO

Negotiations were completed with the European Space Research Organization (ESRO) November 28, on the agreement providing for establishment and operation of an ESRO satellite telemetry and command station near Fairbanks, Alaska. The station, which forms part of a network which ESRO is building to support its scientific satellites, will be the first foreign space-tracking station on U.S. soil. The station will be manned primarily by U.S. contractor personnel but will also have a complement of ESRO technical personnel. The station whould be in operation by the end of 1966 and be available for the launchings of two ESRO satellites which are scheduled for 1967 under the terms of a cooperative agreement between ESRO and NASA.

CONTINGENCY RECOVERY OF ASTRONAUTS

The Department of State and its overseas posts maintained a state of alert throughout each of the manned GEMINI flights. A GEMINI Task Force was briefed and prepared to support DOD and NASA in case of an emergency recovery requiring such support. Similar arrangements will be made for APOLLO flights. The principal purpose of the Task Force is to enable the Department, on a moment's notice in event of a premature landing or other emergency, to call upon the appropriate posts abroad to arrange through the respective host governments for such assistance as is indicated by the nature of the emergency. Another important task is to assist in the maintenance of clear communications channels between the spacecraft and ground stations by alerting posts whenever interference on GEMINI or APOLLO frequencies is reported in any part of the world. When necessary, posts can be instructed to request through their host governments the silencing of potentially harmful interference. To date there has been no instance of radio interference harmful to a GEMINI mission, thanks to excellent cooperation of governments in all areas of the world.

Similarly, each principal Foreign Service post between 32 degrees north and 32 degrees south latitudes has an officer whose duty it is to keep abreast of space flight planning for every manned mission as it evolves.

Prior to each manned spaceflight mission the Department through embassies abroad facilitates the positioning of Air Force SAR (Search and Rescue) Units at strategic locations around the globe. To the maximum extent possible overflight clearances are obtained in advance from countries through which SAR Units might have to fly in event of emergency.

ASTRONAUT TRAVEL ABROAD

Now that the U.S. has passed through the early, critical stages of its manned space flight program, the President has decided to make use of our astronauts from time to time to carry abroad the message of the peaceful character of the U.S. space program. The success of the astronaut visits to France and the Near East and Africa in 1965 was repeated in 1966 in visits to the Far East and Latin America.

WEST GERMAN CHANCELLOR VISITS CAPE KENNEDY

On September 22, the Chancellor of the Federal Republic of Germany visited Cape Kennedy as a guest of the President and toured NASA facilities there. The remarks which the President made to the group gathered in the Vehicle Assembly Building to greet the Chancellor included a statement of U.S. willingness to join with the countries of Europe in space efforts of mutual benefit. The offer included provision of launch vehicles and other types of assistance, as appropriate.

ASSISTANCE TO ELDO

In the interest of encouraging multilateral cooperation in the building of launch vehicles for non-military space purposes, as opposed to national programs which might be militarily oriented, the U.S. reviewed its policy on the export of booster technology. A decision was reached to encourage the continued existence and work of the European Launcher Development Organization (ELDO) by offering technical advice and assistance in the proposed reconfiguration of the ELDO-A launch vehicle and long-range assistance in development of follow-up ELDO projects using high-energy, cryogenic upper stages. In addition, the U.S. offered to supplement ELDO-A launch services by sale of certain U.S. launch vehicles or launch services for scientific or applications satellite projects. In addition to promoting expanded cooperation without enhancing foreign ballistic missile capability this initiative to ELDO provides another approach toward reducing the technological gap.

COOPERATION WITH DEPARTMENT OF DEFENSE

The Department of State continued to work closely with the Department of Defense during 1966 on international aspects of the Initial Defense Communications Satellite Program (IDCSP) and the Manned Orbiting Laboratory (MOL) Project.

COMMUNICATIONS VIA SATELLITE

The International Telecommunications Satellite Consortium (INTELSAT) continued development of a commercial global communications system. INTELSAT-I (EARLY BIRD) continued to operate successfully with 79 of its voice channels leased on a full-time basis. The launch of the first of the second-generation INTELSAT-II satellites took place on October 23, 1966. The vehicle failed to achieve synchronous orbit on its planned position over the Pacific. The investigation of the cause of the failure, caused a delay in the succeeding INTELSAT-II launches. One INTELSAT-II satellite is planned to be positioned over the Atlantic and one over the Pacific in 1967. Construction was authorized for six INTELSAT-III satellites which are designed to provide approximately 1200 voice circuits over a five year operating life.

Six countries joined INTELSAT in 1966 bringing the total membership to 54. The Department of State and the Communications Satellite Corporation maintained a vigorous program of encouraging other countries to join the consortium. All member countries have signed the Supplementary Agreement on Arbitration to the Special Agreement on Technical and Financial Arrangements thus placing the

Agreement in force.

As a contribution to the International Telecommunication Union (ITU) technical assistance program the U.S. sponsored a Seminar on Communication Satellite Earth Station Technology held in Washington in May. Forty-five countries and six international organizations were represented at the Seminar, which was designed to acquaint officials of interested countries with the fundamentals, current developments, and technical details of communication satellite earth stations. Edited copies of pertinent technical materials presented at the Seminar have been distributed to participating countries and to the ITU.

The U.S. actively participated in meetings of the technical organs of the ITU, the International Radio Consultative Committee (CCIR) and the International Telegraph and Telephone Consultative Committee (CCITT) and contributed to their growing interest in space activities. Both of these organizations have shown an increased awareness of the technical problems in utilizing a radio spectrum shared by space and terrestrial radio services.

The Second Session of the Extraordinary Administrative Radio Conference for the Aeronautical Mobile Service adopted a resolution proposed by the United States which asked member countries to consider space radio communication techniques as a means of filling the communication needs on the major world air routes.

At a meeting of the Communications/Operations Division of the International Civil Aviation Organization (ICAO) the U.S. proposed ICAO endorsement of a plan to test a VHF aeronautical voice communications satellite system in the North Atlantic. This proposal was supported by other members of the Organization.

NATIONAL SCIENCE FOUNDATION

CHAPTER VII

INTRODUCTION

This year as in the past, the contributions made by the National Science Foundation to the Nation's space effort consisted for the most part of support given to basic research projects at colleges, universities, national programs, and national research centers throughout the country. Facilities such as radio telescopes and scientific balloon capabilities are also provided by NSF for scientific research that is related to outer space.

National Radio Astronomy Observatory (West Virginia; Virginia)

During the past year major computer facilities and staff headquarters have been established in Charlottesville, Va., to serve the National Radio Astronomy Observatory at Green Bank, W. Va. The 140-foot precision radio telescope was in very active use during the entire year. Areas of research pursued included measurements of the OH spectrum lines in various regions, lunar occultations of extragalactic sources, and hydrogen line observations. The instrument was heavily scheduled by both visitors and members of the staff.

Modifications and improvements in the 300-foot radio telescope have been carried out during this year and it is now a better and more rigid structure. The interferometer using the two 85-foot telescopes has operated very successfully and has also been heavily scheduled.

Instrumentation has been under construction for implementing an extremely wide-base line interferometer using the 140-foot antenna at Green Bank and the 1000-foot reflector at Arecibo in Puerto Rico. The 36-foot radio telescope designed to operate at millimeter wavelengths has been completed and installed at its site at the Kitt Peak National Observatory in Arizona.

The Kitt Peak National Observatory (Arizona)

A second 36-inch reflecting telescope was put into service late in the year. Modifications to the first 36-inch during the summer included a new mirror and tube with provision for a wider angle of view and rapid exchange of the secondary mirrors. These two "workhouse telescopes" will come closer to fulfilling the demand by U.S. astronomers for observing time at the National Observatory. A wide variety of research programs ranged from visual measurement of double stars and photoelectric photometry of stars to spectra of various types of stars, nebulae, galaxies, and of quasi-stellar objects (using image tubes).

New auxiliary equipment on the great McMath solar telescope permits recording the magnetic field of the sun in great detail. Many spectographic researches were carried out during the year.

Cerro Tololo Inter-American Observatory (Chile)

A second 16-inch reflecting telescope was put in operation and both instruments used by U. S. and South American astronomers in several photometric research programs by staff and visitors. The loan of a 24-inch aperture Schmidt telescope by the University of Michigan has added a third telescope expected to come into operation at the same time as the 36-inch and 60-inch reflectors shortly after the year ends. The large field of view of the Schmidt telescope complements the other instruments and they present a powerful battery for exploration of the lesser known southern skies from this superb astronomical site.

The E. O. Hulburt Center for Space Research at the Naval Research Laboratory (Washington, D. C.)

The NSF continued the support of several university staff members, who proposed astronomical research programs using rockets and satellites, to work with the fine staff and facilities of the Center.

National Center for Atmospheric Research (Colorado)

The research programs of the National Center for Atmospheric Research are centered in the High Altitude Observatory and the Laboratory of Atmospheric Sciences. The High Altitude Observatory program is concerned with the sun, the solar atmosphere, and the region between the sun and the earth.

Accomplishments during FY 1966 include:

a. analysis of the combined results of three sets of solar measurements made by: (1) a NASA aircraft over the Pacific during the eclipse of May 30, 1965; (2) the HAO balloon-borne Coronascope II on flights made June 3 and July 1, 1965; and (3) the HAO K-coronameter in daily observations in Hawaii. This analysis has enabled HAO to define the shape of a coronal streamer from the sun and to determine the velocity and distribution of electrons in the streamer. Thus, it is now possible to determine the distance from the sun to which the solar magnetic field governs streamer shape and the point at which the electrons break free of the sun's magnetic field.

b. a survey of the magnetic fields in 50 solar prominences, using the new magnetograph at Climax, Colo. As a result, the range of fields that can occur in prominences has been determined, as well as the manner in which the geometry of the field relates to the geometry of the prominence.

c. detailed analysis of the earth's magnetic field variations which showed that ionospheric currents change in phase with the solar cycle. However, the currents were larger than could be accounted for solely on the basis of increased solar activity as reflected in increased conductivity of the ionosphere. The hypothesis that solar activity also affects the winds of the ionosphere is being subjected to continuing investigation.

At the Laboratory of Atmospheric Sciences, studies on radio emission by droplets colliding in an electric field have led to a quantitative estimate of the radio emission spectrum under a given set of conditions in a cloud. This work has implications for the use of radio techniques for studying terrestrial cloud processes and may inspire a new examination of the microwave emission from cloud-covered Venus.

Project Polariscope

This is a new field of research dealing with the composition and structure of the atmosphere of celestial bodies which made notable advances in FY 1966. A study is being made of the brightness and polarization of light from stars and planets with telescopes on the ground near Tucson, Ariz., and with telescopes carried on high-altitude balloons ("Project Polariscope"). Changes in the brightness, in the color, and in the polarization occur upon reflection or scattering by particles and molecules in space or in planetary atmospheres. Most of the scattering phenomena increase in importance in the far ultraviolet.

Preparations for observations from balloon gondolas and, later, from space probes and satellites required the solution of difficult technical problems such as in far-ultraviolet polarimetry made to unusually high precision, in the operation of high-voltage photo-multipliers and power supplies in a vacuum at low temperatures and in the development of a telescope platform stabilized to within a minute of arc. On December 3, 1965 a small polarimeter obtained the first far-ultraviolet measurements from above the ozone layers in the earth's atmosphere. Launched from Phoenix, Ariz., it obtained measurements on the earth's atmosphere and on the surface of the moon from an altitude of 34 kilometers. On May 27, 1966 from 35 kilometers, a 28-inch telescope obtained precise measurements in the far ultraviolet wavelengths (2200 and 2820 angstroms) on the earth and the moon and on interstellar particles by observations of a star.

International Years of the Quiet Sun (IQSY)

The IQSY, which covered the period from January 1964 to December 1965, was an international program for cooperative observations of the sun and its effects upon the earth during the low activity period of the solar storm cycle. It supplemented the observations made during the International Geophysical Year (IGY) from July 1957 to December 1958 -- a period of high activity in the sun's 11-year cycle.

Since the conclusion of the observational period of IQSY on December 31, 1965, efforts have been devoted to reducing and analyzing the large amount of data collected around the world by individual investigators and made available to all through the World Data Centers. From these studies should come new insights into solar processes and their relationship to the solar and terrestrial atmospheres, and into the interaction between these two atmospheres.

Solar Eclipse in South America, November 12, 1966

The United States solar eclipse expeditions to South America, coordinated by the National Science Foundation, included approximately 40 different American agencies, spending some $10 million transporting 300 scientists and a half-million pounds of equipment (valued at $8 million) to eclipse sites.

In an eclipse, the diameter of the moon just covers the diameter of the sun -- an accident of size and distance that permits scientists to observe solar features otherwise masked by the brilliance of the sun and by the brightness of the sky. The November 12, 1966 eclipse began at sunrise west of the Galapagos Islands, continued in a southeasterly direction across Peru, Bolivia, Argentina, and Brazil, moved across the South Atlantic Ocean and ended at sunset off the coast of Africa. The path of totality was never more than 55 miles wide and the duration of totality at its maximum was about two minutes.

Observations by the U.S. scientific team were made from land-based sites located along the solar eclipse path from the coast of Peru to the extreme southeastern corner of Brazil. In addition, five jet aircraft were used to race along with the moving shadow as it moved across the South Atlantic Ocean. This enables airborne scientists to conduct their experiments for about three minutes, compared to the less than two minutes available to the ground-based researchers. Rocket programs, aimed at investigating the changes in the earth's ionosphere and stratosphere brought about by the eclipse, and balloon-borne instruments, used to monitor ozone concentration and its change with solar illumination, provided U.S. scientists with valuable additional data.

The American studies were part of an overall plan to develop a "history" of a complete solar cycle and the effects of solar events on the earth's atmosphere. Teams of scientists from Argentina, Bolivia, Brazil, France, Italy, Japan, The Netherlands, Peru, and other countries also observed the eclipse complementing the extensive U.S. observations. Thus, from the standpoint of scientific data collection, the great variety and number of observations and experiments made this one of the most completely observed solar eclipses on record.

U.S. Antarctic Research Program

The U.S. space effort has several ties with Antarctica: Data on the ionosphere and magnetosphere obtainable only in the high latitudes owing to the configuration of the earth's magnetic field, result from investigations using a 21-mile-long antenna, satellite readout stations, and cosmic rays apparatus. Satellites are also monitored for the space programs of several agencies to help determine the shape of the geoid, refine orbital paths, acquire gravity data, and establish geodetic ties.

Antarctic environmental factors provide useful parallels to those hypothesized for extraterrestrial bodies. The National Aeronautics and Space Administration, with the cooperation of Foundation grantees performing research in the ice-free areas, tests hardware and techniques being developed for space exploration, such as life-detecting samplers and lunar drills. Logistical aspects of the conduct of a research program in a remote and hostile environment have led to a close study of the U.S. programs in Antarctica by several NASA groups.

DEPARTMENT OF COMMERCE

CHAPTER VIII

INTRODUCTION

A significant number of the activities of the Department of Commerce contribute to the Nation's space program. The major organizational components which contribute directly are three science and technology bureaus, the National Bureau of Standards, the Environmental Science Services Administration, and the Office of State Technical Services. The fourth science and technology bureau, the United States Patent Office, contributes indirectly through the issuance of patents on inventions with space applications. In addition, the Department has the benefit of the Commerce Technical Advisory Board, which consists of 18 non-Government leaders in science, education, industrial research, business, and labor.

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

The Environmental Science Services Administration is engaged in fulfilling the Department's responsibility to describe, understand, and predict the state of the atmosphere, the oceans, the space environment, and the size and shape of the earth.

HIGHLIGHTS OF 1966

With the successful launches of the Environmental Survey Satellites, ESSA 1 and 2 in February, the Administration established the world's first operational weather satellite system. These satellites with ESSA 3, launched on October 2, 1966, provide regular and reliable daily weather observations of the entire globe for central analysis, and local area photographs for more than 180 ground stations scattered around the world.

ESSA assumed control of a meteorological space system on March 15, 1966, when its National Environmental Satellite Center took over the operation of the ESSA 2 satellite. The National Environmental Satellite Center assumed control of ESSA 1 and TIROS IX on June 21.

The Institute for Telecommunication Sciences and Aeronomy designed a solar proton counter which will be flown on the TIROS M satellite late in 1968 and on subsequent operational ESSA satellites. This instrument will provide data to detect and forecast solar disturbances which can affect the operation of manned and unmanned satellites and supersonic aircraft flying at high altitudes.

The quick response of the Weather Bureau's Space Operations Support Division in providing a forecast for an alternate splashdown area for the GEMINI 8 flight, enabled smooth recovery operations when this manned flight had to be terminated early because of an emergency situation. ESSA satellite data contributed significantly to preparation of this emergency forecast.

In September 1966, after a delay of more than two years, an exchange of weather satellite data took place over the Washington-Moscow data link. This link was established in 1963 pursuant to a bilateral agreement between the United States and the USSR for the exchange of satellite data. The Soviet Union was finally in a position to furnish satellite photographs, analyses, and infrared data acquired from their COSMOS 122 experimental satellite which was launched on June 25, 1966.

The Coast and Geodetic Survey and the Institute for Earth Sciences effected a direct geodetic connection between North America and Europe by geometric satellite triangulation. This connection is the first step toward the establishment of a common world geodetic reference datum.

Meteorological Satellites

The daily, worldwide coverage capability desired for the weather system was made possible by redesigning the TIROS satellite so that its cameras look out of the side of the spacecraft instead of its base, and by orienting the satellite in its orbit so the spacecraft rolls along in its orbit like a wheel. As the satellite rolls along its path, each camera looks directly down at the earth once during each revolution of the spacecraft, so the cameras can photograph the earth from any part of the orbit.

The special configuration of spacecraft and orbit necessary to establish the TOS system was tested successfully in 1965 with the TIROS IX satellite, launched by the National Aeronautics and Space Administration on January 22. Photographs from this satellite were used to provide worldwide analyses of clouds for daily operational use.

ESSA 1 and 2

The Environmental Survey Satellite, ESSA 1, was launched February 3, 1966 from the Cape Kennedy launch facility. The launch was carried out for ESSA by the National Aeronautics and Space Administration. This satellite, although identical in configuration to TIROS IX, became the first operational satellite of the TOS system. The pictures taken by ESSA 1 were stored on tape recorders aboard the satellite for later transmission to ESSA Command and Data Acquisition (CDA) stations at Gilmore Creek (near Fairbanks), Alaska, and Wallops Station, Virginia. The signals from ESSA 1 were transmitted via high speed data links from the CDA stations to the National Environmental Satellite Center at Suitland, Maryland. The signals were then reconstituted into pictures. Latitude-longitude grids and coastal outlines generated by a high speed computer were electronically merged with the pictures processed in NESC. This procedure resulted in a marked decrease in handling and analysis time.

During the time ESSA 1 was fully operational, an experiment in computer rectification of cloud pictures was carried out. The area between 30°N and 30°S from 30°W to 150°W was digitized and the picture elements spread out onto a Mercator map of the area. The computer put the digitized map on a magnetic tape which was then fed into a converter, and the cloud mosaic was transmitted via facsimile to the Tropical Analysis Center at Miami. These maps were sent during the three-week period ending July 25, the date on which one of the cameras on ESSA 1 failed.

The loss of one of the two cameras of ESSA 1 reduced its capability for global coverage by about forty percent. The cloud photography needed between July 25 and October 2, the day ESSA 3 was launched, was obtained by using the combined capabilities of ESSA 1, 2, TIROS IX, and NIMBUS II. While this patchwork operation was relatively successful, complete global coverage was not obtained. In addition, the difficulties inherent in using data from these different systems resulted in a large increase in the time needed for the preparation of analyses, and hence, delays in dissemination of the data.

ESSA 2 was launched for ESSA by the NASA on February 28, 1966. Some 35 foreign nations had installed the special equipment needed to receive pictures directly from this satellite. ESSA 2 is equipped with Automatic Picture Transmission (APT) cameras that take pictures of the area beneath the satellite and telecommunications equipment to broadcast the pictures to simply equipped ground stations within a 2000 mile range of the satellite. To date the ESSA 2 satellite has been operating reliably. The response to the direct transmission of these satellite pictures has been unqualified enthusiasm. Since the start of ESSA 2 operations, new stations have been established by both foreign and domestic interests at a rate of about seven stations per month, for a current total of over 180 stations in 45 countries.

ESSA 3

The ESSA 3 satellite was launched October 2, 1966 into its near-polar orbit at an average altitude of 774 nautical miles. The satellite orbits the earth once every 114.5 minutes. It takes and stores 12 photographs on each pass across the daylight side of the earth. The picture signals are telemetered to the ground and are processed as were the ESSA 1 photographs.

ESSA 3 is equipped with two Advanced Vidicon Camera System (AVCS) units, each capable of maintaining global cloud cover surveillance without use of the other camera. The second camera is held in reserve in the event the first camera fails. This configuration is designed to double the useful lifetime of the satellite. The area covered by each picture is 4 million square miles. This area coverage reduces the number of pictures required for global coverage from the 450 per day taken by ESSA 1 to 144 per day. The decrease in total number of pictures has the effect of decreasing the amount of time needed for processing and analyzing the data. In addition, the number of television lines per picture has been increased from 460 lines to 830 lines, which results in a corresponding increase in the information contained in the photographs.

TIROS VII-X

Each of the last four satellites of the TIROS series has one camera usable. TIROS VII and VIII have been in orbit for three and one-half and three years respectively. TIROS IX and X have been in orbit for 23 months and 18 months. While none of these satellites is used routinely, specific camera capability is used occasionally to obtain photographs for special purposes. During the period between July 25 and October 3, when only one camera of ESSA 1 was operational, TIROS IX and occasionally TIROS VII and X were used to complete the coverage necessary for operational purposes.

NIMBUS II

NASA's NIMBUS II satellite, launched May 15, 1966, carried an experimental Medium Resolution Infrared Radiometer (MRIR) system which provided data of great interest to research meteorologists. The data from this system were provided in the form of pictorial representations of the radiation flux from five separate spectral regions. The data contained information related to the horizontal distribution of water vapor and carbon dioxide over the earth, measurements of surface and cloud top temperatures, outgoing terrestrial radiation, and the earth's albedo, or reflectivity. The data on water vapor distribution are particularly useful in studies of hurricanes, and other large scale weather systems. The other sensors on NIMBUS II were television cameras for both stored and direct readout, and a High Resolution Infrared Radiometer (HRIR) system. Pictorial representations from the HRIR system were used in place of picture data during the time between the failure of one camera on ESSA 2 and the launch of ESSA 3. The cameras for stored pictures failed on September 1, the HRIR system failed November 15, and the MRIR system failed July 28. the APT System remained in operation through the end of the year.

Advanced Technology Satellite - ATS I

NASA ATS I, launched December 6, 1966, carried two experiments in which ESSA participated: The Spin-Scan Cloud Camera which takes pictures of the entire Pacific Ocean area from Australia to the West Coast of the United States between 50°N and 50°S, and the WEFAX experiment which uses a satellite to relay weather data and cloud charts from central points of the United States to APT stations within range of the ATS satellite. Both experiments are working well.

Centralization of Satellite Operations

Operational control of the operational weather satellites is now maintained by the National Environmental Satellite Center of ESSA. The TIROS Operations Center (TOC) of the NESC assumes control of ESSA satellites after the NASA has launched and completed inflight engineering checkout of the satellites. The TOC went into operation on March 15, 1966, when the NASA passed control of ESSA 2 to this Center.

The TOC prepares and sends commands for operation of the satellites to the Command and Data Acquisition stations at Gilmore Creek (near Fairbanks), Alaska, and Wallops Station, Virginia, where contact is made with the satellites and command signals are telemetered to the spacecraft. The Center monitors the engineering operation of the system.

Digitized Cloud Mosaics

Digitized cloud mosaics of the Tropical Atlantic, Caribbean, Gulf of Mexico and the eastern Pacific were transmitted experimentally via facsimile from NESC at Suitland, Md., to the Weather Bureau's Tropical Analysis Center at Miami during the early part of July. This successful experiment was discontinued when the number 2 camera system of ESSA 1 failed on July 25, and resumed in October following the launch of ESSA 3.

The digitized cloud mosaics are prepared by means of a high speed digital computer program. In this process, the signals comprising the cloud pictures are assigned numerical values to indicate the relative brightness of each element. These numerical values are then assigned positions on a standard map projection, and a magnetic tape is prepared. This magnetic tape is then used as the input signal to transmit the mapped data over a standard facsimile data channel to weather stations. This computer processing results in a product containing at least 100 percent more information than the manually prepared nephanalyses (cloud maps) now in regular use. Current plans are to use computer prepared digitized cloud maps to replace manually prepared nephanalyses within the coming year.

Research and Development Programs of the National Environmental Satellite Center

The Office of Research of NESC is charged with conducting investigations (1) to extract from satellite data the maximum possible amount of weather and environmental information, and (2) to devise new or improved ways to obtain from satellite platforms environmental information which will contribute toward improvement of the various services provided by ESSA. The Meteorological Satellite Laboratory and the Satellite Experiment Laboratory of NESC's Office of Research carry out analytical studies, research investigations, and experimental programs to achieve these goals.

During 1966 work continued on the interpretation and analysis of cloud pictures and infrared data received from the satellites. These data are used in studies of atmospheric motion, the heat balance of the atmosphere, and the structure and development of storms. The results of these investigations are resulting in an increased understanding of the atmosphere, and improved methods for weather analysis and forecasting. More than 60 individual investigations are under way. Among these are several of particular interest:

a. the flight model of the Satellite Infrared Spectrometer (SIRS), an instrument designed to measure the vertical temperature structure of the atmosphere from satellite altitude, was completed during 1966. This instrument will be tested on NIMBUS B scheduled for launch in 1967.

b. a method developed and tested in 1964 and 1965 for estimating maximum wind speeds in hurricanes using satellite photographs as the sole source of data was used operationally throughout 1966 with excellent results. In 1966 research was started on the development of a method for using high resolution infrared data, such as that from NIMBUS II, to estimate hurricane intensities and stages of development.

c. methods for improving numerical weather prediction models by the use of satellite data will be advanced by the results of studies started in 1966. This research is concerned with determining the dynamics and thermal properties of cloud systems seen in satellite photographs and infrared data.

d. studies of cloud photographs obtained during the GEMINI flights have shown that areas which have had rainfall within the past 24 hours can be identified in the satellite pictures. The areas where rain has fallen recently show as dark streaks, particularly over desert or drought areas. A re-examination of photographs from the weather satellites showed that rainfall areas also can be seen in these lower resolution photographs.

e. the successful test aboard GEMINI 5 of a special spectrograph designed to measure cloud heights from satellites has led to the design of a Cloud-top Altitude Radiometer (CAR) which will be developed and ready for testing on NIMBUS D in 1969.

f. Public Law 480 counterpart funds are being used to continue support for a joint research project of the Hebrew University of Jerusalem and the Israel Meteorological Service. An interesting result of one of their studies is that the location of the jet stream over North Africa and the Middle East can be detected by the presence of cirrus cloudiness in the satellite pictures. The daily position and strength of this important weather feature could only be crudely estimated prior to the availability of weather satellite photography.

Washington-Moscow Data Exchange

On August 18, 1966 the Hydrometeorological Service of the U.S.S.R. started transmitting to Washington nephanalyses (cloud maps) based on data from the COSMOS 122 satellite over the Washington-Moscow data link. This line was established in 1963 pursuant to a bilateral agreement between the United States and the U.S.S.R. for the exchange of meteorological data from satellites. On September 6 the United States reciprocated by sending analyses and cloud pictures from the ESSA 1 satellite over the line.

The U.S.S.R. sent its first pictures from COSMOS 122 on September 11. In addition to cloud photographs, the Soviets have sent pictorial representations of infrared data observed over the night side of the earth. Although the United States operational weather satellites do not have this capability, two infrared systems tested on the NIMBUS II satellite has furnished infrared information. By the end of September receipt of pictures over the line from Moscow became sporadic for about ten days, after which transmissions resumed at the usual rate until October 20, when it became sporadic again. The last transmissions from COSMOS were received by the U. S. National Environmental Satellite Center on October 26, 1966, and COSMOS has been presumed inoperative since then.

International Cooperation

Prior to the launch of ESSA 2 on February 28, the United States furnished to all interested nations detailed information on the ground equipment needed to receive pictures from the Automatic Picture Transmission (APT) system of this satellite. At the time of launch, approximately 35 nations were prepared to receive the pictures; by the end of 1966, over 150 ground stations in 45 countries were in operation and reporting receipt of the pictures.

Early in 1966 a manual, the "APT Users Guide" was prepared and distributed internationally. This manual contains instructions for tracking the satellite, and for receiving and geographically gridding the pictures. The manual also includes a comprehensive section on the interpretation of cloud pictures from weather satellites.

To further aid the world meteorological community in the use of satellite data, meteorologists of the National Environmental Satellite Center wrote a technical note on "The Use of Satellite Pictures in Weather Analysis and Forecasting," which was published by the World Meteorological Organization of the United Nations.

At the request of the World Meteorological Organization, personnel of ESSA's National Environmental Satellite Center prepared material and provided instruction for a workshop on satellite data interpretation at the European regional meeting of WMO held in Moscow during October 1966.

During 1966 the National Environmental Satellite Center also provided study facilities for WMO and AID Fellows from Argentina, Hungary, India, Japan, Pakistan, and Poland for periods ranging from three months to one year. The NESC also was visited by scientists from Afghanistan, Australia, Cameroun, China, England, Germany, Hong Kong, Japan, Korea, Laos, Sweden, and Saudi Arabia for one to five days of general briefings and short study periods.

COAST AND GEODETIC SURVEY OPERATIONS

The Coast and Geodetic Survey is engaged directly in the space program, using satellites to support its work in geodesy and nivigation, and indirectly through its seismic and geomagnetic support to space facilities and activities. The aeronautics and space activities of the Coast and Geodetic Survey during 1966 were partly in support of NASA space operations, and partly in support of the C&GS primary missions.

Navigational Satellites

The Coast and Geodetic Survey furnished a report to NASA evaluating the Navy Satellite Navigation System. It was concluded that the system is the best available operational system for navigational control of oceanographic survey work.

The Navy Satellite Navigation System is currently being used operationally aboard the Coast and Geodetic Survey Ship OCEANOGRAPHER. The system has been successfully used to control gravimetric, magnetic, and bathymetric surveys in the North Pacific.

Geometric Triangulation by Satellite

Extensive theoretical studies were performed by the Coast and Geodetic Survey and the Institute for Earth Sciences in the field of geometric satellite trangulation as part of the continuing effort to improve and refine data acquisition and reduction methods. Full advantage was taken of advanced electronic computing and data handling technology for reducing, in a statistically significant manner, increasingly large amounts of raw data using mathematical models which account for the higher order effects of certain physical parameters. The goal of these studies is to obtain worldwide geodetic reference data with accuracies approaching one part in a million.

Efforts in the satellite triangulation program are concentrated on establishing a common world geodetic reference datum, providing connections to the independent triangulation datums within a continent, and improving the internal consistency of geodetic control within a datum.

Cooperative agreements between the United States and Canada, the Departments of Defense and Commerce, and between the United States and Denmark (Greenland), Iceland, Norway and the United Kingdom have made possible an extension of a densification network of satellite triangulation thus effecting a direct connection between the North American and European continents. This network was based on observations of the ECHO I and II satellites.

Cooperative agreements between the Department of Defense, National Aeronautics and Space Administration, and the Department of Commerce concerning the worldwide geodetic satellite program resulted in the launch of PAGEOS in June 1966, and the establishing of eight Coast and Geodetic Survey and four Army Map Service camera parties on 12 of the 42 stations comprising the worldwide network. These 12 stations are presently concentrated in the northern portion of the worldwide network.

The results have proven the superiority of geometric satellite triangulation over classic or other geodetic triangulation methods. The approach developed for geometric satellite triangulation provides both accuracy and economy. Its economic advantages are not limited solely to the acquisition of new information, but are also related to the usefulness of classic geodetic data collected during the past decades. These data can now be re-evaluated in light of the more accurate frame obtained by satellite triangulation. Thus, the considerable expenditures for field operations in the past can be fully exploited in the future.

In connection with NASA's Earth Resources Survey and Lunar and Planetary Programs, the significance of geodetic-cartographic subprograms has been receiving increased recognition. In pursuit of these problems and in close cooperation with various NASA organizations and the cartographic activity of the U. S. Geological Survey, sensor and system oriented studies have been performed to match present space technology with problem requirements.

Progress has been made in the use of precision airborne photogrammetric techniques for geometric control purposes. The capabilities of precision aerial photogrammetry have been enhanced to such an extent that the method could, for economic reasons, and in certain instances, be considered as a substitute for classic geodetic procedures.

Operations of the Institute for Telecommunications Sciences and Aeronomy

This Institute is using space techniques for basic research on the properties of the very high atmosphere, and the effect of solar activity on communications and manned and unmanned space exploration. Techniques are being developed for monitoring and forecasting upper atmosphere and space disturbances. The activities of the Institute are described in the next four sections.

Space Environment Monitoring and Forecasting Activities

In July 1966, a Space Disturbance Forecast Center located at ESSA's Institute for Telecommunication Sciences and Aeronomy in Boulder, Colo. went into a 24-hour per day operation on a trial basis. Implementing recommendations of the Interdepartmental Committee for Atmospheric Sciences (ICAS), this Center is being developed to meet the common national needs for space environment monitoring and forecasting services. Emphasis is being placed on the early development of several key monitoring systems, including a worldwide solar flare patrol and a ground-based solar proton detection system. Also, improved techniques for space disturbance forecasting are under study. During 1966, a growing number of space environmental services were provided to NASA in support of various unmanned scientific space activities as well as to the manned spaceflight program.

The needs for satellite monitoring of the space environment for the early detection and forecasting of space disturbances have been clarified and defined. Short range plans include an instrument for monitoring solar proton flux, which will be included on the TIROS-M and subsequent improved TOS satellites of the operational environmental satellite system. This instrument will measure protons in the energy range from about 1 to 100 Mev. Solar X-ray and ultraviolet sensors are also under consideration for inclusion in these spacecraft.

Exospheric Electron Content

For studies of exospheric electron content, beacon transmitters were launched on the NASA Orbiting Geophysical Observatory satellites, OGO 1 and OGO 3. The transmitter on OGO 1, which was launched September 4, 1964, is still returning data which are being recorded and analyzed at Boulder, Colo. Owing to failure of the orientation system, the attitude of this spacecraft is unfavorable for optimum transmission, hence the data are of relatively poor quality.

The OGO 3 was launched June 7, 1966. After launch, the radio beacon was found to cause interference in the command receiver and was subsequently shut down to avoid blocking the other experiments on board. Recently, an alternative method for overcoming the effect of the interference has been used successfully. Hence, it is possible that the radio beacon experiment may be turned on at least for selected periods in the future.

Ionospheric Satellites

The Institute for Telecommunication Sciences and Aeronomy continues its participation in the ISIS (International Satellites for Ionospheric Studies) program, studying data received from the Topside Sounder satellites ALOUETTE I, ALOUETTE II, and EXPLORER XX.

The topside sounders have demonstrated the existence of ionospheric irregularities which extend continuously along magnetic field lines. These irregularities can guide high frequency radio waves for great distances. Examples have been found where the guided radio waves have bounced back and forth several times between the northern and southern hemispheres. These irregularities, called conjugate ducts, were first discovered with ALOUETTE I and have been studied in detail with EXPLORER XX; their size, distribution, latitudinal and diurnal occurrence pattern, and other features have been partially determined.

The topside sounders have proven especially useful at high latitudes where the horizontal variations in electron density are too small to be resolved by any reasonable network of ground-based radar sounders. The study of the occurrence of plasma resonance observed by EXPLORER XX has led to a much better understanding of this phenomenon and has led to its use in studying the ionospheric structure. For example, detailed determinations of electron density along the satellite orbit have been obtained from the resonances and related phenomena. Through studies of these curves, latitudinal variations in gradients of electron density were discovered in the polar regions. An understanding of the resonance phenomenon also has led to the development of a new technique for the measurement of local electron density. This technique has been used successfully to measure electron densities in the terrestrial inosphere and could be used for that purpose in interplanetary space. These sounders also have proved to be useful for the study of the ionosphere at lower latitudes, especially throughout the equatorial region where ion composition was inferred from field-aligned electron density data deduced from ALOUETTE I soundings.

Ionospheric Rocket Probe

A number of instruments for the exploration of the lower ionospheric regions have been developed and installed on a NIKE CAJUN rocket (NASA 10.181 AI). For electron density studies, these instruments include a Gerdian condenser to measure positive and negative ions, a VLF receiver at 20 Kc/s to obtain the electron density profile by means of phase and amplitude measurements of signals from the NBS radio station WWVL, beacon transmitters at 2.23 Mc/s and 3.23 Mc/s for Faraday rotation measurements of electron densities, and a radio frequency probe utilizing reactance measurements of cylindrical sensors to determine electron density, electron temperature, and negative ion concentration. Photoelectric devices are included: one in the infrared region to measure a prominent, excited oxygen line at 1.27 microns; the other is in the untraviolet region, to measure the hydrogen (Lyman alpha) line at 1216 angstrom units. The combination of instruments, some of which measure the same ionospheric parameters by different methods, will yield comprehensive results pertaining to the D and E layers of the ionosphere, and will provide data to evaluate the alternate sensors.

This rocket, which can reach a height of 140 km, is scheduled for launch shortly after the launch of a larger rocket, which is instrumented by other groups for dust and micrometeoroid concentration measurements. This combination should yield valuable new information on the relative effects of these influences on the ionosphere.

Support for NASA Space Operations

Telecommunications and Aeronomy Support. ITSA scientists, acting as consultants to the NASA, assist in the planning of experiments to be carried out on manned satellites, including the briefing and debriefing of the astronauts. The experiments concern the airglow layers in the high atmosphere, the twilight bands, a solar eclipse, and the zodiacal light due to sunlight scattered by interplanetary dust.

Services to the space program include special advance predictions of radio frequencies for communication among the ground control stations of the GEMINI program. These are supplemented by special and up-to-the-minute forecasts of propagation conditions and distrubances during the course of each mission. Experimental solar flare forecasts are also provided. Ionospheric sounding observatories at several rocket and satellite launching sites contribute both to operations and research. Under an international arrangement with COSPAR, the radio and geophysical forecast center operated by ITSA assigns the international designations to all satellites and space probes launched, and serves as the Western Hemisphere center for notifying the scientific community of launchings and relevant orbital information.

Seismic Support

The Seismology Division of the Coast and Geodetic Survey conducted a seismic monitoring program for the National Aeronautics and Space Administration at the Kennedy Space Center. It was found that vibrations from industrial machinery produced calibration inaccuracies in testing laboratories at the Center. The seismic data obtained in this program will be used as a factor in the design of a new laboratory in which instruments used for calibrating space equipment will be isolated from the existing vibration environment.

Acoustic and seismic coupling of energy from the SATURN 201 launch was monitored to determine the magnitude of induced ground vibrations.

An intentional detonation of 75,000 pounds of solid propellant with a donor charge of 25,000 pounds of TNT was recorded on seismic instruments at the Rocket Propulsion Laboratory, Edwards Air Force Base, Calif. The objective was to define the potential hazards associated with a possible launch failure.

Vibration measurements taken around various installations of the NASA Goddard Space Flight Center showed that the vibrations were of sufficient magnitude to affect several test procedures adversely. An accurate knowledge of the seismic history of the area was found to be useful in evaluating space system calibrations.

Geomagnetism

The Coast and Geodetic Survey made available to the National Aeronautics and Space Administration the facilities of ESSA's Fredericksburg Geomagnetic Center. The Center provides facilities in which geomagnetic fields for any point on the earth's surface or in space can be simulated. This facility has proved an invaluable asset to the design, development, and testing of magnetic instruments employed in the nation's space effort.

A joint project was conducted by scientists of this Center and of NASA to obtain correlations between geomagnetic field measurements obtained on the earth's surface and those made by instruments aboard satellites and space probes. Nearly current data from 50 magnetic observatories around the world were collected and correlated with the satellite and space probe data. Computer techniques were used to do the correlations.

ESSA's Fredericksburg Geomagnetic Center continued to provide calibration and test facilities for the Navy's Project MAGNET instrumentation. Project MAGNET gathers magnetic data at flight altitudes from oceanic areas still inadequately surveyed for magnetic charting purposes.

Meteorological Support

The Space Operations Support Division of the Weather Bureau continued to furnish meteorological services to the National Aeronautics and Space Administration in support of the manned spaceflight programs. Operational forecasting for the APOLLO program, the next phase of the manned spaceflight program designed to accomplish a manned lunar landing, began with the APOLLO 201 flight early in the year. During the GEMINI flights, the high state of readiness of the flight control program was demonstrated when the early termination of the GEMINI 8 mission necessitated a quick change of the spacecraft recovery area. The Space Operations Support Division forecast favorable weather conditions for the western Pacific, and the GEMINI 8 landing and retrieval were made there. In addition to directly supporting the APOLLO and GEMINI flight operations, Weather Bureau units served in a staff capacity at both the Manned Spacecraft Center and the Kennedy Space Center. Staff support consisted of providing environmental studies and meteorological advice pertinent to the APOLLO systems design and development program, and operational planning and facilities development. Forecast services were also furnished for systems and component tests and evaluation.

The Weather Bureau also continued to provide meteorological support under contract to various National Aeronautics and Space Administration and Department of Defense facilities supporting the United States space exploration and research effort. These services included forecasting, atmospheric measurements, and technical support for launch, test, and performance evaluation of rocket vehicles and payloads. Specialized forecasting of meteorological parameters are required to assure acquisition of desired scientific data from rocket-launched experiments.

NATIONAL BUREAU OF STANDARDS

Basic information on atomic and nuclear processes and interactions developed by NBS are essential to interpreting data gathered by space explorations from the ground as well as by manned and unmanned satellites. NBS measured the spectra of such species as negative ions of oxygen and hydrogen, rare earth elements, and frosts of water and carbon dioxide. The results will be useful to scientists' investigations of the atmosphere, outer space, the stars, and other planets. For exploration of our nearest neighbor, the moon, NBS developed a special X-ray spectrometer designed to function in that inhospitable environment.

Improvements in the Bureau's atomic clock bring its accuracy to the equivalent of one second in 6,000 years. Improvements are needed for tracking satellites and timing sub-nuclear events.

Closer to the ground, the Bureau developed a way of predicting failures in transistors, made a study of the amount of smoke produced by typical combustible airplane materials when they burn, and developed a new method for marking airplane propellers to keep ground crew and other passersby from walking into them. NBS investigations of the properties of chemically-strengthened glass will enable engineers to make better use of this new material in such applications as aircraft windshields. And a study of the nuclear magnetic resonance of liquid hydrogen could lead to a new method for metering the flow of this rocket fuel.

The programs of the National Bureau of Standards in measurement, materials research and engineering standards, are important to the national effort in space and aeronautics. The host of experimental measurements made by space probes depend for meaning and interpretation on the standards of measurement maintained by NBS. These same standards, along with engineering standards developed by the Bureau, enable the Government to specify their needs in hardware and systems, and enable industry to bid intelligently on contracts and sub-contracts to supply the hardware and systems. NBS materials research not only enables the space engineer to select materials for demanding space applications, but facilitate such jobs as routine maintenance of conventional aircraft.

Interpreting Space Data

All investigations on radiation from the sun, atmospheric reactions and exotic rocket propulsion systems depend upon fundamental atomic and molecular data such as atomic energy levels, transition probabilities for atomic energy states and energy release or absorption when atoms and molecules interact with radiation. Many NBS programs seek to provide these necessary data over wider ranges and to a higher degree of accuracy:

a. certain two photon processes play an important role in energy transfer in the upper atmosphere. With the availability of lasers, NBS developed a method to study these processes in the laboratory for the first time. Two photon absorption can now be observed and measured in a cesium vapor and in a beam of negative ions of iodine.

b. negative ions of oxygen and hydrogen also play an important role in atmospheric and astrophysical problems because of their capacity for absorbing light. A technique for the study of light absorption by these negative ions was developed while maintaining temperatures and pressures characteristic of relevant atmospheric conditions.

c. analyses of the atomic spectra from the rare earth elements are receiving first priority in the Atomic Energy Levels program. The spectra and the energy levels determined from the spectra are becoming increasingly important in analyzing the data received from the Orbiting Astronomical Observatory (OAO) Project.

d. NBS released a critical evaluation of all known published atomic transition probabilities for the first ten elements of the periodic chart of the atoms, hydrogen through neon. This brings together for the first time all the available data critically analyzed to show reliability and accuracy for each entry.

e. bibliographies on the literature of ionization and appearance potentials, on gaseous reactions involving small molecules, and other areas of chemical kinetics were prepared. A program of critical review on topics of chemical kinetic interest is well under way. The NBS Kinetics Information Center should prove of great value to scientists and engineers concerned with propellants and combustion reactions.

Frost Fingerprinted

Graphic "fingerprints" of water frost and of carbon dioxide "frost" were obtained in NBS measurements. The results should be useful in studies of the Venus cloud cover, which may be composed of crystals of one or of both of these substances. The fingerprints, or spectra, will be checked against infrared spectra to be obtained from Venus in future space probes. Spectra may also aid in climatic studies of the planet. For example, it is not known why the clouds surrounding Venus apparently remain at the same temperature, both on the bright side of the cloud cover reflecting the sun's rays, and on the dark side away from these rays.

Radiant Flux Measurements

A comparison of two absolute radiant flux detectors was made in the spectral region 500 - 1000 angstrom units. One is a thermopile, the other is a rare gas ionization counter. This work is now providing detector standards to NASA and its contractors so that their observations on the ultraviolet radiation from the sun can be put on an absolute scale.

Study of Surface Chemistry

NBS study of surface ionization processes such as the formation of positive cesium ions on a heated tungsten surface, is leading to an increased quantitative understanding of principles governing the phenomena. These studies are especially pertinent to the development of the ion engines for controlled propulsion of long range space vehicles.

Other NBS surface studies are concerned with the chemisorption of gases on metals under ultra-high vacuum conditions. The space environment is also one of ultra-high vacuum, and doubtless laboratory studies will lead to an appreciation of the surface condition of materials under space conditions.

Other work centered about the reaction of atomic hydrogen with condensed film of unsaturated hydrocarbons at -196°C. This study of surface reactions of atomic hydrogen should provide significant clues to the interaction of atomic hydrogen with dust grains in interstellar space.

Radiation Studies

A program on penetration of high-energy radiation through matter is being directed toward charged particles and Bremsstrahlung encountered in a space environment. Calculations for aluminum and tungsten absorbers for 100 KeV and 10 MeV electrons are showing satisfactory agreement with available experimental data. The energy dissipation by electrons in the earth's atmosphere has been calculated, taking into account the density variation of the atmosphere with height and the influence of the earth's magnetic field. This information will provide a better understanding of the natural aurora as well as auroral studies to be carried out with satellites.

Radiation Measurement

NBS has started preliminary work to develop dosimetry techniques and standards for the Goddard Space Flight Center accelerator laboratory as well as a method to simulate in the laboratory the natural and artificial electron spectrum of the earth's magnetosphere. Efforts are also being directed toward radiation effects on electronic components and the cutoff thicknesses of satellite skins.

The NBS synchrotron was used to calibrate the response of particle detectors to low energy electrons. These detectors will be used by NASA, in its future rocket and satellite programs, to measure radiations in the upper atmosphere and in space.

High Temperature Calorimeter

The importance of high temperature processes in rocket propulsion, in rocket construction materials, and in propellants, is increasing. NBS developed a calorimeter for heat measurements at temperatures between 900° and $2500^{\circ}C$ (about $4500^{\circ}F$). Measurements made on pure aluminum oxide, the heat capacity standard throughout the world, indicate that this calorimeter is the most accurate yet developed for this temperature range.

Data on Diatomic Molecules

The first of a proposed series of critical compilations of data on the structure and spectra of diatomic molecules was published as "The Electronic Spectrum of Carbon Monoxide." These surveys will provide the "best values" available for the scientists working on high temperature reactions, the earth's upper atmosphere, the sun, and other celestial bodies.

New Calibration and Measurement Techniques

Among the new calibration services recently developed is a system to measure high frequency and microwave power to support the urgent needs for calibrating the guidance and detection systems of missiles. In support of research being done on the effectiveness of using lasers in space communications, NBS has developed a new method for measuring the energy of pulsed laser beams.

Improved Time and Frequency Standard

It is important to NASA that its tracking stations have extremely accurate time information and that the time be precisely synchronized among stations. To meet this and other needs, NBS refined its standard of time and frequency -- popularly known as the atomic clock -- until it is accurate to within one second in 6,000 years. A new low-frequency radio station was built to improve the broadcast of time and frequency signals over the globe, and studies on how to best "code" these frequencies for time-signal information are now under way.

Plasma Studies

Plasmas are of strong interest to NASA since, for example, the type of gas which builds up in front of the heat shield of a capsule and interrupts capsule-to-ground communication during re-entry is known as plasma. Plasma devices also have strong potential as future energy sources for rockets. NBS is conducting studies on basic plasma phenomena and on stable plasmas that can be used as standards.

Time Transmission by VLF Radio

Very low frequency (VLF) radio station WWVL at Fort Collins, Colo., was established on an experimental basis, with support from NASA, for studies of the use of VLF in worldwide time synchronization. Sufficient data have now been obtained to indicate that the system is highly promising. To date extensive reception observations have been made at the NASA Goddard Space Flight Center, with the conclusion that WWVL propagation stabilities are sufficient for worldwide data accumulation at NASA tracking stations to be undertaken.

New Microwave Calibration Service

Work has been completed for the establishment of a new microwave calibration service. This is the first calibration service established in the frequency range 1.7

to 2.6 GHz. Calibration requests in this range have been received from both the military and industry; some of the requirements are associated with antennas for satellite tracking and moon-to-earth telecommunications systems.

MATERIALS RESEARCH

New Standard Materials for High Temperature Steels

NBS developed three new standards for analysis and quality control in the production of certain steels. One represents a relatively new type of age-hardening steels called maraging steels. These alloys derived their name from the formation of martensite during age hardening. They are given remarkable metallurgical properties by a simple heat treatment and are being considered for use as the skin material of supersonic aircraft and space systems.

Effect of Atmosphere on Metal Properties

NBS examined the role of the heat treatment atmosphere during the production process to achieve optimum corrosion resistance and mechanical properties in steels widely used in aircraft and space systems. Other studies have dealt with the effect of various atmospheres on metal fatigue, since it is known, for example, that most structural metals have higher fatigue strengths in a vacuum than in ordinary air.

Stressed titanium alloys, in contact with salts (chlorides) at moderate to high temperatures, are known to fail by stress corrosion cracking. When used in supersonic aircraft, these alloys are subjected to these conditions, and failures can occur. Accordingly, NBS is subjecting specimens of these alloys to such environments to determine the mechanism, or cause of the failures.

New Data on High-Temperature Metal

NBS scientists recently obtained new reliable data on the characteristics of the element rhenium at very high temperatures. Rhenium is an extremely hard metal with a high melting point. Because of these properties it has been used in a number of aerospace developments. This research, conducted with support from the National Aeronautics and Space Administration, is one part of a continuing program at NBS to provide science and industry with much-needed high-temperature data on materials.

High Temperature Properties of Chemically Strengthened Glass

NBS scientists have determined several mechanical properties of chemically strengthened glass at elevated temperatures. An increasing number of applications for the glass are being found, for not only does it have superior mechanical strength, but it can be formed in thin lightweight cross sections. The glass shows promise for use in aircraft windshields.

Ceramic Semiconductors Found Superconducting

New knowledge of the superconducting state of matter was obtained in research on semiconducting materials at NBS. The findings are especially significant because they indicate that by varying the composition of semi-conducting materials it is possible to control the essential properties of the superconducting state. Such control could be helpful in the development of superconducting materials having properties tailored to specific applications as in high-field magnets, superspeed switches in compact computers, and magnetic shields in spacecraft.

Studies in Rocket Fuels

NBS scientists have measured the density of liquid and gaseous oxygen at pressures up to 340 atmospheres. This information is valuable in calculating the mass rate of fuel consumption in rockets. Also, NBS scientists are "listening" to faint radio signals, emitted by nuclei in liquid hydrogen, to determine the flow rate of that super-cold liquid. The purpose of the investigation is to explore the feasibility of using nuclear magnetic resonance (NMR) techniques to measure the flow rate of liquid hydrogen under conditions that are encountered in the fueling of rockets. To date, the NBS program has consisted of extensive basic research to accurately determine the nuclear magnetic properties of liquid hydrogen, the determination of feasible techniques, and the construction of experimental equipment necessary to measure fluid velocity. The next phase of the program will be to construct field equipment needed for actual testing at NASA's rocket sites, where liquid hydrogen is used extensively as a propellant in many advanced U. S. missiles.

High Temperature Measurement Standards

Working standards for the measurement of temperatures in excess of 2000°C are being developed at NBS through determining the melting points of ceramic materials, such as aluminum oxide. This work will help fill a long-standing need for high temperature reference points.

Emissivity Measurement Standards

NBS has developed three thermal emittance standards covering the range 800 to 1600°K. These standards can be used to calibrate spectrometers for measuring emissivity of unknown or new materials. Data are used to select materials for satellite construction to maintain the desired internal temperature.

Selenological Instrument Developed

A unique, sanitary, single-crystal X-ray spectrometer was developed at NBS in association with the lunar geology effort, NASA Goddard Space Flight Center. The device, scheduled for completion before the end of the year, will be used in experimentation leading to the development of equipment for lunar geologic exploration.

ATLAS-CENTAUR Fuel Studies

At the request of NASA Lewis Research Center, numerous prelaunch and in-flight problems associated with the liquid hydrogen fueled ATLAS-CENTAUR rocket were pursued at NBS. Experiments were conducted to determine the response time and configuration effects on both liquid level gauges and temperature sensors. The behavior of these instruments must be known to assure proper propellant loading and utilization.

ENGINEERING

Transistor Reliability

Failures among certain transistor types can be predicted from measurements of leakage current before they are placed in service, according to a study recently completed at NBS. The application of screening procedures developed in this study to germanium-alloy transistors may increase the reliability of transistorized equipment, including weapon systems, communications systems, and space vehicle instrumentation.

Semiconductor Flaws

NBS scientists are investigating defects in semiconductor materials, in order to help industry attain the highest possible reliability in these devices. The materials being studied in this long-range program are silicon and germanium, essential in the fabrication of transistors and diodes which are now being widely used in specialized electronic assemblies.

Smoke Danger in Burning Aircraft

NBS completed one phase of a study for the Federal Aviation Agency on the smoke generated by burning aircraft materials. Smoke measurements and the approximate concentration of some poisonous byproducts resulting from flaming and smoldering fires were determined for a number of materials usually found aboard airplanes. Results of this and similar studies will enable engineers to choose materials for aircraft that will produce a minimum of dangerous smoke and will also be useful in designing systems for removal of any smoke that is generated.

Marking Airplane Propellers

NBS scientists developed a technique of marking multi-engine airplane propeller blades so that the moving blades will be more visible to those servicing or working near a plane at night.

The NBS technique involves application of a 4-inch strip of phosphor paint on the tip of each propeller blade, both front and back. Ultraviolet lights are attached to the plane both in front of and behind the propellers. The ultraviolet light causes the phosphor paint to glow; when the propeller is turning, the glowing blade tips form a visible circle of light.

Data for Nuclear Explosion Detection

NBS is collecting geophysical data on various perturbations which can result from naturally occurring phenomena and from nuclear explosions. The information will enable the United States to determine more precisely whether or not nuclear devices have been detonated at high altitudes. An on-line data processor in conjunction with sensors and special-purpose signal conditioners and logical devices is collecting data for this project.

OFFICE OF STATE TECHNICAL SERVICES

The Office of State Technical Services (OSTS), U. S. Department of Commerce, and the Office of Technology Utilization (OTU), National Aeronautics and Space Administration, have complementary responsibilities and objectives in disseminating the results of Federally-supported research and development for the benefit of the national economy. Accordingly the two agencies have established a working relationship through which the technological information generated by NASA's space programs are made available to the State designated agencies and educational institutions participating in programs under the State Technical Services Act of 1965.

Cooperative Efforts of OSTS and OTU

In a joint statement to the State designated agencies, OSTS and OTU announced their agreement for cooperative efforts at the national level. The joint statement also described the functions, operations, and resources of the NASA Regional Dissemination Centers (RDC's) and recommended that State designated agencies investigate such centers as additional sources of scientific and technical information and related services for their State Technical Services programs.

Use of an RDC in STS

The Pennsylvania Technical Assistance Program (PENNTAP), administrator of the STS program for the State of Pennsylvania, announced, September 16, 1966 that the Knowledge Availability Systems Center of the University of Pittsburgh, a NASA Regional Dissemination Center, will be used to provide technical information to the institutions participating in the State's technical services program. The participating institutions will pass on the technical information received from the RDC to the businesses and industries located in their areas of the State. Other States are following the PENNTAP activities carefully, and it is expected that others will follow Pennsylvania's example.

NATIONAL ACADEMY OF SCIENCES-
FEDERAL RESEARCH COUNCIL

CHAPTER IX

INTRODUCTION

The National Academy of Sciences, a private organization of scientists and engineers that serves as an official advisor to the Federal Government, is called upon to provide the government with programmatic and policy advice for the national scientific program in space research. These advisory services are carried out on behalf of the Academy primarily by its Space Science Board, but the counsel of other NAS divisions and committees is also made available where aeronautical or space research activities relate to their fields of specialization. Among those called upon during 1966 were the Divisions of Behavioral Sciences, Biology and Agriculture, and Earth Sciences, and the Committee on Atmospheric Sciences.

SPACE SCIENCE BOARD

Organization

In addition to its governmental responsibilities, the Space Science Board furthers space research generally by encouraging the discussion of advances and opportunities in the field. Internationally, the Board, on behalf of the Academy, represents the United States scientific community on the Committee on Space Research (COSPAR) of the International Council of Scientific Unions.

The Space Science Board is composed of 15 members, a number of consultants, and several invited participants from the major governmental agencies having interest in the space program. These participants, who regularly attend the meetings of the Board, include the Administrator of the National Aeronautics and Space Administration, the Associate Administrator for Space Science and Applications of NASA, the Executive Secretary of the National Aeronautics and Space Council, and representatives of the President's Science Advisory Committee, National Science Foundation, and Department of Defense. Close liaison is maintained with the scientific subcommittees of the NASA Space Sciences Steering Committee. In its relations with the international scientific community, the Board works through its Committee on International Relations, which maintains liaison with interested groups. A small number of standing committees and ad hoc groups carry out much of the Board's work. At the present time, the committees are: Executive Committee, Surfaces and Interiors of the Moon and Planets, Life Sciences, Geodetic Uses of Navigational Satellites, Potential Contamination and Interference from Space Experiments, and Large Space Telescopes.

THE NATIONAL PROGRAM

Scientific Priorities and Balances in Space Research

At a week-long meeting in June 1966, the Space Science Board made a study of possible alternative courses of the scientific space program for the immediate future. Undertaken at the request of NASA, the study proposed to define, in the light of competition for resources, a space program of optimal balance among the various scientific disciplines and tools and a set of priorities in the exploration of space. The findings of the study have been transmitted to NASA, and are undergoing continuing refinement.

Woods Hole 1966 Study of Cardiovascular and Respiratory Physiology

The probable effects of long-duration space flight on the human cardiovascular and respiratory systems was the subject of a two-week study conducted by the Space Science Board at the request of NASA. After initial meetings and preparations during the Spring, 25 specialists convened at Woods Hole, Mass. during July 1966 to investigate the influences of acceleration, vibration, prolonged weightlessness, ambient atmospheric pressure, breathing-gas, and re-entry on the physiological functions of man. The objectives of the study were to determine the current state of knowledge, and to identify courses of research and technical developments that should be undertaken in preparation for long-duration missions. Evaluation of flight experience and the factors involved in long-term missions suggested that the human cardiovascular and respiratory systems will function under space flight conditions; adverse effects of the space environment are likely to be insignificant or remediable by suitable life-support mechanisms. The conclusions and recommendations of the Study have been discussed at reporting sessions and were made available by the end of the Summer to interested agencies to serve as interim guidance pending the publication of the conference proceedings.

Scientists as Astronauts

The Academy is conducting the announcement, processing of applications, and scientific selection of scientists to serve as astronauts in the NASA manned space flight program. These career appointments are open to persons having a doctorate in the natural sciences, medicine or engineering, or the equivalent in experience, and present the opportunity to conduct scientific experiments in manned orbiting satellites and to observe and investigate the lunar surface and circumterrestrial space. Following receipt of all applications by January 8, 1967, selection panels appointed by the Academy will evaluate applicants' scientific qualifications and transmit a list of recommended candidates to NASA in March. Final selection will be made by NASA from among those recommended, and the appointments will begin during the Summer of 1967. Since 1961, the Space Science Board has maintained a continuing interest in the scientific roles of man in space and in the use of scientists in space missions. In 1964, an ad hoc Committee of the Board defined the scientific qualities and qualifications required of scientists as astronauts and was subsequently asked by NASA to undertake the scientific selection of the first group of scientist-astronauts in 1965. This year, the program is being administered by the Academy's Fellowship Office with the cooperation of the Board and the Office of Information; the selection process will again be carried out by members of the ad hoc Committee. In preparation for the current program, members of the first group of scientist-astronauts have met with members of the Committee and staff to discuss their progress, impressions, and suggestions regarding the appointments.

Life Support for Manned Missions

Working groups of the Board's Life Sciences Committee are continuing their study of present and future methods and requirements for providing life support on manned space missions.

Two of the major aspects of support are nutrition and waste management:

The Panel on Space Nutrition

Following its survey and evaluation of current research programs, the panel completed its initial report and recommendations. The Panel's study stresses those aspects which will have importance in long-duration missions, and it will be followed by a report on the acceptability and palatability of certain diets in long-term flight feeding.

The ad hoc Panel on Waste Management

This Panel is reviewing existing and prospective methods of water reclamation and waste disposal within the context of (a) short-duration flights -- up to 30 days, (b) intermediate-duration -- 30 days to 1 year, and (c) long-duration flights of 1 year or more. Since life support requirements for short missions can be stored as end items, they can be dealt with in the framework of available flight experience. In contrast, limitations of weight and space will necessitate some reclamation of water and waste disposal in flights of intermediate duration. The Panel is presently concentrating its attention on such missions.

Committee on Potential Contamination and Interference from Space Experiments

From time to time, the possibility arises that a proposed space activity will have adverse effects on the environment or on work in other fields. The Committee, made up of specialists in several disciplines, attempts to foresee such eventualities, evaluate their likely impact, and, where appropriate, make recommendations to responsible agencies or experimenters. The Committee is currently examining the likelihood of interference, primarily to optical astronomy, that would be caused by a large solar reflector placed in high orbit to illuminate portions of the Earth during nighttime. In the past, problems referred to the Committee include the possible cumulative effects of rocket exhausts expelled into the upper atmosphere, and potential contamination of the atmosphere and the Earth's surface by radioactive material from space-borne nuclear battery accidents.

Committee on Large Space Telescopes

The 1965 Woods Hole Summer Study recommended that a large optical telescope be placed in space in order to exploit the advantages offered by the space environment: dark skies perfectly transparent in all wavelengths, absence of optical distortions caused by the atmosphere, and absence of gravity effects on the instruments. The Study foresaw that something like 15 years of orderly development would be required for such a project. In accordance with a further recommendation, the Space Science Board appointed an ad hoc panel of astronomers to work toward this Large Space Telescope and to encourage studies of those critical areas where particular research and development are required in the near future to advance the program. More specifically, the Committee is a means whereby astronomers can (1) provide the scientific experience necessary to define the technical properties of the telescope, (2) review technical developments relevant to its design, and (3) provide a forum for astronomical interest in the project. Committee meetings during 1966 were concerned with technical aspects of the design, construction, and operation in space of a telescope comparable in size to the largest terrestrial telescopes; and with dialogues with other interested astronomers.

Ad hoc Panel on Small Planetary Probes

At its November 1965 meeting, the Board noted the benefits that would accrue to current knowledge and to preparations for future space exploration from a systematic yet flexible program of small, unmanned space probes to the nearer planets and interplanetary space, carried out over the next five years. A panel of space experimenters was named to examine the possibilities and detail the objectives of the relatively inexpensive probes, and to recommend a balanced program of exploration. Drawing on the counsel of interested NASA officials, the Panel has completed its initial development of a low-cost, vigorous program.

Conference on the Martian Atmosphere

At the request of NASA, the Space Science Board organized a conference of astronomers and spectroscopists to discuss the knowledge available on the Martian atmosphere from spectroscopic observations and to recommend a program that would increase that knowledge.

Accurate information on the Martian surface pressure is one of the critical factors needed for the design of a spacecraft intended to land on Mars. Ultimately, soft landing of an experimental package will be necessary to obtain knowledge on the structure and composition of the planet and of possible existence of living forms. Uncertainty exists, however, regarding the density of the Martian atmosphere. It is known to be very tenuous, but estimates range from pressures where a parachute soft landing would be possible to those requiring a full retrothrust rocket system. The difference between the two techniques could determine whether a small package, severely limited in its instrumentation, or a larger, more useful one could be employed.

The findings and recommendations of the conference indicate that refinement of present observational techniques and the introduction of available new techniques can lead in the near future to substantial increase in knowledge of the Martian atmosphere.

Solar Activity Conference

A working conference on future research in solar activity was attended by astronomers and solar physicists concerned with radio, optical, ultraviolet and x-ray observations of the Sun. The symposium was divided into six sessions reflecting the various aspects of solar studies, and included summaries of recent findings and work in progress; promising lines of investigation; future plans; and suggestions for future research.

INTERNATIONAL ACTIVITIES

COSPAR Ninth Meeting and Seventh International Space Science Symposium

Held this year in Vienna, May 10-19, 1966, the Ninth Plenary Meeting of the International Committee on Space Research was structured around the discussions and recommendations of its six Working Groups and its specialized panels. Each of these groups is concerned with a specific aspect of space research and concentrates on the international advancement and exchange of knowledge and techniques, and cooperative experimentation in that field. Some of the principal positions taken by the meeting included: (a) the establishment of an international Meteorological Rocket Network and procedures for collective distribution of the data; (b) coordinated solar-particle balloon measurements and organization of an alert system; (c) allocation of radio frequencies for satellite studies of the ionosphere, propagation, and geodesy; (d) compilation of southern star catalogues; (e) more-detailed provisions for exchange of rocket and satellite information; (f) space education and training appropriate to the needs of developing nations; and (g) continuing study and refinement of criteria, in which the United States has played a leading role, to prevent contamination of the atmosphere and planetary bodies by space experiments.

The Seventh International Space Science Symposium, held in conjunction with the Plenary Meeting, was divided into three sessions: Life Sciences in Space Research; Moon and Planets; and Interaction of the Neutral Atmosphere and the Ionosphere. Of particular interest were invited papers on recent lunar photography by Ranger 8 and 9, and Luna 9; circadian rhythms in the space environment; Soviet techniques for space probe sterilization; and a series of papers in the "Interaction" session that markedly clarified these complex processes. As is customary, the scientific papers presented at the meeting are being collected and published.

The meetings were attended by some 600 persons from 33 member countries and international scientific unions. U. S. participation was organized by the Space Science Board, which also prepared the annual report and bibliography on U. S. space research during 1965: United States Space Science Program, Report to COSPAR.

International Relations Committee

In order to broaden the base of the Committee and strengthen domestic liaison with the three principal scientific unions adhering to COSPAR, membership of the Board's International Relations Committee was expanded to include the chairmen of the U. S. National Committees for the International Astronomical Union (IAU), the International Union for Geodesy and Geophysics (IUGG), and the International Scientific Radio Union (URSI).

International Years of the Quiet Sun, 1964-1965

The observational phase of the IQSY completed, scientists throughout the world are reducing the data obtained and compiling their findings. The final General Assembly of the International Years of the Quiet Sun will be held in London in July 1967 jointly with the next year's COSPAR Meeting and Space Science Symposium. Since many space research activities are closely related to IQSY disciplines, COSPAR has maintained close cooperation in the planning and accomplishment of IQSY objectives. The current activity of one of its Working Groups is concerned principally with planning for observational coverage during the coming solar maximum, about 1968, which is expected to equal or even exceed the level of solar activity during the 1957-58 maximum of the IGY. To this end, COSPAR technical manuals are being revised and new ones added. The coordination and planning of U. S. participation in IQSY has been carried out by the Academy's Committee for the International Years of the Quiet Sun, working closely with the Space Science Board.

World Data Centers

The World Data Centers, established under the auspices of the International Council of Scientific Unions, collect data from many geophysical sources, especially ionospheric physics, solar activity, aurora, airglow, geomagnetism, and meteorology, and from a great variety of experiments on board rockets, satellites, and spacecraft. There are three World Data Centers: World Data Center A, in the United States; World Data Center B, in the U. S. S. R. and Czechoslovakia; and World Data Center C, in Western Europe and Japan. Each Data Center is divided into a number of Subcenters representing the major disciplines of geophysics and space research. The Rocket and Satellite Subcenter of WDC-A which collects and exchanges results of research conducted with spacecraft and sounding rockets continues to function under the aegis of the Space Science Board.

DIVISION OF BEHAVIORAL SCIENCES

Committee on Hearing, Bioacoustics, and Biomechanics

"Orientation in the Exploration of Space" was the subject of a workshop sponsored by the Committee and held at NASA Ames Research Center, January 25-27, 1966. The general objective of the meeting, which brought together about 150 scientists from all over the world, was to review research on the vestibular organs, the semi-circular canals and the otolith apparatus of the ear. The responses of these organs to space flight conditions, particularly weightlessness and acceleration, are of importance in planning of future space missions. Publication of the proceedings is underway, and arrangements are being made for a similar workshop to be held in January 1967.

A Subcommittee on Aircraft Noise Around Airports was formed during 1966 to assist NASA, the Federal Aviation Agency, and other appropriate agencies, in the planning and accomplishment of research in this area. The Subcommittee was asked in particular to advise on the psychoacoustic research needed for quantitative definition of tolerance levels, the habituation to be expected, and the possible advantages of noise parametric changes.

Committee on Vision

During 1966, the Armed Forces-NRC Committee on Vision was called upon to assist NASA in evaluating a proposed vision tester for use by astronauts while in orbit, and to advise the NASA Ames Research Center in the continuing improvement of space simulators.

Both Committees were asked to assist in the critical review of NASA's Bioastronautics Data Book and to recommend appropriate revisions for the next edition. These tasks have been completed and the reports forwarded to the Agency.

DIVISION OF BIOLOGY AND AGRICULTURE

Committee on Remote Sensing for Agricultural Purposes

The Committee serves in an advisory capacity to those universities and other organizations interested in aerial sensing from aircraft and orbiting satellites of terrestrial soils, plants, and animals. These studies have indicated that aerial photography and satellite imagery in the infrared and other wavelengths offer much promise for accurate and rapid assessment and inventory of agricultural resources, crop growth and health, density of animal populations, and the like. A Committee monograph on the subject is in preparation.

DIVISION OF EARTH SCIENCES

Committee on Space Programs for Earth Observation

The Committee is advisory to the U.S. Geological Survey which, among other interested government agencies under the leadership of NASA, is undertaking a series of studies to define the geologic, hydrologic, geographic, and cartographic applications of scientific data to be acquired from Earth-orbiting satellites. These preliminary studies include early definition of: (a) instruments that are to be used to obtain information; and (b) scientific uses of the data.

Committee on Remote Sensing of Environment

The Committee was established to determine the status of sensor technology and its application to research on the Earth's environment. It is investigating the use of aerial and spacecraft platforms employed in combination with such sensors as multiband photography, ultraviolet, passive microwave, and infrared sensors, and radar. The Committee cooperates with other groups active in sensor technology and provides guidance and recommendations for development of a stronger national program in this field.

Committee on Geography

The Committee on Geography, advisory to the Office of Naval Research, has supported a number of activities in the field of remote sensing, emphasizing both aircraft and satellite platforms. Principal among them have been the annual University of Michigan Symposia on Remote Sensing, with published proceedings, and the conference on the "Use of Orbiting Spacecraft in Geographic Research" held at the NASA Manned Spacecraft Center, Houston, January 28-30, 1965. The conference proceedings, Spacecraft in Geographic Research (NAS-NRC Pub. 1353, 1966), contains specific lists of objectives and requirements for observational satellites employed in fields incorporated in or allied to geography.

International Hydrological Decade, 1965-1974

The U.S. National Committee for the IHD coordinates and stimulates U.S. hydrological studies carried on in connection with the international program. The Committee has proposed that a satellite information system be developed which would measure various hydrologic parameters such as glaciers, snow cover, runoff, and vegetation.

COMMITTEE ON ATMOSPHERIC SCIENCES

The Feasibility of a Global Observation and Analysis Experiment (NAS-NRC Pub. 1290, 1966) is a report of the Committee's Panel on International Meteorological Cooperation, prepared as a U.S. response to a United Nations resolution inviting the international scientific community to develop programs of atmospheric science research to complement those of the World Meteorological Organization. In identifying the components required to obtain a physical definition of the large-scale motions of the entire lower atmosphere, the report stresses the applicability of space research tools. It advances a preliminary concept for a fully integrated observational, interrogation and communications system using satellite-borne sensors in conjunction with balloons, oceanic buoys, automatic land-based observing platforms, ships, and aircraft. A practical goal for this experiment is to develop a capability in long-range weather prediction. The studies indicate that extension of daily predictions for a period of about two weeks is a sound scientific possibility.

The Committee and its specialized Panels examine present activities in research and education as they relate to the opportunities and future progress in the atmospheric sciences. In addition, special studies requested by the Federal Government have been conducted. Currently, the fields under study include air-sea interaction, atmospheric electricity, and weather and climate modification.

Committee on SST-Sonic Boom

The 16-man Committee was established in 1964 in response to the President's request to the National Academy of Sciences to "plan an expanded sonic boom program." Since its inception, the Committee has held 16 meetings and has worked closely with responsible government officials, particularly in OST, FAA, NASA, DOD, Department of Agriculture, and the President's Advisory Committee on Supersonic Transport. The Committee's position on various aspects of the supersonic transport sonic boom problem has been made available to the heads of interested government agencies.

In addition to 6 meetings of the Committee and numerous meetings of several subcommittees over the past year, representatives of the Committee and its NAS staff have attended 8 meetings of the OST Coordinating Committee on Sonic Boom Studies as participant-consultants. Discussions in these meetings have concentrated on recent results on sonic boom field tests and other shorter-range aspects of the sonic boom problem.

In general, the Committee has continuously urged that additional fundamental research on those portions of the problem that have not yet been resolved be supported by FAA, NASA, and DOD in order that the effects of the sonic boom on people, animals, and structures can be predicted with greater precision. The Committee is currently searching for ways in which the sonic boom can be reduced as it is generated at the vehicle.

INTRODUCTION

Ten years of satellite geodesy culminated in the presentation of the Smithsonian Standard Earth, a representation of the geopotential and the figure of the Earth. Significant revisions have been made in the atmospheric model derived from satellite observations.

Other significant accomplishments of the Observatory this year included:

a. the SAO Star Catalog of data on nearly a quarter of a million stars was published.

b. a balloon carrying a spark chamber to detect energetic radiation from celestial sources was successfully flown.

c. a method was proposed for radio communication on the moon.

d. analysis of radar, infrared, and other observations led to the conclusion that the dark areas on Mars are elevations, the bright areas lowlands, and that parachute landings of modest spacecraft on the planet might be possible.

e. two successful injections of artificial meteors into the atmosphere were recorded simultaneously by optical and radar devices.

f. the GEMINI 6 and 7 rendezvous was photographed.

The Observatory continues to operate a network of stations for the photographic and laser tracking of artificial satellites; several networks for meteor astronomy; laboratories for analyses of meteorites; and other facilities for gathering data. The burden of research is carried on by 55 scientists engaged in studies of meteors and meteorites, geodesy, aeronomy, stellar atmospheres, gamma rays, radio astronomy, planetary environments, and other topics.

OPTICAL SATELLITE TRACKING

The Observatory operates a network of astrophysical observing stations around the world for the precise optical tracking of satellites. In addition, 116 moonwatch teams with permanent observing sites distributed in 20 countries and 29 teams available for reentry patrol make visual observations of satellites.

In response to changing scientific needs, the geographic coverage provided by the network of astrophysical observing stations was expanded by the move of three of the twelve Baker-Nunn cameras to newly constructed sites in Ethiopia, Brazil, and Argentina, and by the utilization for the first time of the SAO modified K-50 cameras for geodetic studies. Two of these K-50 were located at the vacated Baker-Nunn sites in Iran and the Netherland Antilles, while a third was set up at a new station established in cooperation with the National Technical University in Athens, Greece.

In addition to furnishing data for scientific research, the camera stations provided launch and tracking support for NASA. Noteworthy among photographic successes were a sequence of the PAGEOS launch showing ignition of the apogee thrust burn, separation and inflation of the balloon, which supplemented and confirmed NASA telemetry data, and photographs taken of the GEMINI 6 and 7 rendezvous just as the spacecraft began their separation.

A laser system for satellite tracking operated throughout the year at the New Mexico astrophysical observing station. Range measurements accurate to about two meters were obtained from the three satellites now in orbit that incorporate retroreflectors: EXPLORERS 22, 27, and 29. The range data were used with the Baker-Nunn observations in the computation of satellite orbits. A geodetic seminar during the summer considered the scientific potential of the laser data, particularly in analyses of the dynamics of the earth.

The SAO Baker-Nunn cameras have photographed in excess of 60,000 flashes of GEOS-A, the first active satellite of the National Geodetic Program. The precise reduction of these flashes will be made available to the National Geodetic Data Archive for eventual use by the international scientific community. At midyear, a second satellite of the Program, PAGEOS, an ECHO-type balloon, was launched, and SAO was given a five-year tracking responsibility. PAGEOS will be used to provide simultaneous observations between SAO Baker-Nunn stations in support of the Geometrical Geodesy Program in the Observatory. The SAO cameras are also photographing PAGEOS simultaneously with the Coast and Geodetic Survey, NASA, USAF, and international groups in support of cooperative efforts.

Using over 40,000 optical satellite observations, Observatory scientists completed the Smithsonian Standard Earth, a determination of the geopotential and figure of the earth, a milestone in global geodetic investigations. The accuracy of station coordinates determined in the solution are of the order of 10 to 15 meters. The SAO Standard Earth will be used as the basis of future orbital analysis and geodetic investigation.

Atmospheric drag determinations based on tracking data for two high-inclination balloon satellites, EXPLORER 19 and EXPLORER 24, have provided information concerning the upper atmosphere in high latitudes that was not available before. This new information has led to a considerable revision in the SAO model of the diurnal bulge in the atmosphere. It now appears that the diurnal bulge is noticeably elongated in the north-south direction and that its center does not move much from the equator.

Recent drag studies have also improved our knowledge of the density variations that accompany geomagnetic disturbances. While the time delay between the peak of the geomagnetic perturbation and that of the atmosphere does not seem to depend on the intensity of the perturbation, there appears to be a slight dependence on latitude. The delay time is somewhat smaller at high latitudes. It also appears that only some of the atmospheric perturbations related to geomagnetic activity are enhanced in the auroral zones.

This year saw the publication of the SAO Star Catalog, a project initiated in 1963 to lessen the manual labor in photoreduction of satellite films and to provide data for the automatic reduction program. Drawing information from more than 40 previously published catalogs, the four-volume work is a uniform catalog of mean positions, proper motions, and other data on nearly a quarter of a million stars throughout the sky. The data are also available on magnetic tape, and will soon appear on specially prepared star charts.

METEORITIC STUDIES

The Observatory operates several photographic and radar sensing systems to observe and record meteors during their passage in the earth's atmosphere. These systems provide data for scientists studying meteoroids in space and estimating the hazard they create for space travel.

A radar system in Havana, Ill., operated jointly with the Harvard College Observatory, makes observations of ionized meteor trails. These measurements permit estimates of the number of meteors of various sizes in different orbits and also determinations of wind velocities at heights of 50 to 70 miles.

To enable a better estimate to be made of the size of meteors being observed by our detection systems, simulated meteors of known composition were fired from rockets by NASA at Wallops Island and their passage through the atmosphere observed by a network of three photographic and five radar stations. During the year, there have been two artificial meteor shots. These stations also make simultaneous observations of natural meteors to assist in providing a closer correlation of photographic and radar data.

Through improved efficiency, the data-acquisition rate of the Prairie Network has increased by a factor of three during the past year, with over 350 meteors photographed simultaneously by two or more of the 16 camera stations. Analysis of the best observations suggests that the brightest bodies observed ablate severely. In these cases, the residue, as meteorites, is small, and always less than one kilogram.

Several new results were obtained from the study of meteorites at SAO. (1) An improved scheme for classifying meteorites according to the degree of recrystallization was developed. This improved system has led to an interesting correlation between the degree of recrystallization and the primordial-gas content. (2) From the distribution of the nickel in the metal of 10 iron and 10 stony meteorites, the rate of cooling from 600°C to 400°C for these bodies was determined to be between 1°C and 10°C per million years. This cooling rate has an important bearing on the size of the parent planet and on the original location of these bodies in the parent planet. (3) A new type of age, called a neutron exposure age, was determined for two stony meteorites. This age indicates that when these meteorites were in space they were subjected either to significant space erosion or to a neutron irradiation. (4) The fall of the Hoba-West meteorite, which is the largest meteorite in the world, was determined to have occurred approximately 80,000 years ago. This result is of significance not only to meteoritics but also to the climatology of the region in South Africa where the meteorite is located.

COMETARY STUDIES

At the astrophysical observing stations, Baker-Nunn photographs were obtained of Comet Ikeya-Seki in January and of three new comets discovered in the summer from August onwards. The observations of Comet Ikeya-Seki were apparently the last obtained anywhere; they are being used to determine a precise orbit. This comet belongs to a group that contains at least eight members, and an investigation has been made of the possible evolution of the group.

Baker-Nunn photographs are also being analyzed in a study of comet-tail structure and motion.

A study is also being made of the past histories of all the short-period comets. Preliminary results indicate the presence of a number of comets moving in nearly circular orbits between Jupiter and Saturn; one of these comets, Schwassmann-Wachmann 1, has been observed there. Close approaches to Jupiter cause the orbits to be deflected to the vicinity of the earth, where they can be readily discovered. The problem of tracing back these orbits is rendered difficult because of repeated moderate approaches to Jupiter, and a slight error in the starting conditions can have a drastic effect on the final result. It is also important to establish whether significant nongravitational forces are involved, and for this reason a new discussion is being made of the observation of Encke's comet.

LUNAR AND PLANETARY STUDIES

Because the moon has no appreciable ionosphere to bend radio waves around its curvature, lunar astronauts will find normal radio communication impossible beyond their visual horizon. It has now been proposed that radio waves shot into the surface of the moon may be bent in a way analogous to ionospheric reflection. The subsurface waves could then be coupled with above-ground antennas to link all parts of the moon. The plan depends on the depth of the dry, pumice-like rock thought to exist beneath the lunar surface; a preliminary test of the moon's internal structure by an orbiting satellite could determine the feasibility of this idea.

On the basis of photographs of the moon by NASA's RANGER series, the suggestion has been made that during its early life that body was kept liquid by radioactivity and that a porous crust with pockets of gas floated on the surface. The old craters were formed by meteoritic impacts and volcanism, and the maria and ghost craters by lava flows.

During the November 12 solar eclipse, the Smithsonian astrophysical observing station in Peru performed with the Baker-Nunn camera an experiment aimed at more accurate determination of the ratio of the moon's diameter to the equatorial diameter of the earth. This experiment was possible because the coordinates of the Baker-Nunn are so well known (unlike those of the usual eclipse-observing instruments).

A comprehensive analysis of radar, infrared, and other observations of Mars has led to a variety of new conclusions about the planet that have a bearing on future space exploration. Major elevation differences between the bright and the dark areas were discovered, suggesting that the dark areas of Mars are comparable to terrestrial continental blocks, and the bright areas to dry, dust-filled ocean basins.

Seasonal variations and wind-blown dust seem capable of explaining the seasonal changes on Mars. The "canals" of Mars are found to be ridges elevated above the dust of the bright areas. Pressures determined from ground-based infrared spectroscopy of Mars refer to an average over bright and dark areas. The pressures found from the MARINER IV occultation experiment are necessarily biased toward elevations and refer to the vicinity of dark areas. If these latter pressures are taken as typical of highlands, the predicted pressures in the centers of prominent Martian bright areas are of the order of 20 millibars, permitting parachute landings of relatively modest spacecraft at these locales.

OTHER SPACE STUDIES

On May 28 a spark-chamber detector was successfully flown for six hours at an altitude of 125,000 feet from the NCAR Balloon Facility at Palestine, Texas. One purpose of the experiment was to search for celestial gamma rays with energy greater than 50 million electron volts and to measure their flux and energy spectra. During the flight, the Crab Nebula, the sun, the galactic plane, and several radio sources came into the field of view of the detector. Data from the flight will also yield the gamma-ray flux and spectrum in the atmosphere as a function of altitude. The data were transmitted from the balloon and recorded on video-tape and kinescope film. The kinescope film is now being analyzed.

A cooperative program with various Argentine agencies has begun to sound the earth's magnetosphere by accurately measuring the variation in transmission time for HF radio waves guided in the magnetosphere by field-aligned ionization irregularities between conjugate points on the earth. The transmitter is located at the SAO astrophysical observing station in Florida, and the receiver at an Argentine Navy installation in Usuhaia in Tierra del Fuego.

FEDERAL AVIATION AGENCY

CHAPTER XI

INTRODUCTION

The Federal Aviation Agency's basic missions are to insure the safe and efficient utilization of the Nation's airspace, by military as well as civil users, and to foster civil aeronautics and air commerce. To support these missions, the Agency conducts a range of research and development activities centering on efforts to improve the air navigation and air traffic control facilities, both individually and as a system; to produce improved aircraft and aircraft components and appliances; and to promote aviation safety in other ways, including aeromedical research.

The growth of U.S. civil aviation, remarkable in recent years, continued during 1966. Key indicators, such as the number of aircraft landings and takeoffs, reached new highs. Reflected in this growth is past progress in the technology of the airway as well as of the airplane. Reflected, too, is progress in the technology of safety, as well as of efficiency, in airspace use.

ADVANCES IN AIRSPACE USE AND CONTROL

ARTS and SPAN

The way toward the automated National Airspace System (NAS) of the future is being pioneered by developments that took place during 1966 at New York - developments growing out of FAA's ARTS (advanced radar traffic control system) and SPAN (stored program alphanumerics) test projects, which the year saw successfully completed. Begun in May 1965, these projects complemented each other: ARTS was concerned with the traffic problems of air terminals; SPAN with those of air route traffic control centers (ARTCC's), which control IFR (instrument flight rules) air traffic en route between airports. Both projects involved equipment that provides air traffic controllers automatically and continuously with the identity and altitude of aircraft appearing on their radarscopes, this information being electronically tagged in alphanumeric data blocks to the blips representing the various aircraft, and moving with the blips across the radarscope or radar display.

The SPAN tests, conducted at the Indianapolis ARTCC, were completed in February 1966, and early in March the equipment was dismantled and shipped to the New York ARTCC. This was a step in FAA's program to semiautomate air traffic control in the very busy New York area by late 1967. The SPAN-tested equipment and procedures will make a vital contribution to this important advance in the handling of en route air traffic.

Results stemming from the ARTS program will contribute to similarly advanced handling of Metropolitan New York airport traffic. The field appraisal of the ARTS operational program was completed at the Atlanta Airport in August 1966, and the equipment is being turned over to FAA's Southern Region for operational use by the Atlanta control tower.

Equipment and procedures similar to those appraised at Atlanta form the basis in large degree of a new facility being constructed by FAA at New York's Kennedy International Airport called a "common IFR room." The capability thus achieved for the New York facility will serve during the interim until installation of a full TRACON M capability (see below). Presently, each of the facilities serving the three radar-equipped airports in the Metropolitan New York area -- Kennedy, La Guardia, and Newark -- controls its own traffic in a "parcel" of airspace allotted for this purpose. Drawbacks to this practice include its dependence on blocked airspace, which requires area-transiting aircraft to "tunnel" over or under, and the great amount of coordination necessary between air traffic controllers in the separate jurisdictions. The common IFR room, by pooling the metropolitan airspace under central control -- and by providing substantial automation improvements, including radar and radar-beacon tracking -- will enable the controllers to utilize the New York terminal airspace to maximum advantage.

NAS En Route Stage A and TRACON M

As mentioned above, equipment and procedures derived from the ARTS and SPAN developments are being used to bring semiautomated air traffic control (ATC) capabilities to New York on an interim and expedited schedule. The more sophisticated equipment under development for the National Airspace System is called, for the air route traffic control centers, the NAS En Route Stage A ATC Subsystem, and for the busiest metropolitan airport complexes, TRACON (Terminal Radar Approach Control) M.

Components of what will be the first operational field model of the NAS En Route Stage A equipment were being assembled, at year's end, at FAA's Jacksonville (Fla.) ARTCC. The latter half of 1966 saw initial delivery there of common-digitizer (CD) equipment, a key part of the NAS subsystem for ARTCC's. This equipment is used by both FAA and the Department of Defense because of its capacity to convert radar and beacon data to digital form usable for either air traffic control or air defense purposes. The Jacksonville field model is expected to be ready to start field tests in the first half of 1968. Plans call for the NAS En Route Stage A equipment to be installed at other ARTCC's as funds and equipment permit, priority being given to those serving the more congested areas and the main routes. The present expectation is that all the ARTCC's in the 48 contiguous States will be equipped by the early 1970's.

The NAS TRACON M (referred to in last year's report as the Metroplex Stage A) is intended, under present planning, for metropolitan terminal complexes annually generating more than 300,000 instrument operations and normally including more than one major airport, served by more than one radar system. A highly sophisticated automation package, TRACON M will be capable of alphanumeric display and tracking of both radar and beacon data, and in addition will perform such computer-based functions as flight-plan processing and intersector coordination. Terminal areas now meeting the foregoing requirements for TRACON M are those at New York City, Chicago, Los Angeles, Oakland-San Francisco, and Washington, D. C. Since much of the equipment planned for TRACON M is similar to that being developed for the NAS En Route Stage A, much of the testing and development will parallel that of the ARTCC equipment, at a substantial saving in time and money.

Common IFR rooms like the one being constructed at New York are planned for Chicago, Los Angeles, Oakland-San Francisco, and Washington. TRACON M equipment, instead of the less advanced equipment being used initially at New York, will be installed at these locations. FAA expects the implementing of these common IFR rooms to take place at approximately the same time as the implementing of the adjacent centers with NAS En Route Stage A equipment.

Direct Altitude and Identity Readout (DAIR) Equipment

TRACON M is the most highly sophisticated version of a design under development by FAA for a modular terminal air traffic control system comprehensive enough to meet the needs of all radar-equipped terminals. Less sophisticated equipment and procedures are scheduled for use at medium-density airports. For low-activity airports the concept specifies equipment capable of showing the altitude and identity of aircraft on controllers' radarscopes in numeric, rather than alphanumeric, form. This direct altitude and identity readout (DAIR) equipment also eliminates the advanced functions performed by a computer, such as automatic tracking or flight-plan processing. A joint civil-military project, pursuant to an FAA-DOD agreement signed in January 1966, the DAIR development effort is aimed for use at certain military facilities as well as at low-density civil terminals.

Other Airway-Improvement Efforts

Besides the foregoing, a variety of FAA research and development efforts bore directly on the improvement of air navigation and air traffic control. Among the more notable of these (outside the field of aeronautical communications, which follows) were:

a. initial testing of large screen displays to help air traffic controllers in their work. Results thus far indicate improvement in handoff procedures and making sector mosaics, and better capability for resectoring. Operational evaluations will continue in the New York common IFR room.

b. first operation of a remote flight strip printer subsystem at the Cleveland air route traffic control center. By printing flight strips at controller positions, this device eliminates the need for manual delivery of the strips to the controllers.

c. completion of development and evaluation of FAA and U.S. Air Force TRACON consoles. FAA and the Air Force have agreed on a common console development.

d. productive use of the air traffic control simulator at FAA's National Aviation Facilities Experimental Center, Atlantic City -- particularly for simulating, as a means of testing and improving, concepts and procedures pertaining to the combined TRACON operation projected for the New York metropolitan area.

e. a significant step toward procurement of a time-frequency collision avoidance system (CAS) test bed was the coordination of the engineering requirement with the ten organizations (from aviation, Government, and industry) represented on the collision avoidance group. The objective is an airborne time-frequency CAS capability that can serve additionally as a test bed for future time-frequency applications in the areas of data acquisition, navigation, and communications.

f. proof of feasibility of using radioactive krypton gas in a guidance system for taxiing aircraft.

g. favorable evaluation of an inertial navigating device, on the basis of a flight-test program in which a U.S. international air carrier cooperated. Results strongly indicate practicality of this device for over-ocean navigation of civil turbojets.

Aeronautical Communications

Management of the radiofrequency spectrum, in which FAA is interested to the extent that it affects aviation, gave rise to particularly notable efforts of the Agency in 1966. These and other noteworthy FAA activities in the vital field of aeronautical communications during the year included:

a. participation in U.S. representation attending at Geneva, Switzerland, in March 1966, the International Telecommunications Union Extraordinary Administrative Radio Conference (Second Session). This conference prepared a revised allotment plan for the aeronautical mobile service, providing approximately 17 more radio channels to ease congestion of the spectrum.

b. the engineering (January through June) of 777 specific frequency assignments within portions of the radio spectrum reserved for use by facilities comprising the National Airspace System, to insure an interference-free environment for these frequencies; 650 of these frequencies were assigned to FAA facilities and the remainder to facilities owned or operated by the military, other Government agencies, or private industries.

c. commencement, January 1, 1966, of 50- rather than 100-kilocycle spacing between voice channels throughout the civil VHF (very high frequency) air-ground communications band (118-136 megacycles). The additional radio-frequencies thus made available for air traffic control are now being applied, as planned, to expanding aviation requirements.

d. completion of plans and their initial implementation, in the interest of air traffic control possibilities, for FAA to work closely with the National Aeronautics and Space Administration (NASA) in evaluating the applications technology satellite (ATS-B), which was launched early in December 1966.

e. further progress, within the National Communications System, in the worldwide integration of FAA and DOD point-to-point long-haul communications, under the FAA-DOD agreement effective February 1, 1963.

AIRCRAFT DEVELOPMENT

Supersonic Transport (SST)

The competitive design phase of the supersonic transport development program ended in 1966.

The best airframe-engine combination was chosen from the rival airframe designs submitted by two airframe companies and the rival engine designs submitted by two engine manufacturers. This selection culminated a careful evaluation of the competing designs by a large body of experts that included broad representation from both Government and the aviation industry. The designs were those resulting from an 18-month period of accelerated effort under contracts awarded in mid-1965, extending an effort begun in mid-1964, when the best two out of three proposed airframe designs and the best two out of three proposed engine designs were selected for further competitive development.

As 1967 begins, the designs in the winning airframe-engine combination are to be further refined and improved under month-to-month contracts, pending decisions re prototype construction. If constructed, the first of the two prototype aircraft called for under present contingent planning would be expected to begin flight testing in 1970, leading to a proved and certificated SST ready for commercial service by mid-1974.

Besides the completion of the design competition, 1966 saw further exploration of the sonic-boom problem in a 6-month test program launched in June at Edwards Air Force Base, Calif. A joint effort of the Air Force, NASA, and FAA, the program gathered additional data on the effects of sonic booms generated by aircraft of various sizes. A mixture of Air Force bomber and fighter types was used in the tests.

Economic studies were also carried out: on the prospective demand for long-range travel through 1990; on the potential effects of a U.S.-developed SST on the international balance of payments; on the costs of the SST, analyzes comprehensively in relation to development, production, and operation; and on the aircraft's prospective facility and service requirements.

Other studies and research during the year included work in the areas of airworthiness standards, flight simulation, air traffic simulation, fuels, materials, operational environment, human factors, and flight controls and displays.

Congress during the year appropriated $80 million to complete the last six months of the 18-month design effort, in which the Government's share of the cost was 25 percent, and $200 million to begin the prototype-construction phase.

Subsonic Aircraft

In the field of subsonic-aircraft development, FAA's main activity during 1966 was in military-civil projects, in which aircraft developed under Defense Department contracts to perform military missions are designed to meet civil airworthiness standards also -- completely in some cases and with deviations at the discretion of the armed service concerned in other cases. Notable items for the year included:

a. signing of an FAA-Army memorandum of understanding (in May) for a follow-on type-certification program applying to a production quantity of a flying crane (Army designation YCH-54A). Originally issued a civil type-certificate by FAA in July 1965, this helicopter has been active for many months in the Army's Vietnam operations.

b. continued progress in the Army's project for an advanced aerial fire support system (AAFSS). A compound helicopter (i.e., having fixed wings as well as rotors), this aircraft has civil potential as a high-speed (200 knot) executive transport or utility vehicle.

c. further progress in the Air Force's project (launched last year with the signing of the design and production contract on September 30, 1965) to develop a "jumbo" turbojet transport -- the C-5A. Under this contract, deviations from civil airworthiness requirements are authorized at the discretion of the Air Force.

The Agency also pursues in the area of aircraft development a continuing program focusing - among other things - on safety problems related to aircraft structure and materials. The aim here is to provide a sound technological basis for improved safety standards applying to this aspect of aircraft development; major emphasis is given to the most important safety problems arising from civil aircraft operations. Efforts in 1966 were concerned notably with:

a. determination of flammability, smoke, and toxicity characteristics of cabin-interior materials.

b. development of crashworthiness of aircraft fuselages (crashworthiness refers to an aircraft's capability to preserve its passengers from injury or death in a crash, as distinguished from its airworthiness, or efficiency as a flying machine). Improved techniques were sought for analyzing the crash resistance of the fuselage as a step toward design guides for a crashworthy fuselage.

c. development of a design procedure that upgrades gust design standards for civil transport aircraft and accounts for the effect of continuous random turbulence on flexible airframe structure.

d. development of a design procedure for predicting loads induced on a flexible airframe when the aircraft is taxiing on uneven pavement.

OTHER RESEARCH AND DEVELOPMENT

Among other notable FAA research and development activities in 1966 to promote aviation safety and foster civil aeronautics were the following:

a. development of a simplified cockpit enabling general aviation pilots to acquire full instrument-flight proficiency in an average of less than half the average time required when training was done with a conventional instrument panel -- 26 hours versus 55.

b. development of a device for preventing stall-spin accidents in general aviation aircraft approaching for landing, and also to prevent loss of speed control during accidental flight into clouds by non-instrument-rated pilots.

c. development of a practical and inexpensive instrument for detecting the presence of harmful gases in the cockpit or cabin -- particularly carbon monoxide.

d. development of a promising device to save aircraft passengers' lives in postcrash flame and smoke environments -- a flameproof bag with 8-minute air supply to be fastened over the head.

e. continued research on the nature of the lightning hazard to aircraft fuel systems, including lightning-triggering experiments and investigation of fuel-vapor phenomena within the aircraft's tanks.

f. laboratory tests of a passive explosives-detection system designed to solve the aircraft sabotage problem.

g. expansion of research on linear explosives for use outside aircraft to make access openings for rescue operations, and for use inside aircraft to make emergency exits.

h. studies shedding light on how human circadian (24-hour) rhythms -- and hence flight-crew energy and efficiency -- are affected by rapid transit of several time zones, as in long jet flights.

i. progress toward developing devices to help pilots with the problems of both clear-air and storm-produced turbulence.

j. appointment of a Noise Abatement Staff to coordinate FAA's efforts in implementing FAA's part of the concerted effort called for by the President to alleviate the problem of aircraft noise, following a special study of the problem and a report to the President on March 18, 1966, by a Jet Aircraft Noise Panel of the Office of Science and Technology.

k. development of more realistic and definitive criteria for flight characteristics of both conventional and new types of aircraft.

l. studies of the role V/STOL aircraft can play in the Nation's transportation complex, and of National Airspace System additions needed to accommodate such V/STOL operations.

FEDERAL COMMUNICATIONS COMMISSION

CHAPTER XII

INTRODUCTION

This year saw a continuation of steps toward realization of the global commercial communications satellite system contemplated by the Communications Satellite Act. Commercial communications via satellite were expanded to provide limited service between the United States and countries in the Pacific area. Earth stations are being constructed around the world. Additional countries have joined the International Telecommunication Satellite Consortium (INTELSAT) so that as of December 31, 1966, 55 countries had become members.

In the United States, the Commission authorized Communications Satellite Corporation's participation in the construction of third generation satellites. The commission issued an Order providing for ownership of United States earth stations by ComSat and the other United States international communications common carriers. It has concluded its consideration of the circumstances under which, entities other than communications common carriers should be permitted to receive direct service from the Communications Satellite Corporation, and has initiated an inquiry into the legal, technical and economic questions involved in the establishment of communication satellite systems for domestic service.

REGULATORY ACTIVITIES

Late in 1965, the Commission issued authorizations to the Communications Satellite Corporation for the construction of two new earth stations, one to be located near Brewster Flat, Wash., and the other near Paumalu, Hawaii. These stations are undergoing final testing. In addition, ComSat continues to operate the Andover, Maine station for commercial satellite communication service between the United States and Western Europe.

In the Fall of 1965 the Commission authorized ComSat to join its foreign partners in the construction of additional satellites of a more advanced type than EARLY BIRD (INTELSAT I) to be used to fill communication needs of the APOLLO Space Program of the National Aeronautics and Space Administration, as well as commercial needs. The first of these satellites was launched in October and was to be placed in synchronous orbit over the Pacific. The synchronous orbit was not attained and the satellite is in an elliptical orbit over the Pacific. In this orbit it can be used only for limited periods of time. The Commission has authorized ComSat to provide commercial service under applicable tariffs to authorized communications common carriers for the period of time the satellite can be used. A replacement satellite is to be launched shortly after the first of the year. A third satellite will be launched subsequently for placement in synchronous orbit over the Atlantic.

The Commission authorized ComSat to construct three new transportable earth stations, one each to be placed at its regular earth station sites, to provide earth station capability for the NASA APOLLO Program pending the completion of the permanent earth stations.

The Commission also authorized ComSat to participate in the construction of six satellites (INTELSAT III) of advanced design, for use at synchronous altitude in the global commercial communications satellite system. Each satellite will be capable of providing approximately 1200 high quality voice grade channels, and simultaneaous communication between a number of earth stations is planned. Tentative launch date for the first of these satellites is in 1968.

The Commission issued a report and order on December 8, 1966, revising its interim policy governing the ownership of earth stations in the United States. Under the revised policy ComSat will own 50% of each earth station and the remaining 50% will be divided among the United States international communications common carriers in accordance with a fixed quota system. The revised policy applies to existing as well as planned earth stations and is to remain in effect until the end of 1969.

The Commission instituted a Notice of Inquiry on March 3, 1966, involving consideration of the legal, policy and technical questions relating to the possible establishment of satellite systems for private or specialized domestic purpose; including distribution of commercial and educational television programs. In view of the novelty and importance of the problems presented, the Commission extended the scope of the inquiry and extended the time for final reply comments to February, 1967.

The Commission concluded its inquiry into the authorized user question, that is, whether or not entities other than common carriers may obtain service directly from ComSat. It concluded that only in unique or exceptional circumstances should it authorize direct service by ComSat to such entities. It was recognized, however, that the statute provides that ComSat may contract directly with the United States Government for the services of the communications satellite system.

The Commission authorized live television broadcasts of GEMINI recovery operations in the Atlantic Ocean which were relayed via EARLY BIRD from the recovery ship to earth stations in North America and Western Europe for distribution by the television networks.

Procurement Activities

The Communications Satellite Act of 1962 requires the Commission to maintain maximum competition in the procurement of equipment and services by ComSat and other carriers for the global communications satellite system and satellite terminal stations. To this end, the Commission nearly three years ago adopted its Communications Satellite Procurement Regulations. This past year saw the first amendment of the regulations, to exclude from their scope procurement by foreign entities for the space segment of the global system. Since January 1966, the Commission staff has reviewed ComSat procurements in the amount of 34 million dollars. Major awards included the spacecraft and related equipment for the INTELSAT III satellites to be launched in mid-1968, and equipment for the Northwest (Brewster Flat, Wash.) and Hawaiian earth stations.

FREQUENCY SHARING CRITERIA AND INTERNATIONAL COORDINATION OF FREQUENCY USAGE

In keeping with internationally agreed criteria, the Commission's rules specify sharing criteria and technical limitations intended to provide adequate protection against mutual interference so as to permit the communications satellite service to share use of certain microwave bands used by terrestrial services. This protection is based on power limitations, permissible angles of elevation for earth station antennas, geographical separation of stations in the sharing services, and advance coordination of assignments.

These criteria are under continuing review at national and international levels to determine the degree to which present limitations can be eased. Commission staff members participated in this and other work as members of the United States Delegation to the XI Plenary Assembly of the International Radio Consultative Committee (CCIR), Oslo, Norway, June 1966, convened under the auspices of the International Telecommunication Union.

The Commission, at the request of INTELSAT, coordinates with all administrations representing parties to the Interim Agreement the proposed frequency usage and physical deployment of INTELSAT satellites to be used in the global communication satellite system. When general agreement has been reached on the frequencies to be employed in the space segment of the system, the Commission notifies the International Frequency Registration Board of the ITU, on behalf of all administrations concurring in the frequency usage, so that the information may be entered in the Master International Frequency Register.

AERONAUTICAL DEVELOPMENTS

The Commission, in discharging its statutory responsibilities with respect to non-government uses of radio for aviation, prescribes the manner and conditions under which frequencies may be assigned for aeronautical telecommunications purposes. Such purposes include flight test telecommunications and telemetry functions used in the development and production of missiles, rockets, and satellites as well as aircraft. Additionally, the Commission assigns frequencies to aircraft radio stations, aeronautical enroute, radionavigation, aeronautical advisory, and other stations comprising the aviation radio services.

Commission staff representatives have continued working, both nationally and internationally, with other government agencies and the aviation industry towards development of system parameters and application of space radiocommunication techniques to the communication requirements of international civil aviation. Of particular interest in that regard was the study, prepared by the Commission staff representatives and industry, submitted by the United States Delegation and adopted by the ITU Extraordinary Administrative Radio Conference - Second Session (Aeronautical), Geneva-1966, of factors to be considered in the utilization of space communication techniques in the aeronautical mobile (R) service. Further, during January, April, June and November, 1966, tests were conducted by the air transport industry under authorization of the Commission to assess the relative merits of amplitude versus frequency modulation emission techniques, using current power versus substantially higher power aboard aircraft, as elements in a communication system between aircraft and aeronautical stations, relayed via satellite.

Commission staff representatives participated in the preparation of material which was submitted by the U.S. Delegation to the Communications-Operations Divisional Meeting, International Civil Aviation Organization (ICAO), Montreal, October-November 1966, responsive to the meeting agenda item on space communications.

The Commission authorized Aeronautical Radio, Inc., and various scheduled airlines to participate in tests using NASA's Applications Technology Satellite #1 (ATS-1) during the first half of December. Satisfactory communications were exchanged, relayed via ATS-1, between a ground terminal and aircraft over the Aleutian Islands, Miami, New York, Kansas City and off the U.S. west coast. Communications were also exchanged, using ATS-1 relay, between aircraft located over the Aleutians and Miami and between aircraft over Miami and San Francisco.

UNITED STATES
INFORMATION AGENCY

CHAPTER XIII

INTRODUCTION

USIA continued to tell the story of the United States in space, as part of its mission of informing foreign nations and audiences. To carry the space story abroad, a wide range of USIA media were employed. Motion picture and television productions covered the GEMINI flights and other special aspects of the space program. Day-to-day developments were reported by the Voice of America and the Agency's wireless service. In the 104 countries where the U. S. Information Service staffs 218 posts, foreign nationals learned about space from Agency book translations, libraries, cartoon strips, space exhibits, pamphlets, pictures, and newspaper features.

In a year dominated by GEMINI flights, USIA exhibited the GEMINI five spacecraft to over two million persons in Argentina, Brazil, and Mexico, put the GEMINI 10 spacecraft on view in Japan, and organized Presidential good-will tours to the Far East and Latin America for astronauts of the GEMINI 6 and 7 and 8 and 11 missions.

With the first manned APOLLO mission in prospect, USIA was already telling the APOLLO story, and further materials on this project were in preparation.

GUIDELINES

The following guidelines formed the basis of USIA treatment of space activities:

a. The United States has a broadly-based, long-range space program which works to develop the technology equally for exploration, applications, and manned space, and reflects a capability second to none.

b. The U. S. is committed to sharing space technology with other countries through international programs, sharing scientific results with others, conducting manned space operations openly, putting space to work for man by practical applications, and landing a man on the moon and returning him safely before 1970.

c. It is U. S. policy to support the rule of law in space, and to use outer space for peaceful purposes. The United States this year supported a United Nations space treaty, first called for by President Johnson on May 7, that is intended to prevent the militarization of outer space and to insure peaceful exploration of the moon and other celestial bodies.

LEADERSHIP IN SPACE

U.S. accomplishments dominated the year in space -- completion of the GEMINI series, and successful lunar reconnaissance by SURVEYOR 1 and ORBITER 1 and 2 were some of the achievements. The United States, which as recently as two years ago was on the defensive with respect to the Soviets, now commands a clear lead. In the eyes of world opinion, the United States was exhibiting a virtuosity and capability that the Soviets were not matching, and which evidenced leadership in space.

TREATMENT

Manned Flight

Primary emphasis was given the GEMINI flights, plus SURVEYOR and LUNAR ORBITER, the lunar reconnaissance missions that support manned flight objectives.

Each of the Agency's media branches gave full treatment to the five GEMINI flights of the year. USIA's wireless service averaged 13 stories per flight. Supporting the Voice of America's short-wave broadcasts were the live relays and delayed re-transmissions by local stations around the world -- providing a tremendous audience. The flight of GEMINI 9, for example, was carried by over 500 stations in 12 Latin American countries alone.

Voice of America's coverage of manned flight events is complex, as GEMINI 11 coverage demonstrates. World-Wide English Division gave comprehensive coverage from lift-off, through the in-flight experiments to splashdown. Live worldwide coverage was restricted to beginning and end of the flight, but live specials on extra-vehicular activity were carried to areas on the air at the time. Correspondents' reports from Houston were broadcast in regional programs, and "Dateline" included highlights of the various World-Wide English specials on appropriate days. Latin-American Division carried live reports and wrap-ups in Spanish from Cape Kennedy, plus commentaries and current news in regular broadcasts. The Near East and South Asia Division reported the flight in all division language broadcasts -- with particularly full coverage in the longer Arabic airshows. The U.S.S.R. Branch covered much of the mission live in Russian, and with the Armenian and Ukrainian services caught the splashdown live via TV monitor. All other language elements gave appropriate coverage drawing on reports from the newsroom, correspondents' reports from Houston and the Cape, and science features.

Foreign newsmen were informed in advance of the GEMINI flights through special packets prepared by the Agency's Press Service. Prepared in cooperation with NASA, they contained six or more special stories and as many as 10 photographs and drawings, and were shipped to all posts by air at least three weeks before launch time. This permitted foreign media to receive from USIA posts detailed pre-launch information on the designated tasks of each flight.

Also in the hands of posts was a GEMINI lecture with 58 slides, with supplements and extra slides. A new slide lecture on APOLLO was being prepared to be on hand before the first manned APOLLO flight.

Television and movie audiences abroad were furnished informative and exciting shows about the U.S. space achievements. In Brazil, Argentina and Mexico the actual

GEMINI 5 spacecraft was exhibited to crowds totalling 2,139,000, many of whom stood four abreast for hours, in lines that stretched almost half a mile, to see the spacecraft.

Manned flight was also the theme of a number of Agency pamphlets. "Destination Moon," which tells the APOLLO story, was updated in a color production with 118,000 copies printed in six languages. The Regional Service Center in Manila produced a fast pamphlet, "Steps to the Moon," from materials furnished by the Press Service, printing 340,000 copies in six languages. Two pamphlets that tell the story of the American aerospace industry, "Wings USA," which details research and development accomplishment in aeronautics and space, and "Behind the Spacemen," an account of the workers who make the astronauts possible, were designed and developed for the Agency free of charge by the Aerospace Industries Association, being printed in two languages for 46,000 copies.

SURVEYOR 1

The successful soft-landing of SURVEYOR 1 and its long-lived picture transmission had great impact abroad. USIA presented its accomplishments in much the same way as Japan's Yomiuri Shimbun, which said the flight "demonstrates the advanced state of U.S. space technology and boosts American confidence in NASA's approach to the problem of putting men on the moon." USIA's wireless service carried 20 stories on SURVEYOR 1.

SURVEYOR pictures serviced by the Agency brought the moon and U.S. space closer to millions. A total of 6,580 prints of SURVEYOR 1 and its close-up photographs were distributed to 154 posts worldwide. A special color view "reconstituted" from hundreds of SURVEYOR photos was sent to 65 posts. SURVEYOR's accomplishments were the peg for a four-panel paper exhibit, "Target Moon," of which 4,845 copies went to 77 posts in English, French, Spanish and in blank copies for vernacular editions.

LUNAR ORBITER 1 and 2

The achievement of the LUNAR ORBITERS was presented as providing what RANGER and SURVEYOR could not: Pictures of the large areas required for a landing to map landing sites. Posts were serviced with 5,415 ORBITER pictures. LUNAR ORBITER 1 was also the subject of a 10-minute film for Latin American television, and of a segment of "Science Report," a bimonthly newsreel for worldwide television. The wireless service sent 18 stories on the ORBITERS.

U.S. Astronauts Abroad

U.S. astronauts were again sent abroad by President Johnson, to share what the United States has learned from space. Whether addressing press conferences or television audiences, students or scientists, chiefs of state or the man in the street, the astronauts were uniquely effective U.S. spokesmen. Their story of peaceful space exploration, supported by in-flight motion pictures, photographs from space, and an actual spacesuit, dramatically affirmed the success of American technology.

Our astronauts traveled to the capitals of Japan, Korea, Formosa, Bangkok, Malaysia, the Philippines, Australia, and New Zealand. In Japan they reached an estimated audience of 46 million in six hours of television programming, and held lengthy sessions with space scientists. In Seoul a quarter million Koreans welcomed them to the capital. In Kuala Lumpur they lectured at the Technical College, where students, supervised by a Peace Corps science teacher, had used scavenged and donated materials to build TELETEK, a tracking station that had tracked a dozen U. S. space probes.

In Latin America where our astronauts visited 13 cities, including 10 South American capitals, plus Panama City, in 24 days, the impact was even greater. They dominated both press and television in each city visited, and street crowds repeatedly swamped their motorcades. The astronauts talked to and mingled freely with the huge crowds, and left the impression that they had come to see the ordinary man, that they were men of the people who had come to talk to the people. They also had audiences with many chiefs of state.

Press and Publications

Space science is a recurring theme in Press Service output, intended to heighten world respect for U. S. technological competence. Principal space projects covered through the year were the ESSA weather satellites, the uprated SATURN, the GEMINI flights, ORBITING ASTRONOMICAL OBSERVATORY, NIMBUS 2, EXPLORER 32, SURVEYOR 1 and 2, PIONEER 7, ORBITING GEOPHYSICAL OBSERVATORY, MAPPING SATELLITE, LUNAR ORBITER 1 and 2, and an INTELSAT Communication Satellite. The wireless file carried 143 stories on these projects, and another 73 on auxiliary space stories. In fact, on very few days did the file not carry some informative story on the U. S. space effort.

In addition to the special GEMINI flight packets, 15 issues of the weekly column, "Science Today," were devoted to space science, and 10 of the biweekly column, "What's New in American Science and Technology," treated space science. The Features section also distributed 15 byliners by space program officials and scientists for publication.

"Amerika Illustrated" carried four major illustrated articles on American space science and a 10-page picture spread for its Russian and Polish readers. "Topic," an illustrated monthly published in English and French for Africa, carried three major articles on space, while "Al Hayat fi Amerika," an illustrated semimonthly aimed at the educated Arab world, averaged one article on space in each of its six issues.

USIA cartoonists treated space science in 15 strips of "It's A Fact," and in eight strips of "True Tales." The same artists produced drawings for the GEMINI flight packets.

In servicing special packets for the Features section, including the GEMINI flights, and special request from posts for exhibits, calendars, and magazines, a total of 497 black and white subjects and 216 in color were covered. Of picture stories prepared, 76 posts ordered the 4-picture story "Monster Takes a Trip," 95 posts the 15-picture story "Doorway to the Moon" and 39 others the same 8-picture story in color; 76 posts the 7-picture story "Make-Believe Maneuvers," and 90 posts the 8-picture story "Goddard's Bold Dream."

Two "paper shows" -- paper panels for exhibit use -- concerned space science. "U.S. Doorway to the Moon," a 5-panel on the Cape Kennedy moonport was ordered for a total of 4,371 copies in four editions: English 1,799, French 829, Spanish 625, and 1,118 blank copies for printing in local languages. "Target Moon," a 4-panel paper show was ordered for a total of 4,845 copies, with new orders still coming in.

Television

The Agency prepared two films for worldwide television use on GEMINI flights, and two more to support astronaut trips abroad. In addition, "Science Report," a bi-monthly film report on American scientific developments distributed to 72 countries in more than three languages, carried reports on most of the GEMINI flights, and the missions of LUNAR ORBITER and SURVEYOR.

Radio

The Voice of America covered all aspects of space in the news as well as in reportage, commentaries, features and reports from correspondents at Cape Kennedy and Flight Control in Houston. President Johnson's address on the peaceful uses of space delivered at Princeton University in May was broadcast in full in worldwide English and excerpted in various foreign languages. A VOA correspondent accompanied the astronaut tours to the Far East and Latin America. During the GEMINI 10 flight in July, a Press Service pamphlet, "Destination Moon," was offered to the World-Wide English audience. Over 7,000 requests were received.

In addition to heavy news coverage, News and Current Affairs this year issued more than 16 commentaries, 140 correspondents' reports, and 90 features for use by World-Wide English and 37 foreign language services.

Motion Pictures

USIA produced a number of films on the GEMINI program, and distributed, worldwide in English, "First Reactor in Space," a 15-minute color film made by AEC, and worldwide in six languages, "Live Via Early Bird," a 30-minute color film of the Communications Satellite Corporation. "Behind the Space Man," a 30-minute color film demonstrating the persons and skills back of the astronauts, was in production.

Exhibits

Space exhibits featuring the actual GEMINI 5 spacecraft, full- and lesser-scale models of GEMINI 5, and 30 displays on the U.S. Space Exploration Program -- all of which in 1966 were made available to USIA by NASA -- plus older models and exhibits on space already in circulation among 300 USIA outlets around the world, attracted 5,700,000 "clocked" viewers to supervised showings in 35 nations.

The total estimated worldwide audience for approximately 19,000 printed exhibits on space themes in the hands of the USIA posts is conservatively placed at 19,000,000. This audience included not only general viewers but, more importantly, high government officials, leaders of the scientific and educational community, students, and representatives of other opinion-molding groups in more than 120 nations around the globe.

In Burma, a space exhibit of models and other components provided by USIA and NASA attracted 250,000 and -- according to reports from the U.S. Embassy in Rangoon -- did more to boost the standing of the United States with the Burmese people than any U.S. Government effort since the Burmese Government took office four years before.

Information Centers

U.S. Information Service posts furnish, in addition to the foregoing, a variety of space information to foreign nationals. A number of books on space have been published and others are planned. A collection of 145 books on American achievements in space science have circulated for showings in 18 countries in Europe, Latin America, and the Far East. Sixteen governmental publications on space such as GEMINI Mid-Program Conference, February 1966" have been sent to post libraries.

ARMS CONTROL AND DISARMAMENT AGENCY

CHAPTER XIV

INTRODUCTION

Space and space activities continue to be important factors in the pursuit of United States arms control and disarmament objectives.

The Arms Control and Disarmament Agency (ACDA) is concerned with preventing the proliferation of nuclear weapons and strategic delivery vehicles from nuclear to non-nuclear countries and also with achieving balanced arms control agreements which will slow down the arms race between existing nuclear nations. ACDA views the outer space treaty, which prohibits placing nuclear weapons and weapons of mass destruction in outer space, as a major step in slowing down the arms race between nuclear weapon powers by preventing space from becoming a future arena for arms deployment.

Space can be a medium for promoting peaceful relations with other nations of the world through cooperative programs and can serve to divert resources from destabilizing armament programs by providing an arena for peaceful competition. Space also affords a medium which can be utilized for unintrusive verification of arms control agreements.

ACDA's interest in space is reflected in international negotiations as well as its internal and external research programs.

ARMS CONTROL PROGRAMS

Preventing the Extension of the Arms Race to Space

In 1963 the U.N. General Assembly unanimously adopted a resolution expressing the intention of all parties to refrain from stationing weapons of mass destruction in outer space. The "Outer Space" treaty would serve to extend, clarify, and codify this resolution. In his statement announcing this treaty the President said: "It is the most important arms control development since the limited Test Ban Treaty of 1963." It prohibits the placing in orbit around the earth, stationing on celestial bodies or otherwise stationing in outer space, weapons of mass destruction. It also prohibits military fortifications or maneuvers on the moon and other celestial bodies with inspection rights to check compliance with the treaty.

ACDA's broad research program, including analyzing the applicability of certain principles of the Antarctic Treaty to outer space, has provided useful support in the negotiation of this treaty. The problem of verification and safeguards for such a treaty has been and continues to be the subject of extensive internal and external research activities.

Space Cooperation as an Aid to Arms Control

Cooperative space programs tend to promote international understanding and greater awareness of common interests, thus creating an atmosphere of mutual trust in which negotiation of balanced arms control agreements becomes more probable. Cooperation in such areas as satellite communications, exchange of meteorological satellite data, space medicine data, and general scientific data all help to foster such a climate.

ACDA has actively supported peaceful multinational space programs such as the European Launcher Development Organization. Programs of this type can assist in restraining the proliferation of rocket technology directly applicable to ballistic missiles at national levels.

Use of Space Vehicles for Inspection and Verification

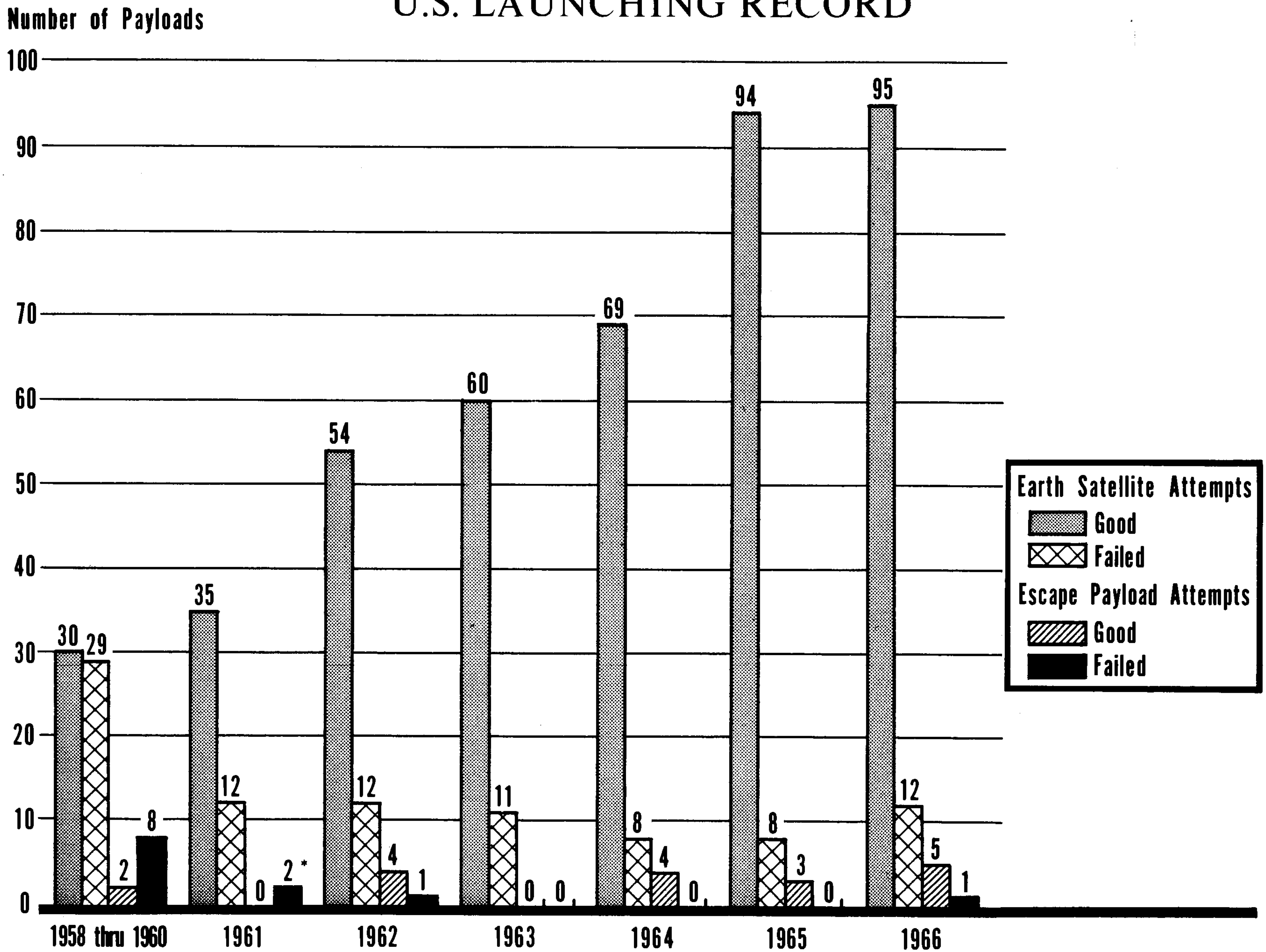
The Department of Defense VELA satellite program continues to be an important system in the monitoring of compliance with the limited nuclear test ban treaty. ACDA participates in this and other DOD Advanced Research Projects Agency developed programs aimed at increasing U. S. overall verification capabilities associated with this treaty and extending it to include all nuclear tests.

Observation and inspection satellites are being carefully studied as potential contributors to unintrusive inspection and verification systems for future arms control measures. Satellites could perform such unintrusive inspection tasks as data collection from unmanned ground stations, photography, and other remote sensing. Studies are under way to develop sensors and data handling techniques for such arms control satellites.

Interaction of Arms Control Measures with Space Programs

The U. S. proposed at the Eighteen-Nation Disarmament Conference that major powers explore the possibility of a freeze on strategic offensive and defensive nuclear weapon systems as a first step toward containing the arms race. Although Soviet reaction to date on this freeze proposal has been negative, studies carried out by the Agency have explored the interaction of various aspects of this proposal with the non-military space program. In cooperation with NASA, ACDA has studied the problem of restraining military missile development programs involving adequate verification without restricting peaceful space programs.

U.S. LAUNCHING RECORD



* INCLUDED IN EARTH SUCCESSES

NASC STAFF

UNITED STATES LAUNCHING RECORD

Year	Earth Satellite Attempts Success	Earth Satellite Attempts Failure	Escape Payload Attempts Success	Escape Payload Attempts 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	2*
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*
Total	437	93	18	12

Notes:

1. Information contained in this table is drawn from unclassified sources and is believed to be complete and accurate in keeping with the definitions given below.

2. Numbers are given in terms of identified separate payloads placed in Earth orbit or sent to the Moon or into solar orbit. A few launchings have put up more than one payload. If these payloads were intended to separate from each other in flight, they are counted individually even though in a limited number of cases such separation failed to occur. A payload is defined as an object put into orbit or sent away from the Earth to accomplish some specific research or application purpose and to return data to Earth. Typically, a payload transmits telemetry, but not always (e.g. ECHO which carried only a radio beacon). Some rocket casings may carry radio beacons, but limited data return incidental to putting up a payload does not classify these as payloads in their own right.

3. The sole criterion of success or failure used for the purpose of this table is that of attaining Earth orbit, or escape to the Moon or solar orbit as appropriate to the column indicated. Some payloads reached orbit or escaped without returning as much data as planned; other payloads failed to reach orbit or escape, yet returned useful data at least briefly.

4. The corresponding data for number of launchings attempted (the count without reference to multiple payloads) are the same as given above except in the Earth orbital category for 1959 (8 failures), 1960 (15 successes and 11 failures), 1961 (29 successes), 1962 (48 successes and 6 failures), 1963 (38 successes and 8 failures), 1964 (53 successes and 7 failures), 1965 (60 successes and 7 failures), 1966 (68 successes and 4 failures), making totals of 325 orbital launch successes, 18 escape launch successes, 72 orbital launch failures and 12 escape launch failures for a grand total of 424 launch attempts (3 escape failures were orbital successes).

5. Data quoted include 2 U.S. payloads with British experiments, two Canadian payloads launched by the United States, one French payload launched by the United States, and one Italian payload launched by an Italian crew from U.S. territory.

* These failed to go to escape as intended, but did attain Earth orbit and are in those totals.

NASC Staff

Appendix A-2

SUCCESSFUL U.S. LAUNCHES -- 1966

[See explanatory notes at end of table.]

Launch Date Name Designation Vehicle	Payload Data	Apogee and Perigee (in statute miles) Period (minutes) Inclination to Equator (degrees)	Remarks
Jan. 19 DEFENSE 2A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	161 86 88.4 93.80**	Decayed January 25, 1966.
Jan. 19 DEFENSE 2B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	122 92 87.6 93.80**	Decayed January 23, 1966.
Jan. 20 APOLLO (A-004) System Test Little Joe II	Total weight: 32,546 lbs. (including 9,361 lbs. ballast) Objective: Test launch launch escape vehicle in abort during power-on tumbling; test canard subsystem for ability to reorient LES with aft heatshield forward. Payload: APOLLO launch escape vehicle, command module, boilerplate service module. Command module instrumented with 2 C-band transponders, 2 tape recorders, telemetry system, 2 cameras, 4 antennas.	Orbit not intended.	Little Joe II performed well; planned pitch-up maneuver was executed and launch escape system provided abort in the power-on, tumbling region. Canard stabilized command module in proper attitude. LES jettisoned, command module parachuted to Earth safely.
Jan. 28 DEFENSE 5A Scout	Total weight: 144 lbs. Objective: Development of space flight techniques and technology. Payload: Not stated.	753 535 105.9 89.70	Still in orbit.
Feb. 2 DEFENSE 7A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	252 112 90.4 75.03	Decayed February 27, 1966.
Feb. 3 ESSA I 8A Thor Delta	Total weight: 305 lbs. Objective: Initiate Tiros Operational Satellite system; obtain complete daily world coverage of weather systems. Payload: 22" x 42" 18-sided hatbox-shaped polygon, with 18" receiving antenna and 4 22" transmitting whip antennas; contains 2 wide-angle vidicon cameras; 2 tape recorders; 2 spin-control systems (magnetic coil; small solid-propellant rockets); 2 infrared horizon sensors; transmitters; 63 nickel-cadmium storage batteries; 9,100 n-on-p solar cells.	520 439 100.3 97.89**	As the first of the Tiros Operational Satellite (TOS) series, ESSA I initiated the world's first operational weather satellite system. Picture-taking on a global basis was initiated 2/5/66; each day, 13 orbits of TV data were read out and data used for operational and research purposes. Quality of TV data excellent. Still in orbit, still transmitting.
Feb. 9 REENTRY V Reentry Test Scout	Total weight: 345 lbs. (including motor and 135 lbs. of propellant). Objective: Evaluate char integrity of low-density charring-ablator nosecap material; determine its thermal effectiveness to withstand high-speed reentry. Payload: Blunt-cone reentry spacecraft instrumented with thermocouples, springwire sensors, 2 telemetry transmitters, batteries, tape recorder; nosecap covered with low-density phenolic-nylon test material; 17" reentry rocket motor.	Orbit not intended.	Scout vehicle and payload instrumentation performance was good; flight trajectory normal. Reentry speed was near the planned 26,950 fps.
Feb. 9 DEFENSE 9A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	316 314 94.8 82.07	Still in orbit.

Feb. 15 DEFENSE 12A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	154 89 96.5 88.8	Decayed February 22, 1966.
Feb. 15 DEFENSE 12B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	159 73 96.48 88.1	Decayed February 16, 1966.
Feb. 15 DEFENSE 12C Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	133 92 96.5 88.6	Decayed February 22, 1966.
Feb. 26 APOLLO SATURN 201 System Test Saturn IB	Total weight: 11,000 lbs. (APOLLO spacecraft, including 300 lbs. of fuel). Objective: Test vehicle and spacecraft for structural integrity, compatibility, communications, separation; test APOLLO heatshield at 27,300 fps reentry speed; recover APOLLO spacecraft; check out ground facilities and equipment. Payload: Complete SATURN IB vehicle, including 80'2" x 21'5" S-IB 1st stage and 59'1" x 21'9" S-IVB 2nd stage, and Instrument Unit; the APOLLO launch escape system, command module, service module, and adapter.	Orbit not intended.	First complete Saturn IB performed well; lor propulsion from service module caused the command module to reenter at 26,500 fps, some 500 mph less than intended 18,500 mph, but within acceptable test limits; heatshield showed expected amount of charring. The Block I Apollo spacecraft performed well in its 1st test. Spacecraft landed in Atlantic 49 mi. from planned landing point, was picked up by U.S.S. Boxer.
Feb. 28 ESSA II 16A Thrust- Augmented Thor Delta	Total weight: 290 lbs. Objective: Add Automatic Picture Transmission (APT) capability to Tiros Operational Satellite system; provide daily coverage of local weather systems for weather stations around the world. Payload: 22" x 42" 18-sided hatbox-shaped polygon, with 18" receiving antenna and 4 22" transmitting whip antennas; containing 2 wide-angle APT vidicon camera systems, FM transmitters, 2 spin-control systems (magnetic coil; small solid-propellant rockets), 2 infrared horizon sensors; 63 nickel-cadmium storage batteries; 9,100 n-on-p solar cells.	876 839 113.4 101.00**	First operational weather satellite to offer cloud photos to local APT stations, sending immediate pictures to ground stations as it passes overhead. Second half of 2-satellite Tiros Operational Satellite (TOS) system which provided pictures of Earth's entire 200-million-sq.-mi. area daily. ESSA II's pictures were "of superior quality." Still in orbit, still transmitting.
Mar. 9 DEFENSE 18A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	260 112 90.5 75.02	Decayed March 29, 1966.
Mar. 16 GATV VIII 19A Atlas Agena D	Total weight: 8,351 lbs. Objective: Provide a rendezvous target for for GEMINI VIII. Payload: 26' x 5' cylinder, containing adapter system, radar transponder, command control system, main engine, 2 secondary engines, attitude control system.	184 177 90.4 28.88	Still in orbit.
Mar. 16 GEMINI VIII 20A Titan II	Total weight: 8,351 lbs. (for GEMINI, including reentry and adapter modules). Objective: Rendezvous and dock with target vehicle; perform extravehicular activity for 1 orbit. Payload: 18'5" x 10' 2-module bell-shaped spacecraft, containing 2 astronauts, guidance and control equipment, rendezvous radar, cameras, 1 HF and 1 UHF transceiver, high and low frequency telemetry transmitters, tracking and recovery communications, fuel cell, environmental control system, recovery and reentry systems.	164 99 88.8 28.90 Rendezvous orbit: 184 177 90.4 28.88	GEMINI VIII achieved world's first docking in space, took place at 6:33 into flight. At 7 hrs. unexpected yaw and roll motion forced Astronauts Neil A. Armstrong and David R. Scott to undock, use their reentry control system to stabilize the GEMINI spacecraft, and reenter on revolution 7 of planned 44 (10 hrs. 42 min. of planned 72 hrs. 50 min.); landed in stipulated emergency area in Western Pacific, March 17, 1966, were hoisted aboard U.S.S. Mason. The 2nd primary objective--EVA for 1 orbit--was not achieved. Flight trouble had been caused by constant firing of short-circuited yaw

Mar. 18 DEFENSE 22A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	187 91 89.0 101.00**	Decayed March 24, 1966.
Mar. 18 DEFENSE 22B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	146 85 88.2 100.90**	Decayed March 23, 1966.
Mar. 25 DEFENSE 24A Scout	Total weight: 144 lbs. Objective: Development of space flight techniques and technology. Payload: Not stated.	699 553 105.3 89.72	Still in orbit.
Mar. 30 OV1-4 25A Atlas D	Total weight: 193 lbs. Objective: Determination of zero G effects on photosynthetic organisms and small vascular plants, and environmental effects on thermal control coatings. Payload: Cylinder with hemispheric ends, 27 inches in diameter, 55 inches long. Carried chlorella algae and multi-cell duckweed, with photocells to measure cell division; wafers and coatings for thermal experiment. 5000 solar cells for power of 22 watts.	627 550 104.11 144.50**	Completed its assigned biological and thermal control missions. Still in orbit.
Mar. 30 OV1-5 25B Atlas D	Total weight: 252 lbs. Objective: Measurement of the optical radiation of Earth, background and space to provide a basis for surveillance techniques. Payload: Cylinder with hemispheric ends, 27 inches in diameter, 55 inches long. Carried 5 optical sensors, 0.5 to 30 micron region, 3 pointing at Earth, and 2 at horizon. Had a veristat gravity gradient stabilization system. 5000 solar cells for power of 22 watts.	662 607 105.6 144.60**	Stabilized successfully and provided optical radiation information. Still in orbit.
Mar. 30 DEFENSE 26A Thor Altair	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	580 392 100.5 98.61*	Still in orbit.
Apr. 7 DEFENSE 29A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	187 118 89.5 75.07	Decayed April 26, 1966.
Apr. 7 SURVEYOR 30A Atlas-Centaur	Total weight: 1,730 lbs. Objective: Demonstrate capability of Atlas-Centaur to place a SURVEYOR spacecraft on simulated lunar transfer trajectory using two-burn, indirect-ascent launch trajectory. Payload: SURVEYOR mass model, ballasted to simulate SURVEYOR's retrorocket and solar panels and antennas; S-band transponder; operational-type separation system.	198 109 89.6 30.77	Atlas-Centaur attained 100-mi. parking orbit, but 2nd Centaur burn to inject SURVEYOR mass model from parking orbit into lunar transfer trajectory was unsuccessful. Centaur engines ignited but shut down within 8 sec. because hydrogen peroxide which operated propellant-feed boost pumps had leaked out. Improved RL-10 engines, flown 1st time, operated successfully in 1st burn; modified guidance system and redesigned, balanced vent system performed satisfactorily; propellant control worked well in 25-min. coast. Reentered May 5, 1966.
Apr. 8 ORBITING ASTRONOMICAL OBSERVATORY I 31A Atlas Agena D	Total weight: 3,900 lbs. (including 1,000 lbs. of scientific instrumentation). Objective: Prove operational capability of OAO system; stabilize and control so scientific data can be obtained. Payload: 10' x 7' octagonal cylinder, from which extend 6 solar paddles for total width of 21'. Radio command system includes 2 VHF	498 491 100.9 35.02	OAO I orbited and functioned normally for 36 hrs.; on 4/10 battery failure ended communication with the satellite. No experiments had a chance to return data. Spacecraft did function and complex stabilization and control system was operating with intended accuracy. Still in orbit.

	antennas and 2 pairs of command receivers; 2 transmitters for wideband telemetry; 2 transmitters for narrowband telemetry; 2 radio tracking beacon transmitters; attitude control system; 4 experiment packages; 3 nickel-cadmium batteries; 74,618 p-on-n solar cells.		
Apr. 19 DEFENSE 32A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	233 86 89.6 116.90*	Decayed April 26, 1966.
Apr. 22 OV3-1 34A Scout FW4S	Total weight: 152 lbs. Objective: Measurement of the angular distribution and energies of charged particles in the magnetosphere and upper ionosphere, with pitch angle of particles of primary interest. Payload: Right octagonal cylinder 29 inches across and 29 inches high. Two 54-inch plasma probe booms and 2 18-inch magnetometer booms. Carries proton and electron spectrometers, electrostatic analyzer, plasma probes, Geiger counter, 2 magnetometers, 2-watt transmitter. 2560 n-on-p solar cells providing 30 watts of power, and nickel-cadmium batteries.	3,557 219 151.7 82.46	Still in orbit. Performed successfully.
May 14 DEFENSE 39A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	222 83 89.4 110.5**	Decayed May 21, 1966.
May 14 DEFENSE 39B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	344 322 95.4 109.94**	Still in orbit.
May 15 NIMBUS II 40A Thor Agena B	Total weight: 912 lbs. Objective: Test instrumentation for studying structure of the atmosphere; extend meteorological observations to regions of the electromagnetic spectrum not previously covered and simultaneously observe cloud cover; test basic technology for meteorological satellites. Payload: 10'-tall structure, consisting of 56"-diameter sensory ring forming the base, connected by a truss structure to smaller hexagonal-shaped package, and flanked by 2 8' x 3' solar paddles covered with 10,500 n-on-p solar cells; containing 3 TV cameras, APT vidicon camera system, HRIR instrumentation, MRIR instrumentation; active 3-axis control system; 8 nickel-cadmium batteries; 3 transmitters; 2 receivers; tape recorders; temperature control system.	732 683 108.1 100.30**	In good near-polar orbit, NIMBUS II provided excellent data from all experiments, including weather photographs on a global scale. Achieved final test objective of 800-orbit continuous operation on 7/15/66. TV tape recorder froze 9/2/66, making picture storage impossible. Still in orbit, still transmitting.
May 19 DEFENSE 41A Scout	Total weight: 144 lbs. Objective: Development of space flight techniques and technology. Payload: Not stated.	552 534 103.4 90.00	Still in orbit.
May 23 DEFENSE 42A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	151 104 88.6 66.02	Decayed June 9, 1966.

May 25 ATMOSPHERE EXPLORER XXXII 44A Thor Delta FW-4S	Total weight: 495 lbs. Objective: Measure temperatures, composition, densities, and pressures in the upper atmosphere on a global basis. Payload: 35"-dia. hermetically sealed sphere fitted with 2,064 solar cells, with a canted turnstile antenna projecting from the bottom and 2 18" electrostatic probes from the sides; sphere contains ion mass spectrometer, 2 neutral particle mass spectrometers, 3 magnetron density gages, optical aspect sensors and switch detectors, 2 PCM telemetry systems, command receiver, tracking transmitter, tape recorder and timer clock, magnetic spin-axis orientation dipole, silver-zinc batteries.	1,688 175 116.0 64.65	Higher apogee than planned (750 mi.) caused by excessive burn of Delta vehicle's 2nd stage. Programming adjustment of onboard sensors compensated for high orbit and the aeronomy satellite returned good data. Still in orbit, still transmitting.
May 30 SURVEYOR I 45A Atlas Centaur	Total weight: 2,194 lbs. (weight at launch, including 1,3777-lb. retromotor, propellants, etc.; weight of SURVEYOR lander on the Moon, 596 lbs.) Objective: Demonstrate capability of launch vehicle, spacecraft, and ground equipment to fly a lunar-intercept trajectory, maneuver and communicate effectively, and softland the SURVEYOR spacecraft on the Moon. Payload: 10'-high x 14' (around 3 extended landing gear) spacecraft, consisting of triangular aluminum frame to which are attached: a mast supporting rotatable planar array antenna and solar panel (with 3,960 solar cells); 2 folding booms deploying conical omnidirectional antennas; thermal compartment housing 2 transmitters, 2 receivers, silver-zinc battery; thermal compartment housing decoder and signal processing equipment; 2 altitude-radar antennas; survey TV camera; retromotor with propellants and equipment; 3 vernier motors.	Softlanded on Moon.	SURVEYOR I made softlanding on Moon (on 1st U.S. attempt) on June 2, 1966, landing in Oceanus Procellarum; transmitted 11,237 photos to Earth as well as engineering data indicating a lunar surface bearing strength of 5 psi. Survived lunar night, transmitted last photos July 14, 1966.
Jun. 1 ATDA 46A Atlas D	Total weight: 1,748 lbs. Objective: To provide a rendezvous target for GEMINI IX. Payload: An ascent shroud target docking adapter, equipment section, reaction control system, battery.	177 177 90.3 28.88	Decayed June 11, 1966.
Jun. 3 GEMINI IX 47A Titan II	Total weight: 8,268 lbs. (for GEMINI, including reentry and adapter modules). Objective: Conduct rendezvous and docking maneuvers; conduct extravehicular activities. Payload: GEMINI, 18'5" x 10' (dia. at base) 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment, cameras, 1 HF and 1 UHF transceiver; rendezvous system computer; high and low frequency telemetry transmitters, tracking and recovery communications; 2 fuel cells; environmental control system; reentry and recovery systems.	169 167 89.9 28.80 Rendezvous orbit: 177 177 90.8 28.88	GEMINI IX A began on June 1 with the launch of ATDA, substitute for the more complex Agena target vehicle; launch of GEMINI IX A was postponed until June 3 because of problems in the guidance system; on 3rd revolution rendezvous was achieved as planned, but shroud on ATDA had not separated; docking was canceled, but 2 more rendezvous were made. EVA was conducted on 3rd day by Astronaut Eugene Cernan while Astronaut Thomas Stafford controlled the spacecraft. At 72 min. of EVA, Cernan's faceplate fogged as he attempted to don and operate Astronaut Maneuvering Unit, so EVA was terminated after 2 hrs. Reentry came June 6, 1966 after 72 hrs. 21 min. in orbit, landing 2 mi. from target in view of live TV carried by EARLY BIRD satellite. Spacecraft and astronauts were hoisted aboard U.S.S. <u>Wasp</u>.
Jun. 3 DEFENSE 48A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	127 89 88.4 86.90	Decayed June 9, 1966.

Jun. 3 DEFENSE 48B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	75 75 88.3 87.00	Decayed June 9, 1966.
Jun. 7 ORBITING GEOPHYSICAL OBSERVATORY III 49A Atlas Agena B	Total weight: 1,135 lbs. Objective: Demonstrate operation of 3-axis stabilized spacecraft for 1 mo.; make correlated geophysical measurements within magnetosphere and interplanetary space. Payload: 67" x 32" x 31" box-shaped satellite; from the sides extend 2 rotatable solar panels (covered with 33,000 solar cells) and 2 solar-oriented experiments, one of them with a 30' antenna; from the ends extend 2 22' booms and 4 shorter booms, all supporting experiments; total of 21 experiments; attitude control system; 3 tracking beacon transmitters; 2 telemetry transmitters; 2 tape recorders; 2 nickel-cadmium batteries.	75,602 169 2,907.9 30.90	OGO III went into planned highly elliptical orbit; all 21 experiments returned good data; attitude control system exceeded primary objective of 1-mo. operation, operating more than 6 weeks, then going into spin-stabilized mode. Still in orbit, still transmitting.
Jun. 7 DEFENSE 51A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	2,206 115 124.3 90.04**	Decayed December 3, 1966.
Jun. 9 SECOR VI 51B Atlas Agena D	Total weight: 46 lbs. Objective: To continue geodetic measurements to tie the Pacific Island chain to North America and to provide an equatorial net. Payload: Solid state transponder and telemetry transmitter in a rectangular package 9 x 11 x 13 inches covered with solar cells.	2,248 106 124.9 90.05**	Still in orbit.
Jun. 9 ERS 16 SIC Atlas Agena D	Total weight: 11 lbs. Objective: Test of cold-welding experiments to test metal-to-metal adhesion of space propulsion materials. Payload: Octohedron 9 inches one side with 5 experiment actuators, including 4 with seat-and-poppet valves and 1 cyclical metal-to-metal contactor with 8 materiel combinations. Telemetry transmitter and solar cells to supply 2.5 watts, plus battery of experiment functions.	2,233 110 124.7 90.02**	Still in orbit. Performed to supply useful data.
Jun. 10 OV3-4 52A Scout	Total weight: 173 lbs. Objective: Measurement of the spectral and and depth dose of the inner Van Allen belt. Payload: Right octagonal cylinder 29 inches across and 29 inches high, with 5 18-inch booms. Carries tissue equivalent ionization chambers, linear energy transfer spectrometer, electron and proton spectrometers, solid state charged particle spectrometer and tri-axial magnetometer, 2-watt transmitter, 2560 n-on-p solar cells, and nickel-cadmium batteries.	2,933 398 142.2 40.79	Still in orbit. Performed as planned.
Jun. 16 GGTS 1 53A Titan IIIC	Total weight: 104 lbs. Objective: Test of gravity gradient stabilization at high altitude, intended to achieve steady state pointing accuracy of $\pm 8^{\circ}$ in pitch and roll within 60 days. Payload: Symmetrical polyhedron with 24 faces, 32 inches high and 36 inches in diameter. Two 52-foot booms extended in gravity gradient test. Main body covered with 1824 n-on-p solar cells. Two Earth albedo sensors and 5 Sun sensors. Telemetry transmitter.	21,004 20,857 1,333.8 0.17	Still in orbit. Performed as planned.

Jun. 16 IDCSP 1, 2, 3, 4, 5, 6, and 7 53 B, C, D, E, F, G and H Titan IIIC	Total weight: 700 lbs. (100 lbs. each). Objective: Establishment of an interim defense communications satellite system with the first 7 of 22 spacecraft. Payload: Symmetrical polyhedrons with 24 faces, 32 inches high and 36 inches in diameter. Each covered with 8000 n-on-p solar cells, supplying 40 watts primary power.	(Orbital range:) 21,004-21,295 20,857-20,905 1,334.4-1,347.4 0.04-0.40	Still in orbit. Successfully distributed in planned orbits and payloads activated.
Jun. 21 DEFENSE 55A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	221 121 90.0 80.09	Decayed July 4, 1966.
Jun. 23 PAGEOS I 56A Thor Agena D	Total weight: 247 lbs. (including PAGEOS, inflation powders, canister, and adapter; PAGEOS alone, 125 lbs.) Objective: Orbit 100' sphere into circular orbit to act as passive portion of worldwide geodesy system. Payload: 100' (when inflated) Mylar sphere; inflation powders; canister; adapter.	2,656 2,602 181.4 87.05	PAGEOS I went into orbit remarkably close to planned one (2,646/2,636 mi.). Still in orbit.
Jul. 1 AIMP EXPLORER XXXIII 58A Thrust-Augmented Improved Delta	Total weight: 206 lbs. (including 81-lb. 4th-stage motor). Objective: By means of lunar-anchored spacecraft, study magnetic tail and magnetohydrodynamic wake of Earth once a month; measure interplanetary magnetic fields, solar plasma, and energetic particles. Payload: 28" (dia.) x 8" octagonal spacecraft, with 2 7' booms deploying flux-gate magnetometers; 3 radiation monitors; solar-wind analyzers; 4 solar paddles mounting 6,144 n-on-p solar cells; 13 silver-cadmium batteries; transmitter.	269,964 9,858 8,540.0 28.69	AIMP EXPLORER XXXIII's intended lunar orbit was changed to alternative highly elliptical orbit when launch vehicle acquired excess speed. All experiments returned good data. Early results indicated tail of Earth's magnetosphere extended more than 75,000 mi. beyond Moon's orbit. Still in orbit, still transmitting.
Jul. 5 APOLLO SATURN 203 59A Saturn IB	Total weight: 58,500 lbs. (includes S-IVB stage, instrument unit, and nose cone and 19,000 lbs. of hydrogen). Objective: Evaluate S-IVB/IU stage in orbit, including behavior of liquid hydrogen in orbit. Payload: 92'-long S-IVB/IU/nosecone combination; liquid hydrogen and liquid oxygen fuel; 2 cameras; telemetry.	131 113 88.5 31.98	Heaviest weight orbited by U.S. to date. S-IVB stage went into good orbit; simulated restart of engine was confirmed. Intended 3-day flight ended in 4th orbit, when deliberately induced internal over-pressures ruptured bulkhead, fragmented payload. Fragments began reentering July 5, 1966.
Jul. 12 DEFENSE 62A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	162 93 88.7 95.53**	Decayed July 20, 1966.
Jul. 14 OV1-8 63A Atlas D	Total weight: 74 lbs. Objective: To test whether a passive reflector more efficient in performance and less subject to solar wind can be developed for communications relay. Payload: 30-ft. diameter balloon, inflated in orbit, which was to photolyze, leaving a fine wire grid.	627 619 105.3 144.20**	Experiment successful. Still in orbit.
Jul. 18 GATV X 65A Atlas Agena D	Total weight: 7,184 lbs. Objective: To provide rendezvous target for GEMINI X. Payload: 26' x 5' cylinder, containing adapter system, radar transponder, command control system, main engine, 2 secondary engines, attitude control system.	216 214 91.5 28.86	Decayed December 29, 1966.

Jul. 18 GEMINI X 66A Titan II	Total weight: 8,248 lbs. (for GEMINI, including reentry and adapter modules). Objective: Conduct rendezvous and docking maneuvers with GATV. Payload: 18' x 10' (dia. at base) 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; cameras; 1 HF and 1 UHF transceiver; rendezvous system; computer; high and low frequency telemetry transmitters, tracking and recovery communications; 2 fuel cells; environmental control system; reentry and recovery system.	After GATV boost: 468 185 95.2 28.80	GEMINI X achieved rendezvous and docking with its GATV; while docked, Astronauts John W. Young and Michael Collins used the AGENA engine to maneuver the combination into proper orbit for rendezvous with GEMINI VIII GATV, undocked from its GATV and rendezvoused with passive GEMINI VIII GATV. Collins performed 2 periods of EVA. Standup EVA was terminated because of eve irritation and umbilical EVA because of spacecraft fuel shortage. Reentry occurred on 44th revolution after 70 hrs. 47 min. of flight on July 21, 1966. Astronauts were picked up by helicopter, flown to U. S. S. Guadalcanal.
Jul. 28 DEFENSE 69A Titan IIIB Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	146 94 88.3 94.14**	Decayed August 6, 1966.
Aug. 4 OV3-3 70A Scout	Total weight: 165 lbs. Objective: Measurement of the charged particle hazards to space payloads. Payload: Hexagonal cylinder containing: Triaxial fluxgate magnetometer to measure magnetic aspect in correlation with directional particle data. VLF experiment for spectral power density of electrostatic plasma waves; magnetic fluctuation experiment; omnidirectional proton and electron spectrometers; high and low energy hydrogen-helium nuclei telescopes; Faraday cup and electron and proton spectrometers; medium energy electron spectrometer; induction coil to measure magnetic field; electron field antenna. Solar cells and telemetry system.	2,781 223 136.9 81.47	Still in orbit. Successful in returning the desired data.
Aug. 9 DEFENSE 72A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	176 118 89.2 100.10**	Decayed September 11, 1966.
Aug. 10 LUNAR ORBITER I 73A Atlas-Agena D	Total weight: 853 lbs. Objective: Place 3-axis-stabilized LUNAR ORBITER spacecraft in lunar orbit; obtain high-resolution photos of various types of lunar terrain related to APOLLO and SURVEYOR. Payload: 5'6" x 5' (dia.) (when deployed, 18'6" along the antenna booms and 12' across solar panels) conical spacecraft, with body containing attitude control system, retro-motor, S-band transmitter, dual-lens (24" and 3" focal length) camera system, 2 radiation dosimeters; high and low gain antennas.	/Lunar orbital data/ 1,152 119 218 12.2	LUNAR ORBITER I on August 14 became 1st U. S. probe to achieve lunar orbit; on August 21 perilune was reduced to 36 mi., on August 25 to 30 mi.; photographed all 9 primary APOLLO landing sites, including the one containing SURVEYOR I, and 7 other APOLLO sites, and 11 areas on back side of the Moon. Total of 207 frames (sets) of photos were taken and relayed back to Earth; a malfunction caused image smear in high-resolution camera. On October 29, 1966 LUNAR ORBITER I was crashed into the Moon's far side to make way for next launch.
Aug. 16 DEFENSE 74A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	205 89 89.2 93.20**	Decayed August 24, 1966.
Aug. 16 DEFENSE 74B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	325 316 94.9 93.16**	Still in orbit.

Aug. 17 PIONEER VII 75A Thrust-Augmented Improved Delta	Total weight: 140 lbs. Objective: Obtain scientific data on magnetic field, solar plasma, cosmic ray, and electron density at points farther from the Sun than from Earth for a period of at least 3 mos. Payload: 37" (dia.) x 35" cylindrical spacecraft, with a boom protruding from the top containing communications antennas; the sides covered with solar cells except for a narrow band in which are located the experiments and 3 booms, 2 for orientation jets and 1 for the magnetometer; data storage; transmitter; batteries; total of 6 experiments.	1.125 au* 1.010 au 402.95 days .0946	PIONEER VII went into planned orbit outside that of Earth and away from the Sun. All experiments returned data. On September 25, 1966 PIONEER VII appeared to have detected the tail of the Earth's magnetosphere at 3.25 million mi. from Earth as Earth passed between the Sun and the probe. Still in orbit, still transmitting.
Aug. 18 DEFENSE 76A Scout	Total weight: 144 lbs. Objective: Development of space flight techniques and technology. Payload: Not stated.	689 649 106.8 88.85	Still in orbit.
Aug. 19 DEFENSE 77A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	2,294 2,283 167.6 90.13**	Still in orbit.
Aug. 19 SECOR VII 77B Atlas Agena D	Total weight: 46 lbs. Objective: To continue geodetic measurement program. Payload: Rectangular package 9x11x13 inches covered by solar cells, and 8 antennas extended from sides, 1 from top. Contains solid state transponder, plus telemetry system.	2,295 2,282 167.6 90.02**	Still in orbit.
Aug. 19 ERS-15 77C Atlas Agena D	Total weight: 11 lbs. Objective: Development of space flight techniques and technology. Payload: Octahedron 9 inches on a side faced with solar cells, and 1 dipole antenna.	2,295 2,275 167.4 90.11**	Still in orbit.
Aug. 25 APOLLO-SATURN 202 System Test Saturn IB	Total weight: 56,900 lbs. (includes S-IVB stage, instrument unit, and APOLLO modules and launch escape system). Objective: Evaluate command module heatshield at high heating load; test vehicle/spacecraft for structural integrity, separation, and general functioning. Payload: 144'-long S-IVB/IU/APOLLO adapter-command module-service escape system combination; cameras; telemetry; 3 fuel cells; guidance and control system.	Orbit not intended.	Successful suborbital flight was 3rd flight for Uprated SATURN I, 2nd for operational APOLLO command module. After separation from S-IVB 2nd stage, service module engine boosted spacecraft to 706-mi. altitude, then restarted 3 more times on way down, accelerating command module to reentry speed of 19,900 mph and maximum heat of 2,700°; splashdown occurred in Pacific some 500 mi. SE of Wake Island; pickup was by U.S.S. Hornet.
Sep. 12 GATV 80A Atlas Agena D	Total weight: 7,199 lbs. Objective: To provide a rendezvous target for GEMINI XI. Payload: 26' x 5' cylinder, containing adapter system, radar transponder, command control system, main engine, 2 secondary engines, attitude control system.	185 174 90.5 28.83**	Decayed December 30, 1966.
Sep. 12 GEMINI XI 81A Titan II	Total weight: 8,509 lbs. for GEMINI, including reentry and adapter modules. Objective: Conduct rendezvous and docking maneuver with GATV XI during 1st revolution. Payload: 18'5" x 10' (dia. at base) 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; cameras; 1 HF and 1 UHF transceiver; rendezvous system; computer; high and low frequency telemetry transmitters, tracking and recovery communications; 2 fuel cells; environmental control system; reentry and recovery system.	After GATV boost: 851 180 107.0 28.83	GEMINI XI spacecraft rendezvoused with GATV XI and then docked with it 1 hr. 34 min. into the flight. Astronauts Charles Conrad and Richard F. Gordon each docked twice. While still docked, they used the GATV propulsion to maneuver to an 851/180 orbit, then to lower orbit again. After separation a tether exercise was conducted, followed by another rendezvous. EVA was performed twice, but the umbilical one was curtailed when Astronaut Gordon became excessively fatigued. Automatic reentry was normal;

			splashdown came on 45th revolution within 2 mi. of predicted impact point, on September 15, 1966. The flight had lasted 71 hrs. 17 min. Astronauts were picked up by helicopter and flown to U. S. S. Guam.
Sep. 15 DEFENSE 82A Thor Burner II	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	559 432 100.8 98.50**	Still in orbit.
Sep. 16 DEFENSE 83A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	203 91 89.2 93.90**	Decayed September 23, 1966.
Sep. 16 DEFENSE 83B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	306 290 94.2 92.02**	Still in orbit.
Sep. 20 SURVEYOR II 84A Atlas Centaur	Total weight: 2,194 lbs. (weight at launch, including 1,377-lb. retromotor, propellants, etc.; weight of SURVEYOR lander on the Moon, 596 lbs.) Objective: Demonstrate capability of launch vehicle, spacecraft, and ground equipment to fly a lunar-intercept trajectory, maneuver and communicate effectively, and softland the Surveyor spacecraft on the Moon. Payload: 10'-high x 14' (around 3 extended landing gear) spacecraft, consisting of triangular aluminum frame to which are attached: a mast supporting rotatable planar array antenna and solar panel (with 3,960 solar cells); 2 folding booms deploying conical omnidirectional antennas; thermal compartment housing 2 transmitters, 2 receivers, silver-zinc battery; thermal compartment housing decoder and signal processing equipment; 2 altitude-radar antennas; survey TV camera; retromotor with propellants and equipment; 3 vernier motors.	Impacted the Moon.	SURVEYOR II was launched into near-perfect lunar-transfer trajectory by Atlas Centaur; at midcourse maneuver, failure of 1 of 3 vernier engines to ignite caused spacecraft to tumble; 39 other attempts were made to start balky engine, without success. Since softlanding was impossible, many engineering checks were made, then on September 22, 1966 the retromotor was fired; all communication was lost 30 sec. later; SURVEYOR II crashed on Moon SE of crater Copernicus.
Sep. 20 DEFENSE 85A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	254 111 90.4 85.05	Decayed October 12, 1966.
Sep. 28 DEFENSE 86A Titan IIIB Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	178 91 88.8 93.97**	Decayed October 7, 1966.
Oct. 2 ESSA III 87A Thrust Augmented Delta	Total weight: 325 lbs. Objective: Orbit TOS satellite carrying 2 Advanced Vidicon Camera Systems (AVCS) to maintain satellite weather system capability of providing worldwide cloud-cover photos once a day for operational use by ESSA. Payload: 22" x 42" 18-sided hatbox-shaped polygon, with 18" receiving antenna and 4 22" transmitting whip antennas; containing 2 AVCS, FM transmitters, 2 spin-control systems (magnetic coil; small solid-propellant rockets), 2 infrared horizon sensors; 8 solar and terrestrial radiation sensors; 63 nickel-cadmium batteries; 9,100 n-on-p solar cells.	923. 861 114.6 101.02**	ESSA III was put into near-polar orbit by 1st Delta vehicle launched from WTR. All systems functioned normally and photos were of excellent quality. Still in orbit, still transmitting.
Oct. 5 DEFENSE 89A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	2,298 2,280 167.6 90.24**	Still in orbit.

Oct. 5 SECOR VIII 89B Atlas Agena D	Total weight: 46 lbs. Objective: To continue geodetic measurement program Payload: Rectangular package 12x14x10 inches, covered with solar cells. High altitude transponder, storage batteries, telemetry system, power regulator.	2,299 2,282 167.6 90.20**	Still in orbit.
Oct. 12 DEFENSE 90A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	131 95 88.6 90.95**	Decayed October 20, 1966.
Oct. 12 DEFENSE 90B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	103 103 88.9 90.88**	Decayed October 21, 1966.
Oct. 26 SURVEYOR 95A Atlas Centaur	Total weight: 1,627 lbs. Objective: Demonstrate capability of Centaur vehicle to perform a two-burn, indirect ascent mission. Payload: SURVEYOR mass model, ballasted to simulate SURVEYOR's retrorocket and solar panels and antennas; S-band transponder assembly; operational-type separation system.	Completed part of geocentric orbit.	Atlas Centaur attained 100-mi. parking orbit; Centaur liquid hydrogen engines reignited and burned full thrust to send SURVEYOR mass model on simulated lunar transfer trajectory. Reentered November 6, 1966. Eighth and last Centaur development flight.
Oct. 27 INTELSAT II A 96A Thrust Augmented Improved Delta	Total weight: 357 lbs. (with apogee motor; 192 lbs. in orbit). Objective: Place satellite and apogee motor into proper transfer orbit, provide tracking and telemetry, and backup calculations through the transfer orbit so the satellite can be injected into synchronous orbit. Payload: 56" (dia.) x 26 1/2" circular satellite, with apogee motor and whip antennas beneath and sleeve rising above and covering the antennas; 2 frequency translation mode repeaters; 4 traveling wave tube amplifiers; control system; 2 batteries, 12,756 n-on-p solar cells.	23,342 185 669.6 26.41 After apogee motor firing: 23,330 2,072 728.0 17.6	Delta launch vehicle put INTELSAT II-A in even better transfer orbit than hoped for; test signals were excellent; on October 30, 1966 apogee motor was fired in attempt to put the satellite into synchronous orbit but engine did not perform. Satellite remained in elliptical orbit, transmitted occasional commercial messages. Still in orbit, still transmitting.
Oct. 28 OV3-2 97A Scout	Total weight: 201 lbs. Objective: Measurement of the charged particle environment near Earth. Payload: Electrostatic analyzer; ion mass spectrometer; plasma probe; retarding potential analyzer; standing wave impedance probe; 2 aspect sensors (a magnetometer and a solar sensor); transmitter and power supply.	991 198 104.2 81.99	Still in orbit. Successful in returning the desired data.
Nov. 2 DEFENSE 98A Atlas Agena	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	181 100 89.0 90.95	Decayed November 15, 1966.
Nov. 2 DEFENSE 98B Atlas Agena	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	161 114 88.8 90.60**	Decayed November 16, 1966.
Nov. 3 OV4-3 99A Titan IIIC	Total weight: 21,300 lbs. Objective: To carry various experiments, and to provide data on the aerodynamics of its long shape during launch and exit from the atmosphere. Payload: A modified Titan II oxidizer tank 34 feet long by 10 feet in diameter, including: a hydrogen-oxygen fuel cell generating 200 watts; a biocell experiment to test cell growth under weightless conditions; 18 corner reflectors experiment of laser optical measurements; 2 micrometeoroid detectors; heat transfer experiment	184 183 90.4 32.85	Still in orbit.

	with potassium fluid, 35-foot ionospheric sounding antenna.		
Nov. 3 OV4-1R 99B Titan IIIC	Total weight: 300 lbs. Objective: To test whether intersatellite messages can be transmitted at low power through ionosphere ducts of the F layer. Also, to measure cosmic noise and electron and air density. Payload: Cylinder with one end domed, 55 inches long and 17 inches in diameter. Receiver, plus telemetry system to relay OV4-1T data. Silver oxide-zinc batteries.	182 180 90.3 32.83	Still in orbit.
Nov. 3 OV1-6 99C Titan IIIC	Total weight: 445 lbs. Objective: Development of space flight techniques and technology. Payload: Cylinder with hemispheres covered with solar cells at each end, 27 inches in diameter, 68 inches long.	180 179 90.3 32.83	Decayed on December 31, 1966.
Nov. 3 OV4-1T 99D Titan IIIC	Total weight: 240 lbs. Objective: Same as OV4-1R above. Payload: Cylinder with one end domed, 55 inches long and 17 inches in diameter; transmitter on 20, 34, and 46 mc, silver oxide-zinc batteries.	197 179 90.6 32.84	Still in orbit.
Nov. 3 GEMINI Vehicle Test Titan IIIC	Total weight: Not stated. Objective: To test a reentry at orbital speed in actual suborbital flight launched from a vehicle on its way to orbit with other satellites. Payload: A used GEMINI capsule modified to accommodate a 2-foot diameter hatch through the heat shield.	Not applicable.	Driven downward at 17,500 mph and and reentered near Ascension Island where recovered only 6 to 7 miles from intended landing point.
Nov. 6 LUNAR ORBITER II 100A Atlas Agena D	Total weight: 850 lbs. Objective: Place 3-axis-stabilized LUNAR ORBITER spacecraft in lunar orbit; obtain high-resolution photos of various types of lunar terrain relating to APOLLO and SURVEYOR. Payload: 5'6" x 5' (dia.) (when deployed 18'6" along the antenna booms and 12' across solar panels) conical spacecraft, with body containing attitude control system, retromotor, S-band transmitter, dual-lens (24" and 3" focal length) camera system, 2 radiation dosimeters; high and low gain antennas.	[Lunar orbital data] 1,162.6 121.8 218 12.2	LUNAR ORBITER II on November 10 deboosted and went into lunar orbit; on November 15 another retromotor firing dropped the perilune to 31.4 mi., then to 25.8. Some 211 high and medium resolution photos of the lunar surface were taken, including 13 primary APOLLO sites and 17 secondary. Readout of photos proceeded until December 6, when failure of high-power transmitter terminated readout; several photos of 1st APOLLO site photographed were lost. Engineering and selenodesy data continued to be transmitted. Still in orbit, still transmitting.
Nov. 8 DEFENSE 102A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	193 107 89.3 100.00**	Decayed November 29, 1966.
Nov. 11 GATV XII 103A Atlas Agena D	Total weight: 7,000 lbs. Objective: To provide a rendezvous target for GEMINI XII. Payload: 26' x 5' cylinder, containing adapter system, radar transponder, command control system, main engine, 2 secondary engines, attitude control system.	177 156 90.0 28.85	Decayed December 23, 1966.
Nov. 11 GEMINI XII 104A Titan II	Total weight: 8,297 lbs. for GEMINI, including reentry and adapter modules. Objective: Conduct rendezvous and docking maneuver with GATV XII during 3rd revolution. Payload: 18'5" x 10' (dia. at base) 2-module bell-shaped spacecraft, containing 2 astronauts; guidance and control equipment; cameras; 1 HF and 1 UHF transceiver; rendezvous system; computer; high and low frequency telemetry	179 158 89.9 28.84	GEMINI XII rendezvoused and docked with GATV XII in 3rd orbit as planned, but trouble in the GATV prevented Astronauts James A. Lovell, Jr., and Edwin E. Aldrin, Jr., from using the GATV propulsion system for further maneuvers. Aldrin had 3 EVA periods, 2 standup and 1 umbilical, for total of 5 hrs. 58 min. On

	transmitters, tracking and recovery communications; 2 fuel cells; environmental control system; reentry and recovery systems.		November 12, 1966 GEMINI XII rendezvoused with total solar eclipse and photographed it. Reentry occurred in 59th revolution on November 15, 1966; splashdown was in the Atlantic, 4 mi. from aiming point, after 94 hrs. 34 min. 31 sec. of flight. Astronauts were picked up by helicopter and landed on U. S. S. Wasp.
Dec. 5 DEFENSE 109A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	226 86 89.7 104.63**	Decayed December 14, 1966.
Dec. 6 ATS I 110A Atlas Agena D	Total weight: 1,550 lbs. (including 76-lb. apogee motor system and 768 lbs. of apogee-motor propellant; 775 lbs. after apogee-motor firing). Objective: Place into synchronous orbit and on station the spin-stabilized spacecraft; operate spacecraft for minimum of 30 days; obtain useful data from a number of the application, technology, and scientific experiments. Payload: 58" (dia.) x 53" cylinder, surfaced with 22,000 n-on-p solar cells; from the bottom end protrude 8 VHF antennas and apogee motor; from the top end protrude 8 whip antennas for telemetry and the microwave antenna; within the spacecraft are the guidance and control system; 2 VHF traveling-wave-tube transponders; 4 telemetry transmitters; 3 applications, 5 technology, and 6 scientific experiments; 6 nickel-cadmium batteries.	22,870 22,228 1,466.0 0.23	ATS I was launched into elliptical orbit; on December 7, 1966 the apogee motor was fired, circularizing orbit at synchronous altitude; all experiments performed well; by December 13 the Applications Technology Satellite had photographed a 1-day weather pattern over one spot on Earth, relayed color TV from one U. S. coast to the other; relayed earth-to-space-to airliner conversation using existing VHF equipment in airliner. Still in orbit, still transmitting.
Dec. 11 OV1-9 111A Atlas D	Total weight: About 300 lbs. Objective: Study of radiation hazards of space flight. Payload: Cylinder with hemisphere at each end covered with solar cells, 27 inches in diameter and 55 inches long. Experiment on altitude determination and spin rate. Three experiments on cosmic radiation and biohazards, employing tissue-equivalents.	2,290 295 142.2 99.14**	Still in orbit. Experiments performed as expected.
Dec. 11 OV1-10 111B Atlas D	Total weight: About 300 lbs. Objective: Study of space environment around the Earth. Payload: Cylinder with hemisphere at each end covered with solar cells, 27 inches in diameter and 55 inches long. Eight experiments on Lyman-alpha, dayglow, nightglow, solar X-ray, cosmic radiation, magnetic fields, and thermal coatings, plus a vertistat system of 6 controllable stabilizing booms.	477 397 98.8 93.79	Still in orbit. Experiments performed as expected.
Dec. 14 DEFENSE 113A Titan IIIB Agena	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	228 86 89.5 109.50**	Decayed December 24, 1966.
Dec. 14 BIOSATELLITE I 114A Thrust-Augmented Improved Delta	Total weight: 936.5 lbs. (includes 275-lb. experiment capsule). Objective: Investigate effects of weightlessness and controlled gamma radiation plus weightlessness on living organisms aboard an attitude-controlled spacecraft with less than 10^{-4}g effect for 3 days; maintain onboard environmental control to keep the organisms alive and expose radiation sources for the flight duration; recover the spacecraft. Payload: 6' x 56" (dia. at base) cylinder-cone adapter section, covered with thermal insulating material, and containing attitude control system (nitrogen jets, IR sensors,	192 184 90.5 33.50	Onboard systems and experiments performed normally, but spacecraft was not recovered. Command to initiate retrofire and reentry was sent on December 17, 1966 but retrofire did not occur. Still in orbit.

	magnetometer), telemetry (transmitter, 2 receivers, decoders, tape recorder, tracking beacon), silver-zinc batteries and power controller; antenna; 40" (dia. at base) reentry vehicle, containing experiment capsule with 13 biological experiments, Strontium 85 radiation source and dosimeter; life support system; separation and entry systems; deorbit telemetry transmitter; programmer, tracking beacon, tape recorder; recovery system.		
Dec. 21 PRIME XV-5D Vehicle Test Atlas SLV-3	Total weight: Under 900 lbs. Objective: Development of maneuverable, lifting body spacecraft technology. Payload: A wedge-shaped body with flat bottom, rounded nose and top, with 2 short vertical tailfins.	Orbit not intended.	Flew close to the planned path, and reached the intended recovery area. Telemetry returned, but recovery of the craft not achieved.
Dec. 29 DEFENSE 118A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	329 300 94.4 75.02	Still in orbit.

NOTES: Successful launches are judged solely by the criterion of whether orbit of Earth or escape from Earth was achieved when so intended. Additionally, the table includes listings of important probes and vehicle tests not intended to orbit, but in these cases, no criterion of success has been applied; some achieved their purposes, others did not. Seven additional Earth-orbital launchings with eight payloads not in this table failed to achieve orbit.

Launch date is based on Greenwich mean time.

Name is the payload identification.

Designation is the international COSPAR astronautical number of orbital objects.

Vehicle is the launch craft type.

Total weight refers to the orbital weight of the object containing the payload; it does not include the weight of any separate miscellaneous burned-out rocket casings, protective coverings, etc.

Objective and Payload are self-explanatory.

Orbital elements are those filed with the United Nations as available; otherwise they are taken from the NASA Goddard Satellite Situation Report or other official public releases.

Apogee and Perigee refer to the greatest and least distances respectively from the Earth of geocentric orbiting objects. In the case of data marked with an asterisk(*), the data refer to Aphelion and Perihelion, the farthest and closest distance between objects in heliocentric orbit and the Sun. These latter instead of being measured in statute miles are measured in astronomical units. (The mean distance between Earth and Sun is called 1 au.)

Period refers to the time in minutes (unless otherwise marked) required to complete one Earth orbit. (In the case of heliocentric orbits the period is measured in days.)

Inclination refers to the tilt of Earth orbits in relation to the Equator, measured in degrees of latitude at the points of the orbit farthest away from the Equator. Inclinations in excess of 90 degrees carry double asterisks (**), indicating some amount of retrograde flight, i.e., somewhat westerly instead of the normal easterly. In the case of heliocentric flights, the inclination is measured in degrees of tilt to the Ecliptic (the plane of the Earth's orbit in relation to the Sun.)

Remarks are self-explanatory.

UNITED STATES SPACE LAUNCH VEHICLES

Vehicle	Stages	Propellant	Thrust (in Thousands of pounds)	Max. Dia. (feet)	Height less Spacecraft (feet)	Payload (pounds) 300 NM orbit	Escape	First Launch
Scout	1. Algol (IIB)	Solid	88	3.3	72	320	50	1965 (60)*
	2. Castor II	Solid	60.5					
	3. Antares II	Solid	22					
	4. Altair III	Solid	5.9					
Thor Delta	1. Thor (DSV-3E-1)	LOX/RP	169	8	90	950	150	1966 (60)
	2. Delta (DSV-3)	IRFNA/UDMH	7.1					
	3. Altair III	Solid	5.8					
Thrust augmented Thor Delta	1. Thor (DSV-3E-1) plus three TX33-52	LOX/RP Solid	169 plus 54 each	11	90	1,275	275	1965 (60)
	2. Delta (DSV-3)	IRFNA/UDMH	7.1					
	3. Altair III	Solid	5.8					
Thor Agena	1. Thor (DM-21)	LOX/RP	170	8	76	1,600	--	1962 (59)
	2. Agena	IRFNA/UDMH	16					
Thrust augmented Thor Agena	1. Thor (DM-21) plus 3 TX 33-52	LOX/RP solid	170 54 each	11	76	2,200	--	1963 (60)
	2. Agena	IRFNA/UDMH	16					
Atlas Agena	1. Atlas booster and sustainer	LOX/RP	388	10	91	6,300	1,150	1961 (60)
	2. Agena	IRFNA/UDMH	16					
Titan II (GLV)	1. Two LR-87	N_2O_4/Aerozine	430	10	90	(8,000 @ 105 NM)	--	1964
	2. LR-91	N_2O_4/Aerozine	100					
Titan IIIA	1. Two LR-87	N_2O_4/Aerozine	430	10	110	5,000	--	1964
	2. LR-91	N_2O_4/Aerozine	100					
	3. Transtage	N_2O_4/Aerozine	16					
Titan IIIB Agena	1. Two LR-87	N_2O_4/Aerozine	430	10	112	7,700	1,700	1966
	2. LR-91	N_2O_4/Aerozine	100					
	3. Agena	WFNA/UDMH	16					
Titan IIIC	1. Two 5-segment 120" diameter	Solid	2,400	10 x 30	110	23,000	5,000	1965
	2. Two LR-87	N_2O_4/Aerozine	430					
	3. LR-91	N_2O_4/Aerozine	100					
	4. Transtage	N_2O_4/Aerozine	16					
Atlas Centaur	1. Atlas booster and sustainer	LOX/RP	388	10	112	8,500	2,300	1962
	2. Centaur (Two RL-10)	LOX/LH	30					
Saturn I	1. S-I (8 H-1)	LOX/RP	1,500	21.6	120	15,000	--	1st stage 1961 2nd stage Block II 1964
	2. SIV (6 RL-10)	LOX/LH	90					
Uprated Saturn I	1. S-IB (8 H-1)	LOX/RP	1,600	21.6	142	23,500 (40,500 @ 105 NM)		1966
	2. S-IVB (1 J-2)	LOX/LH	205					
Saturn V	1. S-IC (5 F-1)	LOX/RP	7,500	33	281	220,000 (285,000 @ 105 NM)	95,000	1967
	2. S-II (5 J-2)	LOX/LH	1,025					
	3. SIVB (1 J-2)	LOX/LH	205					

NOTES: Definitive data are difficult to compile. Payload capacity data vary according to the place and direction of launch as well as intended orbital altitude. Vehicles still under development may fall short of or exceed their projected capacities, both in payload and in engine thrust. First stage thrust shown is sea level value. Modifications of existing vehicles have already raised their performance, and future modifications may be expected in several cases. In general, these data apply to the latest versions now under development.

* The date of first launch applies to this latest modification with a date in parentheses for the earlier version.

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 Dimethlhydrazine--IRFNA/UDMH; Nitrogen Tetroxide and Aerozine--N_2O_4/Aerozine; Liquid Oxygen and Liquid Hydrogen--LOX/LH.

Values marked -- are either zero or not pertinent for the vehicle.

EXECUTIVE OFFICE OF THE PRESIDENT
NATIONAL AERONAUTICS AND SPACE COUNCIL
WASHINGTON

December 31, 1966

LISTING OF MAJOR SPACE "FIRSTS" ACHIEVED BY THE U. S. AND THE U. S. S. R.

One of the indexes used to compare the space programs of the United States and the Soviet Union are the "firsts" achieved by each nation. Like all indexes which measure the quantity but not the quality of achievement, such compilation can be misleading. However, a compilation of "firsts" broken down into meaningful areas can help in judging emphasis and even relative progress if coupled with other evidence.

Regardless of whether a "first" gives either country a significant lead in a particular area of space technology, the fact of being first is not insignificant in the formation of public opinion. In fact, regardless of actual technological competence, the relative position of the U.S. and the U. S. S. R. in space is often judged by the "firsts" achieved by each.

A list of all of the "firsts" scored by each side would be long and meaningless. An effort has been made to select those actions or accomplishments which seemed to be of major importance. Moreover, because of the closed nature of some aspects of both nations' space programs, the list of "firsts" is even less complete.

In order to establish some measure of perspective, the list of "firsts" printed on the reverse, is divided into major categories of space interest. Other breakdowns could have been employed. Most important to note is that this is not a comparison of space competences but rather is primarily a cataloging based upon the timing of events.

LISTING OF MAJOR SPACE "FIRSTS" ACHIEVED BY THE U.S. AND THE U.S.S.R.

	UNITED STATES			UNION OF SOVIET SOCIALIST REPUBLICS		
	Event	Satellite	Launch Date	Event	Satellite	Launch Date
SCIENCE	Discovery of Van Allen Radiation Belts	Explorer I & III	2/1/58 3/26/58	First orbiting geophysical laboratory	Sputnik III	5/15/58
	Discovery that Earth is "pear shaped"	Vanguard I	3/17/58	First photos of the moon's far side	Luna III	10/4/59
	First orbiting solar observ.	OSO I	3/7/62	First comprehensive cosmic ray station	Proton I	7/16/65
	First probe of Venus	Mariner II	8/27/62	First pictures from lunar surface	Luna IX	1/31/66
	First geodetic satellite	Anna IB	10/31/62	First lunar surface test	Luna XIII	12/21/66
	First close-up pictures of the lunar surface	Ranger VII	7/28/64			
	First coded data over 100 million miles	Mariner IV	11/28/64			
	First Mars space pictures	Mariner IV	11/28/64			
	First comprehensive micrometeoroid satellite	Pegasus I	2/16/65			
	First lunar orbit pictures	Lunar Orbiter I	8/10/66			
APPLICATIONS	First active communications satellite	Score	12/18/58			
	First TV pictures from space	Explorer VI	8/7/59			
	First weather satellite	Tiros I	4/1/60			
	First navigation satellite	Transit IB	4/13/60			
	First missile detection satellite	Midas II	5/24/60			
	First passive communications satellite	Echo I	8/12/60			
	First nuclear explosion detection satellite	Vela Hotel	10/17/63			
BIOASTRONAUTICS AND MANNED SPACE FLIGHT	First manned orbital maneuver	Gemini III	3/23/65	First biosatellite	Sputnik II	11/3/57
	First manned propulsion outside craft	Gemini IV	6/3/65	First orbited animals recovered	Korabl-Sputnik II	8/19/60
	First sustained space rendezvous	Gemini VII and VI	12/4/65 12/15/65	First orbited human recovered	Vostok I	4/12/61
	First docking of two craft	Agena Target Gemini VIII	3/16/66 3/16/66	First approximate rendezvous	Vostok III & IV	8/11/62 8/12/62
				First multi-manned craft in orbit	Voskhod I	10/12/64
				First man to leave capsule in space	Voskhod II	3/18/65
SPACE FLIGHT AND PROPULSION	First multiple payloads	Transit IIA & Solrad I	6/22/60	First satellite	Sputnik I	10/4/57
	First recovered payload	Discoverer XIII	8/10/60	First escape payload	Luna I	1/2/59
	First air snatch payload recovery	Discoverer XIV	8/18/60	First lunar impact	Luna II	9/12/59
	First synchronous satellite	Syncom II	7/26/63	First orbital launch platform	Sputnik V	2/12/61
	First multiple orbits	Vela Hotel I and II	10/17/63	First flight-by Venus	Venera I	2/12/61
	First hydrogen-fueled rocket to orbit	Centaur II	11/27/63	First flight-by Mars	Mars I	11/1/62
	First sub-orbital test of an ion engine	SERT IA	7/20/64	First ion engine test in orbit	Voskhod I	10/12/64
	First propulsion of two craft docked in orbit	Agena Target Gemini X	7/18/66	First plasma rocket tested in orbit	Zond II	11/30/64
				First Venus impact	Venera III	11/16/65
				First lunar soft-landing	Luna IX	1/31/66
				First lunar orbiter	Luna X	3/31/66
AUXILIARY POWER SYSTEMS	First solar cells on craft	Vanguard I	3/17/58			
	First craft with isotope power	Transit IVA	6/29/61			
	First craft powered only by nuclear energy	Transit VBN 1	9/28/63			
	First nuclear reactor in orbit	Snapshot I	4/3/65			
	First space use of fuel cell	Gemini V	8/21/65			

December 31, 1966
NATIONAL AERONAUTICS AND
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HISTORICAL SUMMARY -- PROJECT GEMINI

Mission and Launch Date	Crew	Duration	Highlights
Gemini 3 Mar. 23, 1965	Grissom & Young	4 hours, 53 minutes	First U.S. two man crew, first use of orbital maneuvering system, first controlled reentry.
Gemini 4 June 3, 1965	McDivitt & White	97 hours, 56 minutes	First extravehicular activity, first use of personal propulsion. Near rendezvous achieved.
Gemini 5 Aug. 21, 1965	Cooper & Conrad	190 hours, 56 minutes	Demonstrated psychological feasibility of lunar trip by staying in space for period of lunar trip.
Gemini 7 Dec. 4, 1965	Borman & Lovell	330 hours, 35 minutes	Set manned space flight duration record.
Gemini 6 Dec. 15, 1965	Schirra & Stafford	25 hours, 51 minutes	Accomplished first rendezvous, coming within six feet of Gemini 7.
Gemini 8 Mar. 16, 1965	Armstrong & Scott	10 hours, 42 minutes	First dual launch and docking with an Agena. Mission curtailed by short circuit in craft's thrusters.
Gemini 9 June 3, 1966	Stafford & Cernan	72 hours, 21 minutes	Unable to dock due to failure of shroud to completely separate from the target's docking adapter. Extravehicular activity performed.
Gemini 10 July 18, 1966	Young & Collins	70 hours, 46 minutes	First dual rendezvous (with its own target vehicle and the one launched for Gemini 8). First docked vehicle maneuvers using Agena as propulsion stage. Extravehicular activity with first manned retrieval of an experiment.
Gemini 11 Sept. 12, 1966	Conrad & Gordon	71 hours, 17 minutes	Rendezvous and docking achieved on first revolution. Extravehicular activity. Successful station keeping with Agena target vehicle tied together by a tether. Highest apogee (851 miles).
Gemini 12 Nov. 11, 1966	Lovell & Aldrin	94 hours, 34 minutes	Extravehicular activity record set (five hours, 37 minutes). Station keeping with target vehicle achieved by use of tether.

RADIOISOTOPIC POWER SYSTEMS FOR SPACE APPLICATIONS

SNAP NO.	Power Electrical (watts)	Design Life	Application	Fuel	Status
3	2.7	5 Years	Navigational satellites (DoD)	Plutonium-238	Units launched in June and November 1961. June unit still operating in orbit, but quantitative performance data not available.
9A	25	5 Years	Navigational satellites (DoD)	Plutonium-238	Units launched in September and December 1963 are still operating, but at a lower power level. Third unit aborted April 1964.
11	25	90 Days	Moon Probe (NASA)	Curium-242	First fueling of a generator with Curium-242 accomplished in July. In October fueled unit completed 90-day test under simulated lunar conditions. Testing of two electrically heated generators will complete planned SNAP-11 work.
19	30	5 Years	NIMBUS-B Weather satellite (NASA)	Plutonium-238	Electrically-heated system undergoing compatibility testing with NIMBUS-B spacecraft. Two prototype fueled generators tested to flight system qualification levels.
27	50	5 Years	Apollo Lunar Surface Experiment (ALSEP) (NASA)	Plutonium-238	Electrically-heated engineering generators placed on test. Electrically-heated prototype system undergoing compatibility testing with ALSEP hardware.
29	500	90-120 Days	Manned and Unmanned space applications (DoD and NASA)	Polonium-210	Detailed design and subcomponents development initiated.

SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT

Historical Summary and 1968 Budget Recommendations January 24, 1967

NEW OBLIGATIONAL AUTHORITY

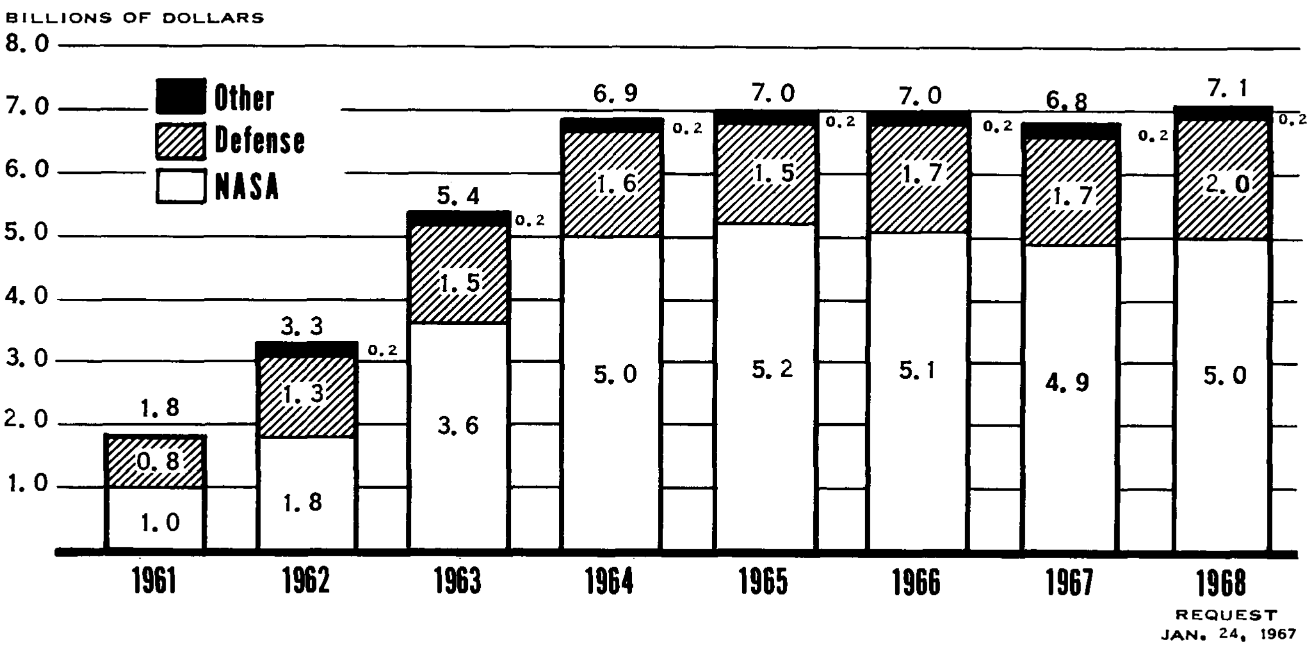
(In millions of dollars)

	NASA Total	NASA Space 1/	Dept. of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total Space
1955	56.9	56.9	3.0	--	--	--	--	--	59.9
1956	72.7	72.7	30.3	7.0	--	--	--	7.3	117.3
1957	78.2	78.2	71.0	21.3	--	--	--	8.4	178.9
1958	117.3	117.3	205.6	21.3	--	--	--	3.3	347.5
1959	305.4	235.4	489.5	34.3	--	--	--	---	759.2
1960	523.6	461.5	560.9	43.3	--	--	--	.1	1065.8
1961	964.0	926.0	813.9	67.7	--	--	--	.6	1808.2
1962	1824.9	1796.8	1298.2	147.8	50.7	--	--	1.3	3294.8
1963	3673.0	3626.0	1549.9	213.9	43.2	--	--	1.5	5434.5
1964	5099.7	5046.3	1599.3	210.0	2.8	--	--	3.0	6861.4
1965	5249.7	5167.6	1579.4	228.6	12.2	--	--	3.2	6991.0
1966	5174.9	5094.5	1692.8	186.8	26.5	4.1	--	3.2	7007.9
1968 Budget									
1967	4967.6	4864.2	1670.5	181.3	29.6	4.3	--	2.4	6752.3
1968	5050.0	4930.4	1998.3	151.6	34.8	4.8	0.4	2.8	7123.1

1/ Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA-NACA aircraft and space activities not separately identifiable prior to 1959.

Source: Bureau of the Budget

U.S. SPACE BUDGET · NEW OBLIGATIONAL AUTHORITY



NASC STAFF

SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT

Historical Summary and 1968 Budget Recommendations January 24, 1967

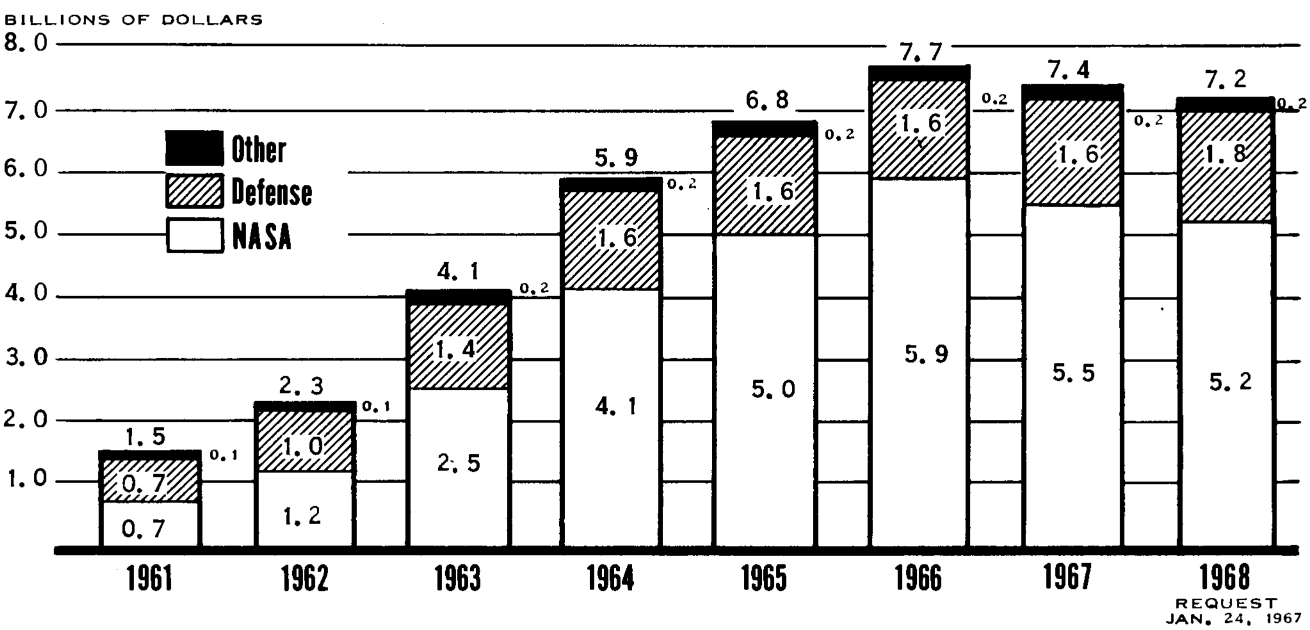
EXPENDITURES
(In millions of dollars)

	NASA Total	NASA Space 1/	Dept. of Defense	AEC	Commerce	Interior	Agriculture	NSF	Total Space
1955	73.8	73.8	1.5	--	--	--	--	--	75.3
1956	71.1	71.1	16.5	6.3	--	--	--	6.2	100.1
1957	76.1	76.1	47.5	19.2	--	--	--	7.3	150.1
1958	89.2	89.2	135.5	20.2	--	--	--	4.0	248.9
1959	145.6	58.8	341.0	32.6	--	--	--	1.5	433.9
1960	401.0	329.2	518.1	41.1	--	--	--	--	888.4
1961	744.3	693.6	710.0	64.3	--	--	--	--	1467.9
1962	1257.0	1225.9	1028.8	130.0	1.0	--	--	.9	2386.6
1963	2552.3	2516.8	1367.5	181.0	12.2	--	--	1.1	4078.6
1964	4171.0	4131.3	1563.5	220.1	12.3	--	--	2.6	5929.8
1965	5092.9	5035.0	1591.8	232.2	24.1	--	--	3.0	6886.1
1966	5933.0	5857.9	1637.4	188.3	28.1	4.0	--	2.8	7718.5
1968 Budget									
1967	5600.0	5505.0	1680.0	182.6	29.5	4.1	--	2.0	7403.2
1968	5300.0	5190.0	1840.0	152.2	40.1	4.6	0.4	2.4	7229.7

1/ Excludes amounts for aircraft technology in 1959 and succeeding years. Amounts for NASA-NACA aircraft and space activities not separately identifiable prior to 1959.

Source: Bureau of the Budget

U.S. SPACE BUDGET - EXPENDITURES



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SPACE ACTIVITIES BUDGET

1968 Budget Document

January 24, 1967

(In millions of dollars)

	New Obligational Authority			Expenditures		
	1966 (Actual)	1967 (Estimated)	1968 (Estimated)	1966 (Actual)	1967 (Estimated)	1968 (Estimated)
Federal Space Programs						
NASA 1/.................	5094.5	4864.2	4930.4	5857.9	5505.0	5190.0
Department of Defense. ...	1692.8	1670.5	1998.3	1637.4	1680.0	1840.0
Atomic Energy Commission	186.8	181.3	151.6	188.3	182.6	152.2
Department of Commerce..	26.5	29.6	34.8	28.1	29.5	40.1
Department of Interior.....	4.1	4.3	4.8	4.0	4.1	4.6
Department of Agriculture.	--	--	0.4	--	--	0.4
National Science Foundation	3.2	2.4	2.8	2.8	2.0	2.4
TOTAL	7007.9	6752.3	7123.1	7718.5	7403.2	7229.7
NASA						
Manned space flight......	3530.3	3398.2	3435.8	4210.2	3825.0	3575.0
Scientific investigations...	689.0	559.5	602.5	664.1	660.0	600.0
Space applications........	115.3	112.2	161.0	113.6	110.0	140.0
Space technology.........	403.7	384.8	424.3	435.4	450.0	440.0
Aircraft technology......	80.4	103.4	119.6	75.1	95.0	110.0
Supporting operations	333.8	349.6	366.8	434.6	460.0	435.0
Adjustments to NOA basis	+22.5	+60.0	-60.0	--	--	--
Total...............	5174.9	4967.6	5050.0	5933.0	5600.0	5300.0

1/ Excludes amounts for aircraft industry.

Source: Bureau of the Budget

INDEX

GSA DC 67-11743