

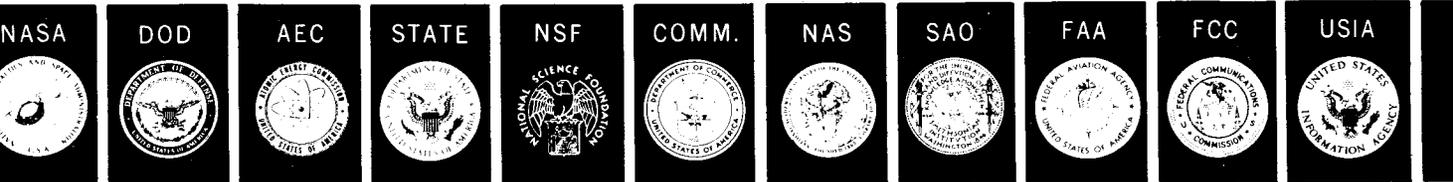
# REPORT TO THE CONGRESS

## FROM THE PRESIDENT OF THE UNITED STATES



### UNITED STATES AERONAUTICS AND SPACE ACTIVITIES

1964



**NOTE TO READERS: ALL PRINTED PAGES ARE INCLUDED,  
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# REPORT TO THE CONGRESS

## FROM THE PRESIDENT OF THE UNITED STATES



*EXECUTIVE OFFICE OF THE PRESIDENT*

NATIONAL AERONAUTICS AND SPACE COUNCIL

WASHINGTON, D. C. 20502

THE WHITE HOUSE

WASHINGTON

January 27, 1965

TO THE CONGRESS OF THE UNITED STATES:

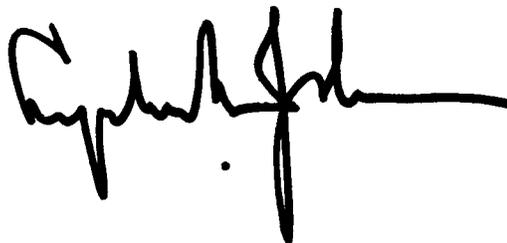
I am proud to transmit -- as I know the Congress will be proud to receive -- this review of the significant successes of our Nation's aeronautics and space efforts in the calendar year of 1964.

The advances of 1964 were gratifying and heartening omens of the gains and good to come from our determined national undertaking in exploring the frontiers of space. While this great enterprise is still young, we began during the year past to realize its potential in our life on earth. As this report notes, practical uses of the benefits of space technology were almost commonplace around the globe -- warning us of gathering storms, guiding our ships at sea, assisting our map-makers and serving, most valuably of all, to bring the peoples of many nations closer together in joint peaceful endeavors.

Substantial strides have been made in a very brief span of time -- and more are to come. We expect to explore the moon, not just visit it or photograph it. We plan to explore and chart planets as well. We shall expand our earth laboratories into space laboratories and extend our national strength into the space dimension.

The purpose of the American people -- expressed in the earliest days of the Space Age -- remains unchanged and unwavering. We are determined that space shall be an avenue toward peace and we both invite and welcome all men to join with us in this great opportunity.

In summary form, the accompanying report depicts the contributions of the various departments and agencies of the Government to the Nation's aeronautic and space accomplishments during 1964.

A handwritten signature in black ink, appearing to be "Lyndon B. Johnson", with a long horizontal flourish extending to the right.

# TABLE OF CONTENTS

Chapter I	U. S. Aeronautics and Space Activities -- 1964 Summary . . . . .	1
Chapter II	National Aeronautics and Space Council . .	5
Chapter III	National Aeronautics and Space Administration . . . . .	9
Chapter IV	Department of Defense . . . . .	41
Chapter V	Atomic Energy Commission . . . . .	63
Chapter VI	Department of State . . . . .	69
Chapter VII	National Science Foundation . . . . .	77
Chapter VIII	Department of Commerce . . . . .	81
Chapter IX	Space Science Board . . . . .	93
Chapter X	Smithsonian Astrophysical Observatory . .	99
Chapter XI	Federal Aviation Agency . . . . .	103
Chapter XII	Federal Communications Commission . . .	113
Chapter XIII	United States Information Agency . . . . .	119
Appendix A-1	U. S. Launching Record (Chart) . . . . .	124
Appendix A-2	U. S. Launching Record (Table) . . . . .	125
Appendix A-3	Successful U. S. Launches - 1964 . . . . .	126
Appendix B	SNAP Radioisotopic Electric Power Units for Space . . . . .	151
Appendix C	U. S. Space Launch Vehicles . . . . .	152
Appendix D	Major Communications Satellite Ground Terminals . . . . .	154
Appendix E-1	Historical Summary and FY 1965 Budget Recommendations (New Obligational Authority) . . . . .	156
Appendix E-2	Historical Summary and FY 1965 Budget Recommendations (Expenditures) . . . .	157
Appendix E-3	Space Activities Budget . . . . .	158
Index	. . . . .	159



# CHAPTER I

## U. S. AERONAUTICS AND SPACE ACTIVITIES 1964

### *SUMMARY*

Nineteen sixty-four was the year the United States began to reap significant dividends from the seven-year effort to conquer space. Almost commonplace were satellite storm warnings, television and communication transmissions spanning oceans and continents, all-weather navigational fixes for Naval ships at sea, precise map-making via satellite triangulation, and U. S. space launchings providing new information valuable to science and mankind on the average of once every five days.

Coupled with these dividends was the development of a capability which would help maintain freedom of space for all who would explore there. The operational deployment of two anti-satellite systems and over-the-horizon radar contributed security for the peaceful exploration of space. The addition of two more satellites to the nuclear detection system added greater safeguards for compliance to the Nuclear Test Ban Treaty.

The United States did not keep its space competence as a closely held secret or its space benefits as a national monopoly. Over 60 stations throughout the world read-out pictures from U. S. weather satellites aiding local foreign forecasts, and 12 stations owned by other countries have been, or are being built to receive television and communication transmissions from U. S. communications satellites. As part of the U. S. program to assist other nations in placing satellites into orbit, the United Kingdom's ARIEL II was launched, and the U. S. assisted Italy in its successful effort to become the third nation to build and launch a satellite: SAN MARCO.

Major accomplishments of 1964 included the photographing of the moon from a spacecraft, obtaining pictures 1,000 times clearer than those taken from earth observatories; the dispatching of a satellite on a picture-taking mission to Mars; and the orbiting of a large geophysical satellite.

Though the United States accomplished much towards its goal of space leadership during 1964, its chief competitor did not stand still. The Soviet Union successfully orbited a three-man spacecraft, also sent a spacecraft on its way towards Mars, and increased the number of satellites placed into orbit over the previous year 112 per cent. Their efforts reemphasized the Soviet intention to be the leading space power, and re-stressed the point that the U. S. cannot afford the luxury of complacency.

To meet the Soviet competition, and to achieve the objective of placing men on the moon within this decade, significant milestones were reached in the development and testing of large rocket boosters. Three times, the large SATURN I orbited almost 39,000 pounds -- a weightlifting record. Important successes were also made in the development of large solid, hydrogen, nuclear, and electrostatic powered rockets.

In many respects as outstanding as the new rocket achievements was the reliability attained by our time-tested boosters. For example, over a period of eighteen months the Atlas launch vehicle performed 26 consecutive successful flights for a reliability record of 100%. Other boosters also showed fine reliability scores. By exceeding anticipated reliability, such performance resulted in savings to the taxpayers for the missions accomplished.

Plans were studied to formulate goals for the space program after the manned lunar landing. Recommendations that Mars should be studied intensely with unmanned and manned spacecraft were given serious consideration.

The U. S. view that space should be a cooperative effort of many nations for peaceful purposes was forwarded by an international agreement with 19 countries for a global communications satellite system. The United States and the Soviet Union participated in a series of communication satellite experiments, and agreement was reached on the sharing of meteorological satellite data and the establishment of a direct Washington-Moscow data communications link.

The flight testing of three military aircraft with supersonic speed capabilities furthered U. S. competence in the field of aeronautics. Also, design and materials studies leading toward the development of a commercial supersonic transport were conducted.

Of particular note during 1964 were the following events and accomplishments.

... RANGER VII took 4,316 TV pictures of the lunar surface, showing details with 1,000 times the clarity of earth telescopes.

... MARINER IV started on its way toward Mars on a photographic mission.

... An orbiting geophysical observatory was placed into orbit to become the U. S.'s largest scientific satellite. Weighing more than 1,000 pounds, OGO I carried 20 different experiments -- a record number.

... SYNCOM III was launched into a "stationary" or synchronous orbit and provided live television coverage of the Olympic Games in Tokyo.

... The Department of Defense began to implement a decision to develop a military communications satellite system. They plan to use existing SYCOM and RELAY satellites during the interim period.

... The NIMBUS weather satellite photographed and reported cloud conditions during both day and night, and accurately measured temperatures of the earth's surface.

... TIROS VII successfully tested the automatic picture transmission (APT) system which gave direct read-out of regional weather patterns to 60 stations -- government and private -- throughout the world.

... Three SATURN I rocket boosters were launched as part of the APOLLO test program. Record weights of about 39,000 pounds were orbited.

... The TITAN IIIA space booster was successfully launched for the first time.

... Two anti-satellite systems became operational.

... The existence of an over-the-horizon radar system was announced.

... The VELA spaceborne nuclear detection project successfully orbited two additional satellites.

... Greater coordination of effort was attained in the space and aeronautics programs. Among major areas of such cooperation were: the use of the XB-70 aircraft to confirm theoretical and laboratory data of the supersonic transport program; the establishment of a national pool of instrumentation ships to meet the requirements of both NASA and DOD; and the common use of tracking, data acquisition, communication, and control facilities of the GEMINI B/MOL project.

... An international agreement was arrived at with 19 countries to provide the basis for a global communications satellite system.

... The military navigational satellite system was declared operational, and is in use with submarines and surface ships to provide precision fixes on a world-wide, all weather basis.

... The United States and the Soviet Union reached some degree of agreement on cooperation in bioastronautics, geomagnetics, and meteorological research.

... The F-1 and J-2 engines, destined to rocket the APOLLO spacecraft towards the moon, were qualified for flight.

... Liquid hydrogen became a powerful fuel ready for use in operational flight after successful tests of CENTAUR and the SATURN I's upper stage.

... An electrostatic (ion) engine operated in space for the first time.

... Gains in nuclear rocket propulsion were achieved when two KIWI reactors and one Nuclear Engine for Rocket Vehicle Application (NERVA) were tested at full power conditions.

- ... Two models of the APOLLO spacecraft were placed into orbit for test purposes.
- ... A 156 inch diameter segmented solid rocket motor was successfully static test fired, demonstrating the feasibility of constructing segmented motors of this size and weight.
- ... The XB-70 and the F111A passed their initial flight tests.
- ... The existence of an advanced interceptor system, the YF-12A, was announced.
- ... During its second year of activity, the Communications Satellite Corporation conducted technical studies, scheduled the launch of its first satellite (EARLY BIRD), issued stock to the public and the carriers, elected a board of directors, and signed an international agreement to act as manager of the initial global communications satellite system.
- ... The laser beam was successfully harnessed and used to track a satellite in orbit.
- ... The United States launched ARIEL II for the United Kingdom, and assisted Italy in its successful effort to become the third space-launching country with the orbiting of SAN MARCO.
- ... The EXPLORER family of diversified small scientific satellites increased more than 25 per cent in 1964.
- ... Data from several NASA Interplanetary Monitoring Probes revealed a new picture of our magnetosphere with supersonic winds of positively charged particles from the sun creating shock waves upstream from the earth's magnetic field and a long tail of the field downstream.
- ... Several successful flights of the ASSET winged reentry test vehicle were conducted at near orbital velocities to test radiative materials and structural concepts.
- ... The experimental NASA-DOD hypersonic rocket plane, X-15, entered its fifth year of powered flight and made its 121st successful flight to the edge of space.
- ... Also launched were the RELAY II and ECHO II for communications purposes, as well as Project FIRE for test heating of a spacecraft returning to the Earth's atmosphere from outer space.
- ... The U. S. placed about 73 payloads in earth and solar orbits.



## CHAPTER II

Nineteen hundred and sixty-four was a year of steady progress toward this Nation's objective of attaining and maintaining a front-ranking position in the exploration and utilization of space for the benefit of mankind. Among this year's many aerospace accomplishments were: three successful flights of the million and a half pound thrust SATURN I rocket; two launches of APOLLO model spacecraft into orbit; an orbital test of a GEMINI model spacecraft; significant advances in the ROVER nuclear rocket reactor program with five successful tests; the world's first close-up photographs of the moon's surface by RANGER VII; global night-time cloud pictures by NIMBUS I; orbiting of the first geophysical observatory; launching of SYNCOM III into a fixed position over the Pacific and providing space communications links between the Far East and the United States; continued progress in the X-15 experimental flights project; and attaining a major degree of success in improving our national security through the use of orbiting spacecraft.

During the year, the United States was successful in placing about 69 satellite payloads into earth orbit, raising the Nation's total from the beginning of the Space Age to approximately 248. Four payloads were sent to escape, raising the Nation's total to 10. In addition, with the assistance and cooperation of the United States, Italians constructed and launched a satellite from Wallops Island. This was numerically the most successful year for our space activity, and that is a source of encouragement. However, it should be noted that the year was by far the most active one in space for the Soviets, as they more than doubled the number of payloads orbited as compared with 1963. In fact, the relative acceleration of the Soviet space program was one of the most significant space features of the year 1964. Not only did they orbit the first multi-manned spacecraft, but they accelerated their entire space program.

Although only the United States and the Soviet Union were officially committed to carry out ambitious space missions around the earth, to the moon or the planets, it is becoming apparent that these great powers will not be able to maintain for long a monopoly on the techniques of space travel. Comprehensive knowledge of space operations has become more and more widespread, and it can be anticipated that satellite and escape payload launches will be made by other nations. In this march toward space mastery, the U.S. goal is to become the leading spacefaring nation and in so doing rededicate its efforts to improving and maintaining the peace. It is by this premise that the National Aeronautics and Space Council has been consistently guided.

The space effort is the focal point of diverse efforts in many technical areas essential to national excellence. In no small measure it has been a catalyst and a stimulus to education at all levels, especially in science and engineering. Educational goals and standards have already been raised substantially as a result of the challenges of space. While the value of the educational benefits cannot be given a definite price tag, in the long run the realizations from this feature alone may exceed the

total cost of the space effort.

Combining as it does the best talents in management, in engineering, and in science with the most modern facilities, the end result is the production of progress in education, research and development, productivity, employment, and the improvement of international relations.

Budgetary aspects of the space program received detailed critical review both within the Executive Branch and by the Congress. Significantly, both branches of the Government favored funding levels which represented continued support for a progressive space effort, even though the desired budgetary totals varied somewhat.

In the discharge of its responsibilities, the Council directly, and through its staff, engaged in a broad range of policy and coordinating activities. Among these were:

- a. supervised the preparation of the President's Annual Report to the Congress on Aeronautics and Space Activities for 1964.
- b. submitted frequent reports to the President on significant space activities.
- c. increased the public understanding of the national space program through speeches, articles, public appearances, and interviews.
- d. participated in the analysis and development of the FY 1966 budgets for aerospace.
- e. reviewed the coordination of the national geodetic satellite program and of the meteorological satellite systems, the radiation hazards of manned interplanetary flight, and the instrumentation ship support for space operations.
- f. assisted in the formulation of communication satellite policies, including governmental relationships with the Communications Satellite Corporation, and the development of international agreements for a global ComSat system.
- g. coordinated the settling of policy issues regarding the launching of auxiliary nuclear-powered devices aboard spacecraft.
- h. made technical studies of propulsion technology, including high-energy upper stage air augmentation of launch vehicle and gaseous-core nuclear reactors.
- i. visited space installations, examined facilities, and discussed space developments and problems with managerial and technical specialists.
- j. engaged in numerous interagency as well as government-industry meetings and briefings on new developments in space technology and space benefits.
- k. participated in the decision to make facilities available for TV broadcast of the 1964 Olympics by communication satellite.

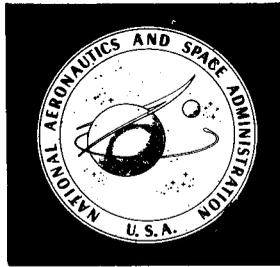
- l. assisted in technical studies of cooperative arrangements for the location of U.S. overseas space installations.
- m. cooperated with committees of the Congress in matters affecting space plans and programs.
- n. aided in the development of the U.S. positions on space-related matters in meetings of the United Nations.
- o. maintained a current record of U.S. and Soviet space launches, developed comparisons between U.S. and U.S.S.R. space activities, and reviewed space accomplishments and potentials of other nations.

The Space Council activity was not characterized by formal meetings during the year. This was due in large measure to the vacancy in the position of Chairman. Although the President had identified the Executive Secretary as Acting Chairman during this hiatus, the functioning was mostly on the basis of reports to the President, interagency staff contact, exchange of memoranda, informal meetings, and like measures.

The year 1964 revealed a much improved degree of cooperation and coordinating action as between the major agencies engaged in the national space program. Not only was there improvement in the exchange of information between such agencies, but there also was a useful interagency assignment of experienced personnel. Moreover, the space program stood as a symbol of close and effective government-industry teamwork. It revealed effectively how vital elements of a free society could join together to meet major challenges and to meet them successfully.

The impact of the national space program upon man's standard of living, national security, education, and accumulation of knowledge is tremendous. Outstanding is the impact of the program upon man's way of living in peace and freedom. In fact, the benefits from the national space program run the gamut from new production processes to new approaches to world peace. Science and technology play a great role, not only in influencing public policy but in making intelligent policy decisions possible. The U.S. space program is now firmly established as a national asset of proven worth and incalculable potential.

Our national space program has reached such a stage of early maturity that the challenge is no longer whether to go into space, but rather is what should we do next and how soon.



INTRODUCTION

During 1964, the National Aeronautics and Space Administration continued to make progress in developing the equipment and technology to help attain U.S. preeminence in space science and technology.

Design, manufacture, ground, and flight test milestones achieved in the GEMINI and APOLLO programs reflected major technological advancements and gave evidence that a broad and basic operational capability was being developed for the manned exploration of space.

Accomplishments in the scientific investigations of space and in satellite applications were likewise significant. Particularly impressive was the successful RANGER VII mission, during which thousands of high-quality pictures of the moon's surface were transmitted back to earth. Also important were the TIROS VIII cloud picture transmissions and the SYNCOM III communications relay tests.

NASA also moved forward in its advanced research and technology programs with the successful testing of a life support system able to maintain five men in a sealed chamber for a month; ground tests of nuclear rocket reactors to propel spacecraft; and a space test of an electric rocket engine.

All other programs contributed support as the Agency moved steadily toward the National goal of manned lunar exploration within this decade.

MANNED SPACE FLIGHT

In its manned space flight program, NASA made progress in both the GEMINI and APOLLO programs. These advances included extensive progress in space vehicle hardware design, manufacture, ground testing, and flights in both projects; substantial progress in the construction of necessary industrial, test, and operational support facilities across the nation; and the definition of advanced manned missions program requirements.

The nation's government-industry manned space flight team reached its peak strength by the end of 1964, when the combined work force totaled about 300,000.

The Manned Spacecraft Center (MSC), Houston, Tex., became operational during the year with the completion of twelve laboratory, administrative, and support facilities, permitting the move to the Clear Lake site from leased space and from Ellington Air Force Base. At Cape Kennedy's Merritt Island Launch Area, facilities for spacecraft operations and checkout were placed in operation. Progress was also made in construction at the Mississippi Test Facility, with the first units placed in service.

Progress was made in the GEMINI program to develop a general purpose two-man spacecraft system, in the APOLLO program to begin manned lunar exploration in this decade, in the planning of mission operations, and in the study and planning of possible advanced manned missions.

During 1964, the U.S. carried out six successful major unmanned launchings in its manned space flight program--three SATURN I missions, two carrying boilerplate APOLLO spacecraft for unmanned orbital tests; one GEMINI orbital mission; and two suborbital tests of the APOLLO spacecraft. These extended to 20 a series of successful launches of manned and unmanned payloads which began in April, 1961. (The total includes three unmanned and six manned MERCURY flights, seven SATURN I flights, one in GEMINI, and three suborbital APOLLO tests.)

### GEMINI Program

The GEMINI program, in which the U.S. is taking the second step in manned space flight, reached the flight operational phase in 1964. During the year, the first flight test was carried out successfully and nearly all preparations were completed for the second, which will finally qualify the system for manned flights.

Progress was made in the development, production, and test qualification of GEMINI equipment for the planned program goals of rendezvous missions and extended earth orbital flights of up to 14 days. The GEMINI system, built around a general purpose 2-man spacecraft suitable for a variety of operations and experiments, will provide capability for maneuvering in orbit, rendezvous and docking of the spacecraft with a target vehicle, post-docking maneuvers of the mated vehicle, and egress of astronauts into space.

The primary and alternate two-man crews were selected for the first two manned flights and were undergoing intensive training. Flight Commander and Pilot for the first will be Virgil I. Grissom and John W. Young, with Walter M. Schirra, Jr. and Thomas P. Stafford as the backup crew. James A. McDivitt and Edward H. White were named as the flight crew for the second, with Frank Borman and James A. Lovell, Jr. as backup.

Progress was made in the GEMINI spacecraft and the launch vehicle, a modified Air Force TITAN II, and in the target system - a modified AGENA D and ATLAS standard launch vehicle.

GEMINI spacecraft No. 2 underwent checkout at the new facilities constructed in 1964 at the Cape Kennedy Merritt Island Launch Area. GEMINI Spacecraft No. 3 was in the final stage of systems test before delivery to Cape Kennedy for mating to the launch vehicle for the first 1965 manned mission. Test articles of the various subsystems were subjected to intensive development, qualification, reliability, and systems testing to qualify them for the manned mission. Nine other GEMINI spacecraft were being manufactured and assembled or were undergoing spacecraft systems test at the manufacturer's plant.

Additional parachute drops were made to evaluate the landing system, using two of the non-flying spacecraft. Flotation and egress tests were successfully conducted under actual sea conditions in Galveston Bay with test spacecraft and astronauts. Additional water landing impact tests were conducted to qualify the structure for all

possible landing conditions.

NASA made significant progress in qualifying the fuel cell production hardware as a prime electrical power source for the spacecraft. The fuel cell will be used in place of batteries to meet the increased power requirements for later missions. Also, the agency furthered development and qualification of the spacecraft on-board propulsion system which maneuvers the spacecraft while in orbit. The propulsion system has demonstrated its capability to meet the long periods of operation required for rendezvous missions.

The launch vehicle, procured for NASA by the Air Force Space Systems Division, was modified to comply with the safety requirements for launching a manned spacecraft. At year's end, one vehicle had been launched, one was in final preparation for launch, and a third was ready for shipment to Cape Kennedy. Other vehicles were being tested, assembled, or were in various stages of manufacture.

The target system also was being procured through the Air Force Space Systems Division. The first basic AGENA D, received in early 1964, was modified to the GEMINI configuration and was undergoing systems tests at the manufacturer's plant. Flight qualification of the propulsion systems was essentially completed.

Spacecraft water recovery equipment was developed and being produced. Three Department of Defense range tracking ships were modified to support flight control of the spacecraft. Two mission simulators were completed and put into use to train the astronauts in flying their assigned GEMINI mission. Other training was devoted to academic matters, spacecraft systems test, centrifuge, pre-flight, and egress operations.

A Mission Control Center for manned space flight was among the mission support facilities nearing completion at Houston. This MSC facility will serve as backup for the early GEMINI missions controlled from the Cape Kennedy Mission Control Center, and will be the primary center for worldwide network operations on GEMINI rendezvous missions and all APOLLO missions.

In flight operations, planning and documentation for the first manned GEMINI flight was complete. Negotiated agreements with various foreign countries were made for prepositioning spacecraft recovery forces to recover the spacecraft after reentry and landing, should the spacecraft be forced to land in an area other than the planned primary target area.

The first of two scheduled unmanned flight missions was successfully conducted in April. This mission demonstrated the structural integrity and compatibility of the spacecraft and the launch vehicle; it also validated the performance capability of the launch vehicle.

The second mission, scheduled for early in 1965, will provide inflight qualification of the spacecraft and subsystems and will demonstrate the capability of the spacecraft to successfully reenter the earth's atmosphere. This mission will essentially complete flight qualification of the spacecraft and the launch vehicle, setting the stage for the first GEMINI manned mission scheduled in the spring of 1965.

The first GEMINI manned flight is planned for three orbits of the earth, with the next two flights to be long duration missions. The fourth manned flight will be the first in which the GEMINI spacecraft will rendezvous with the AGENA target vehicle previously launched into earth orbit from Cape Kennedy by an ATLAS booster during the GEMINI countdown. On this rendezvous mission the on-board radar and computer will be used, one of several rendezvous techniques to be tested.

The experiments program for GEMINI was established to obtain more data on man's ability to survive and perform useful work in space. A Manned Space Flight Experiments Board, established late in 1963, was formally organized in February of 1964 to review experiments submitted by the scientific community and government agencies. Forty-nine experiments were selected for the GEMINI program: ten medical experiments, eighteen DOD technological experiments, nine engineering experiments, and twelve scientific experiments. Modifications of various spacecraft to accommodate the experiments were complete or in process.

### APOLLO Program

During 1964, the APOLLO program also continued to make progress. Adhering to rigid cost, schedule, and performance commitments, the APOLLO government-industry team accomplished gains in each of its program elements: detailed program planning and definition; design and development of large launch vehicles and the necessary rocket engines, sophisticated spacecraft, comprehensive ground support equipment, and worldwide mission support facilities; and development of trained space flight crews and support teams. Intensified program status review and control procedures were adopted by APOLLO management as the program approached its peak effort.

The overall advancement of the APOLLO program during 1964 provides a strong basis for confidence in successful fulfillment of all program objectives within the allotted time and cost while establishing U. S. pre-eminence in manned space flight.

Spacecraft--Major milestones were reached in 1964 in development of the APOLLO spacecraft, which incorporates command, service, and lunar excursion modules and provides extensive capability for maneuvering in space. In the lunar mission, the command module will transport the three-man APOLLO crew on its flight to lunar orbit; the two-stage lunar excursion module will carry two of the crew to a lunar landing and return to the command module in lunar orbit; the service module will carry scientific instruments, the electrical power generation system, oxygen for the command module life support system, and the propulsion system for in-flight velocity corrections and return to earth.

Early in 1964, the engineering design was frozen for the APOLLO command and service module configuration to be used for the APOLLO earth-orbital missions. Following an October review of full scale mockups, final design was in progress for the later configuration of the APOLLO command and service modules, incorporating 80 percent of the preliminary design. The later configuration will provide rendezvous and docking capability for the lunar APOLLO missions.

The lunar excursion module also reached near final design during 1964, and work progressed on the 11 LEM subsystems. A metal mockup with fuel cells, environmental controls, reaction control thrusters, rendezvous radar, and other subsystems

installed was inspected in October. Parallel development of two variable thrust engines for lunar landing of the LEM moved forward. Successful tests of the injector and thrust chamber spurred the development of the LEM ascent engine.

At year's end, manufacturing of components and subsystems was 85 percent complete for the spacecraft to be flown in the first unmanned mission of the APOLLO earth-orbital space vehicle, scheduled for early 1966. Ground testing and qualification of all systems and equipment supporting the second earth-orbital mission was well under way.

Four successful unmanned flight tests of APOLLO boilerplate spacecraft were carried out during the year; two were suborbital flights from White Sands Missile Range, New Mexico, in May and December, and two were orbital flights from Cape Kennedy aboard SATURN I launch vehicles.

The APOLLO spacecraft contract was extended in 1964 to include 16 spacecraft for the APOLLO missions, 18 boilerplate spacecraft for developmental test, four engineering simulators and evaluators, and two mission simulators for crew training. By the end of 1964, 16 boilerplate spacecraft for ground testing had been delivered, and the two others were nearly complete.

At White Sands Missile Range, the APOLLO spacecraft propulsion development test facilities were completed and placed in operational status. Also, the Lunar Excursion Module (LEM) test facilities neared completion. Facilities were essentially completed for APOLLO spacecraft development at Downey, California. Included were facilities for development, qualification testing, fabrication, operations, and check-out of the command and service modules.

Launch Vehicles--Development of the SATURN I, IB, and V series of launch vehicles for the APOLLO program proceeded at a rapid pace in 1964. Three successful flights of the complete, two-stage SATURN I launch vehicle, using a liquid hydrogen-fueled second stage, gave three demonstrations of its power to boost into orbit the heaviest known space payload.

The launch vehicle technology development phase of the SATURN I, first in the SATURN series, was essentially completed with the first two launches in 1964, or a total of six developmental launches instead of the ten originally scheduled. All seven SATURN I launches have been highly successful in meeting assigned objectives. The seventh flight (September 18), boosting an APOLLO boilerplate into orbit, was in essence an operational flight since the remaining SATURN I vehicles will be used operationally to orbit the unmanned PEGASUS micrometeoroid-detecting spacecraft.

Many important accomplishments were registered on the 1964 flights of the SATURN I. A kerosene-fueled first stage with total thrust of 1.5 million pounds was placed in operation. A second stage consisting of six liquid hydrogen-liquid oxygen engines was successfully developed. The guidance system to be used in the SATURN IB and SATURN V launch vehicles was proved flight-worthy. A new launch facility, Complex 37B at Cape Kennedy, was placed in operation. And a launch vehicle with the ability to place up to 22,500 pounds in earth orbit was added to the family of operational U.S. vehicles.

While SATURN I was completing the first step in the SATURN launch vehicle development, preparation advanced steadily for flight tests of the two-stage SATURN IB. Early in the year, specifications were defined for the more powerful SATURN IB, with an 8-engine first stage generating thrust of 1.6 million pounds, and a new single-engine liquid hydrogen-liquid oxygen second stage. The IB has a payload capacity of 35,000 pounds; it will provide the launch power for APOLLO's earth orbital missions.

Manufacturing of both the SATURN IB stages began in 1964. By the end of the year, structural testing was 95 percent complete on the first stage and 80 percent complete on the second stage.

Initial design was completed in May for the three stage SATURN V launch vehicle, which will weigh six million pounds at launch. Generating a 7.5 million pound thrust in its five-engine kerosene-fueled first stage, the SATURN V will provide the power to launch manned APOLLO lunar missions. It was uprated in 1964 to enable it to place a 280,000 pound payload into earth orbit or a 95,000 pound payload on a lunar trajectory. During the year, mockups were completed and the vehicle stages for ground and flight tests continued steadily through assembly and early testing.

Successful tests of the SATURN V rocket engines were completed in 1964, including flight rating tests of the kerosene-liquid oxygen first stage F-1 engines and the liquid hydrogen-liquid oxygen J-2 engines for the second and third stages. The F-1 tests overcame a problem of combustion instability and verified that the F-1 is now ready for cluster firings and actual flight.

At Santa Susana, California, a new J-2 engine test stand and the SATURN V second stage test firing stand became operational. At Edwards Air Force, California, three new F-1 engine test stands became operational. Engine development and production equipment was installed at Canoga Park, California and production of engines was started. The test complex for the S-IVB test and development program at Sacramento, California was almost complete. One test stand became operational and a second was near completion.

At the Michoud Plant in New Orleans, La., where production of the SATURN IB and SATURN V booster stages is underway, a new engineering building was completed. Also, construction of the stage checkout facility was nearing completion, and improvements were initiated for the road system that will be used to transport stages to Port Michoud. SATURN V second stage assembly and test facilities at Seal Beach, California, were substantially complete and in various stages of operation.

Mission Operations--As production and ground testing activity approached peak levels in 1964, considerable effort was building up in preparation for APOLLO mission operations, which comprise space vehicle launch and flight operations, experiment planning, crew readiness training, flight controller training, the worldwide manned space flight network, the Mission Control Center, and recovery support.

Planning of APOLLO recovery operations using ocean surface vessels and aircraft was carried out in considerable detail. Recovery requirements were published and liaison established with the Department of Defense. Training of NASA and

Department of Defense personnel was well under way.

In APOLLO, mission operation was defined in detail. In the interface between the launch vehicle and the spacecraft, a spacecraft guidance and control backup of the primary launch vehicle during the early powered flight phase was established. APOLLO ground tracking stations were selected as the primary navigation system for the APOLLO lunar mission after the spacecraft achieves earth orbit. Backup will be provided by the on-board navigation and guidance capability of the spacecraft and crew. Use of the ground navigation system will allow greater flexibility in determining initiation of the earth - moon flight and in execution of flight path corrections by the flight crew upon receipt of tracking information from the earth.

The space environment was reassessed on a continuing basis in 1964, as the scientific community and NASA's Office of Space Science and Applications provided information pertinent to the design of in-flight protection required against radiation, micrometeoroids, and other environmental conditions. A set of reference trajectories was completed describing conditions under which the APOLLO lunar mission can be carried out.

APOLLO astronaut training was intensified. General training activities included science and engineering, flight and parachute training, physical conditioning, zero gravity orientation, and training for desert and tropical survival.

Specific training for APOLLO crew participation included work with systems trainers, a part task trainer, an egress trainer, a centrifuge, and a mission simulator. A free flight lunar landing research vehicle, which will eventually become a training device, flew for the first time in 1964. It will simulate flight dynamics in a lunar gravity environment to train the crew for LEM flight operations.

Increased emphasis was placed on scientific training, both in the classroom and in the field. Instruction was continued in geology, mineralogy, petrology, and other related subjects. These studies will enable the astronauts to identify meaningful features of the moon's surface, and to collect representative samples.

In addition to classroom and laboratory work, the astronauts studied geological phenomena throughout the western U.S., with special training in lava flows with the apparent roughness and topography of lunar terrain.

Significant accomplishments were achieved during 1964 in space medicine activities of the manned space flight program.

The coordination of the NASA Space Medicine and Air Force Bioastronautics programs was completed for Fiscal Year 1964 and 1965. Coordination of the programs and exchange of technical information at the task-scientist level was facilitated by the NASA liaison office at the Aerospace Medical Division, Brooks Air Force Base, Texas.

NASA and the Air Force organized an ad hoc Space Medicine Advisory Group to consider medical problems involved in orbiting research laboratories and to recommend experiments for these missions. Additionally, the Agency initiated a contract with the Atomic Energy Commission to bring together information relating to radiation problems that may be encountered in manned space flight.

Experiments for the first manned APOLLO earth orbiting mission were selected late in 1964 by the Manned Space Flight Experiments Board.

In October NASA began receiving applications from scientists and engineers for participation in a scientist-astronaut training program to be begun in 1965. About 1,000 applications were received. This program for 10 to 20 qualified personnel with scientific, medical, or engineering specialties, will assure maximum scientific benefits from lunar exploration. Selection of candidates will be carried out by mid-1965 in conjunction with NASA's Office of Space Science and Applications, and the National Academy of Sciences. The scientist-astronauts will be trained in aircraft and helicopter operation and other basic astronaut oriented subjects and skills to prepare them for participation in manned space flight.

Launch Operations--Most of the approximately 88,000 acres comprising the Merritt Island Launch Area (MILA) at Cape Kennedy, Florida were acquired during 1964. The Merritt Island railroad was completed and the construction program for the industrial area kept pace with progress on Launch Complex 39, where APOLLO/SATURN V flights will begin. Within the MILA industrial area, nine major buildings became operational and two causeways were finished.

At the end of the year, the steel framework of the Vehicle Assembly Building (VAB) at Launch Complex 39 stood more than 400 feet high. When completed, this building will be 524 feet high and almost as wide and deep, providing assembly and checkout space for the 360-foot APOLLO/SATURN V space vehicle.

One mobile launcher for Launch Complex 39 also was fabricated and erected, while construction of a second launcher was started. Work began on the on-site assembly of the football field-size crawler-transporters for moving the assembled APOLLO space vehicle from the VAB to the launch pad in vertical position. Also under construction were the pads, crawler-ways, related supporting buildings, and the mobile servicing tower.

In all areas of the APOLLO program... spacecraft, launch vehicle, and mission operations, consistent progress was made in 1964 toward timely achievement of the key program milestones leading to accomplishment of the complex mission of lunar landing and safe return to earth of the APOLLO space flight crew.

#### Organizational Realignments

Late in December, NASA announced key organizational changes to meet the requirements imposed by concurrent GEMINI and APOLLO launch schedules. Included were creation of a new position, Mission Operations Director, Office of Manned Space Flight, at NASA's Washington headquarters; and two Mission Directors reporting to the Mission Operations Director. The Mission Directors, working from Washington, will have overall responsibility for the mission to which they are assigned.

Other realignment of elements in the Manned Space Flight organization was effected by creation of an Operations Support Requirements Office in the Office of Mission Operations; transfer of the Manned Spacecraft Center's Florida Operations to the Kennedy Space Center; and establishment of the position of Director, Launch Operations.

## Advanced Manned Missions

Studies of possible advanced manned missions conducted in 1964 gave increased evidence of the advisability of basing plans for the immediate future on the exploitation of the capabilities being created in the APOLLO program. These capabilities include trained people, a base of industry throughout the U.S., versatile ground facilities, powerful launch vehicles, advanced spacecraft, operations know-how, and the ability to manage very large research and development efforts.

Studies and plans for possible advanced manned missions were carried out in conjunction with thorough evaluation of the state of technology. These assessments covered technology employed in presently approved programs, and the NASA advanced Research and Technology programs.

To prepare for alternate APOLLO missions and other advanced missions representing future manned progress in space, effort was devoted to the investigation, analysis, conceptual design, and evaluation of such missions. Beyond the GEMINI and APOLLO programs, three broad possibilities are being examined.

First, alternate and growth concepts will be provided as a contingency within the scope of these programs. The APOLLO spacecraft and system can be used for other earth orbital or lunar missions.

Second, concepts were being examined for the logical extension of the approved programs, with some modification to the in-development hardware. For example, modification of the APOLLO spacecraft could make possible extremely long earth-orbit missions.

Finally, there were studies of the manned mission concepts which would require major new development efforts for their implementation.

Studies of future mission possibilities indicated three rather broad areas: earth orbital operations, lunar operations, and planetary operations. In the earth orbital area, long duration missions would permit long term biomedical, engineering, and scientific research to be carried out in the space environment. They would also provide a test bed for the experiments and operational tests relating to future manned earth-orbital and deep-space missions, as well as means of using approved flight hardware for such purposes and maneuver and rendezvous in other modes than those of approved missions.

In the area of lunar operations, beyond the basic APOLLO mission, identifiable activities include the following: exploration of the lunar surface in detail from lunar orbit or on the surface; establishment of semi-permanent and perhaps permanent bases and outposts for extensive observations of the universe; and the use of the resources of the moon, itself. And in area of planetary operations, mission analyses were being performed to define an overall exploration program and the early research and development needed to lay a basis for later systems development.

All advanced manned space operations are dependent upon launch vehicle capabilities. Presently-approved launch vehicle programs provide for increasing capabilities over the next few years, culminating in the SATURN V vehicle. It may be possible to provide even greater payload capability for the advanced missions by uprating the SATURN IB and SATURN V in a number of ways; analyses were being conducted to

evaluate these possibilities. However, new and more powerful launch vehicle stages may be required for some of the advanced missions being considered, particularly the planetary ones. Concepts for such vehicle stages were being studied.

Altogether, in the areas of earth-orbital, extended lunar, and planetary missions, NASA moved forward considerably in 1964 in defining the available capabilities and the next steps to be taken to advance manned space flight beyond the scope of present programs.

### SCIENTIFIC INVESTIGATIONS IN SPACE

The past year witnessed a number of noteworthy advances in NASA's scientific investigations in space. Among these were:

- a. launching of the first Orbiting Geophysical Observatory with 20 integrated experiments designed for simultaneous observations of space phenomena.
- b. orbiting of an interplanetary monitoring satellite (EXPLORER XXI), an ionosphere sounder (EXPLORER XX), a micrometeoroid hazard satellite (EXPLORER XXIV), an energetic particles and fields satellite (EXPLORER XXV), and a satellite to study radiation in the Van Allen belt (EXPLORER XXVI).
- c. first orbiting by NASA of two satellites with one launch vehicle (EXPLORERS XXIV and XXV).
- d. first launching by NASA of a satellite completely designed and built by a university (EXPLORER XXV).
- e. first satellite launch operation in the NASA international cooperative program conducted by a team of foreign nationals.
- f. discovery by instrumented rockets of new sources of x-rays in the nighttime sky and the transmission of ultraviolet spectra of Mars, Venus, and Jupiter.
- g. establishment of a National Geodetic Satellite Program and initiation of work on the GEOS satellite.

### Flight Programs

Ten earth satellites were launched during 1964 in NASA's physics and astronomy programs ushering in an era of greater precision in evaluating overall data on space phenomena, at the same time exacting more detailed knowledge of earth's space environment as a whole from observing scientists.

Seven of these spacecraft were of the EXPLORER class-the twentieth EXPLORER orbited on August 25; EXPLORER XXI on October 3; EXPLORER XXII on October 9; EXPLORER XXIII on November 6; EXPLORERS XXIV and XXV both on November 21; and EXPLORER XXVI on December 21.

Others were the second ARIEL U.S.-U.K. geophysical satellite launched March 27; the first Orbiting Geophysical Observatory, weighing 5 to 10 times as much as the EXPLORERS, placed in orbit September 4; and the Italian SAN MARCO satellite launched December 15.

EXPLORERS--EXPLORER XX was launched primarily to study the earth's ionosphere using six fixed radio frequencies. The satellite will seek out the finer details of the ionosphere. These data include the height of the ionosphere above the earth, motions of irregularities, the number of electrons between EXPLORER XX and the ionosphere, and ion composition.

An Interplanetary Monitoring Platform (IMP) type of satellite, EXPLORER XXI was designed to study radiation in space beyond the limits of the earth's magnetosphere. Furnishing data regarding the hazards of this radiation for astronauts, the satellite measures magnetic fields which it traverses, plasma which it encounters, and energetic electrons, ions, and cosmic rays coming to earth from space.

EXPLORER XXII determines the electron count in the ionosphere between the satellite and the earth by radio transmission. This spacecraft was also equipped to study the observation of the orbital positions of satellites by taking advantage of the short wavelengths of light in a laser beam, a procedure promising greater accuracy.

EXPLORER XXIII was launched from Wallops Island with a SCOUT launch vehicle. The upper stage went into orbit with instrumentation designed to investigate the hazards created by impacts of micrometeoroids. It reports micrometeoroid flux and effects.

EXPLORERS XXIV and XXV were launched simultaneously with a single SCOUT vehicle. EXPLORER XXIV is a twelve-foot sphere that continues the measurement of EXPLORER XIX on atmospheric drag and density through orbital tracking. EXPLORER XXV was designed and built by the State University of Iowa as the fourth INJUN spacecraft for use in the measurements of energetic particles and magnetic fields in space.

EXPLORER XXVI was launched on December 21. It carried five experiments designed to study natural and man-made radiation.

ARIEL II--The second U.S.-U.K. geophysical satellite, ARIEL II, was orbited from Wallops Island, Va., in March by a SCOUT launch vehicle. The spacecraft was developed in this country; its experiments were designed and its instruments built by British scientists. It investigates galactic radio noise from space, the vertical distribution of ozone in the upper atmosphere, and micrometeoroid flux from space.

Orbiting Geophysical Observatory--OGO-I (the first Orbiting Geophysical Observatory) was launched September 4. Weighing more than a 1,000 pounds, this earth satellite was placed in a highly elliptical orbit ranging from 175 miles to a height of 92,721 miles. The 20 experiments aboard were designed to take simultaneous readings and produce an integrated study of the earth's magnetic field, radiation in space about the earth, and the interaction of the two.

While the launch of OGO-I was successful, two of the experiment booms failed to deploy properly and interfered with the attitude control, thus preventing the observatory from stabilizing in orbit and pointing at the earth. Despite the fact that the

satellite is spinning or tumbling in space and is therefore considered a failure, useful data is being received from many of the scientific experiments and the mission is considered to have contributed significantly to the understanding of the earth-sun relationships.

SAN MARCO--The SAN MARCO satellite was designed and built by Italian scientists and space technologists. Its launch by an American-trained Italian crew marks the first time in the NASA international cooperative program that a NASA satellite launch operation was conducted by a foreign team. The SAN MARCO satellite provides measurements of air density by an original method that makes use of two concentric spheres.

Sounding Rockets--In addition to EXPLORERS XX through XXVI, ARIEL II, OGO-I, and SAN MARCO, NASA launched 100 sounding rockets in 1964. These rockets investigated x-rays coming from outer space and the distribution of sodium in the atmosphere, and obtained ultra-violet spectra of Mars and Venus. They also studied the whitish green night airglow in the atmosphere described by U.S. astronauts, and examined earth's magnetic field and its interaction with solar plasmas.

RANGERS VI and VII--On July 31 the six TV cameras of RANGER VII transmitted to earth 4,316 high-quality photographs of the moon's surface--pictures with a resolution 3,000 times greater than those ever supplied by the most powerful telescope. Data furnished by the spacecraft were being studied by NASA's geophysicists and astronomers and being made available to scientists throughout the world. The photographs have already contributed substantially to the Nation's manned lunar program at the same time advancing significantly scientific knowledge in this area.

Although successfully launched on January 30, the sixth RANGER failed to take the planned photographs of the lunar surface. However, it impacted the moon on February 2 only 20 miles from its aiming point, supplying invaluable data to engineers designing spacecraft for lunar missions and providing a great deal of information on the gravitational fields of the earth and the moon.

The last two RANGER flights are scheduled for early 1965. Their mission will be to obtain additional high-resolution photographs of the moon's surface at other locations to help pave the way for manned lunar exploration and provide further information to scientists.

MARINER Mars Flyby-- MARINER IV was launched on November 28 on a flyby of Mars. This spacecraft is similar to MARINER II, which performed the first successful planetary mission to Venus in 1962, although its technology is considerably advanced. The trip to Mars will take more than eight and one-half months during which time it will travel over 350 million miles. In addition to performing scientific measurements in the vicinity of the planet, it will also, if successful, take a series of TV photographs along a narrow strip of the Martian surface. The spacecraft is currently on a trajectory that will carry it to within about 5,000 miles of Mars.

The MARINER III launch of November 5 failed to place the spacecraft in the proper trajectory when the booster rocket's second stage failed to burn long enough.

As MARINER IV goes behind Mars its radio signals will pass through the planet's atmosphere. By studying the effect of the atmosphere on the frequency and strength of the transmitted signals, certain characteristics of the space environment can be determined.

PIONEER--A contract for the design and development of four PIONEER spacecraft to be used to explore interplanetary space was awarded by NASA in 1963. Integration of the scientific payload with the prototype PIONEER spacecraft began in November 1964. The first flight was scheduled for launching late in 1965.

PIONEER will measure magnetic fields, solar plasma, energetic particles, and cosmic dust in a 35-million mile wide belt extending along an orbital path 50-million miles ahead of and behind the earth.

Planetary Studies--During the past year several possible concepts for future Mars missions were studied to aid in planning planetary exploration following the 1964 MARINER flight. Flyby, orbiter, and capsule-lander missions were evaluated for the ATLAS-CENTAUR, TITAN III-C, three-stage SATURN I-B, and SATURN V launch vehicles. These studies indicated that several of the follow-on missions appeared to have considerable scientific value and that missions based on the three-stage SATURN I-B vehicle will ultimately be required to explore Mars thoroughly.

Preliminary studies were also conducted of Jupiter, Mercury, comet, and asteroid missions to estimate mission profile, spacecraft technology, and launch vehicle requirements for future space science programs.

LUNAR ORBITER--NASA signed a contract, in May, for the development of the Nation's first satellite of the moon-LUNAR ORBITER. Cameras aboard the satellite are designed to provide high-quality pictures of considerable areas of lunar surface and assist in picking out landing sites for future manned and unmanned spacecraft.

SURVEYOR--NASA made substantial advances in 1964 in the program to soft land a payload on the moon. Studies continued on the possibility of building small lunar-surface roving vehicles to be flown aboard more advanced SURVEYORS to conduct surveys and explore various features of particular interest to scientists.

### Bioscience Programs

Biosatellites--NASA has contracted for the design, fabrication, testing, and delivery of six recoverable biosatellites for launch from Cape Kennedy beginning in mid-1966. To be orbited by THOR-DELTA rockets for three days to a month, these biological satellites will be used to study the effects of radiation, weightlessness, and other outer space stresses on various life forms through experiments with single cells, insects, plants, rats, and monkeys.

The 20 biological experiments were selected from over 185 proposed by prominent life scientists throughout the United States. Each experiment package was designed, fabricated and tested from conceptual through prototype stages.

Life Support System for Spacecraft--Scientists have developed a biological regenerative life support system able to produce oxygen, food, and water from astronauts' waste products during extended space flights. This system uses electrolysis of

water and Hydrogenomonas (soil) bacteria. The bacteria utilize hydrogen and carbon dioxide and urine from space explorers to provide food. In turn, fuel cell water and excess water of respiration from the astronauts are used in electrolysis.

This method requires, on a batch basis, only 10 percent of the electric power and 10 to 20 percent of the volume and weight of the best algae (Chlorella) gas exchanger system.

Optimal concentrations of oxygen, nitrogen, temperature, and other growth conditions were established for this life support system and a continuous cyclic culture apparatus was in operation. These bacteria will be fed to human volunteers and animals.

Exobiology--In 1964 the National Academy of Science through its Space Science Board completed a study at Stanford University for NASA outlining a well defined program in the field of extraterrestrial biology.

The Jet Propulsion Laboratory in another project undertook to define a minimum acceptable biological payload for spacecraft to land on Mars. Since the Agency is developing several devices to detect life on other planets and in interplanetary space, this study seeks to determine what combination of these detection devices can yield the most data.

A study project was initiated to determine the feasibility of an automated biological experiment system as the major biological instrumentation for VOYAGER spacecraft to land on Mars in the early 1970s. These missions would gather a broad spectrum of information on the biological status of a planet by using automated equipment made up of combined detection devices.

A scientific breakthrough was achieved in the laboratory with the synthesis of the life-related compound adenine--a first building block to adenosine triphosphate, the energy storage system in all of earth's organisms. This development also provides a channel through which the nucleosides can be constructed--elements which carry heredity from one generation to another in every living thing.

## SATELLITE APPLICATIONS PROGRAM

### Meteorological Systems

TIROS--TIROS VIII, launched in December 1963, has successfully flight tested the Automatic Picture Transmission (APT) system providing pictures of local cloud cover directly from the satellite to relatively simple inexpensive ground stations rather than requiring complex command and data acquisition stations. This picture transmission system originally designed for NIMBUS, broadcast over 4,000 APT cycles in five months of operation on TIROS VIII.

During the summer the seventh TIROS set a new record when it passed the 66,674 pictures taken by TIROS VI. Since the first TIROS was orbited in April 1960 this meteorological satellite series has supplied about 400,000 photographs and identified and/or tracked 25 hurricanes and 45 typhoons as of November 30.

The next TIROS--built like a cartwheel with its cameras looking out through the sides instead of through the base--will allow earth-oriented pictures throughout the sunlit

portion of each orbit. This is the basic design for the Weather Bureau-funded TIROS Operational Satellites (TOS) which are to provide daily global pictures and infrared data for operational uses.

NIMBUS--The first NIMBUS, a meteorological observatory in space, was launched on August 28. The spacecraft carried stabilization and control systems which kept its cameras and sensors pointed earthward at all times. (TIROS satellites were space-oriented, pointing to the earth part of the time.)

Although its orbit was more elliptical than planned, throughout the spacecraft's 3-1/2 week active lifetime all sensors provided data as commanded. Cloud cover data of greatly improved quality were furnished by the Advanced Vidicon Camera System. The Automatic Picture Transmission System (APT) supplied pictures of local cloud cover to ground stations all over the world. In addition, a high resolution infrared radiometer, first flown by NIMBUS, provided the first high resolution nighttime cloud cover maps and measurements of temperatures from which the heights of cloud tops could be estimated.

Success with the initial NIMBUS flight has also resulted in other countries building simple APT ground stations to receive meteorological data.

#### Communications Systems Satellites

TELSTAR--TELSTAR II launched on May 7, 1963, continued to operate successfully from its elliptical orbit, relaying TV demonstrations and performing many technical experiments. The spacecraft linked Japan and Europe via communications satellite for the first time and supplied data on the Van Allen radiation belt.

RELAY--RELAY II, orbited on January 21, provided European viewers with TV coverage of the Democratic and Republican National Conventions.

When the timer failed to turn off RELAY I as planned late in 1963, the spacecraft became the first communications satellite to exceed its designed lifetime. RELAY I carried televised coverage of the British elections to this country and the Olympics games between the U.S. and France. It is still operating.

SYNCOM--Launched August 19, SYNCOM III, became the world's first geostationary satellite. (Geostationary in that it "hovers" over a point on the equator rather than describing a figure 8 as SYNCOM II does.) By October 2, the spacecraft completed all necessary maneuvers to reach its station over the International Date Line to perform experiments for the Defense Department. Enough hydrogen peroxide fuel remained to maintain the spacecraft on station for several times its designed lifetime of one year.

In addition to helping to meet the communications needs of the Department of Defense, SYNCOM III relayed TV coverage of the Olympic Games from Japan to the U.S. The quality of the pictures transmitted exceeded technical expectations.

(SYNCOM II and III will be turned over to the Defense Department early in 1965.)

At the beginning of the 1964 SYNCOM II was stationed over Brazil, where it was placed for its experiments in 1963. On March 15, 1964, at the request of the

Defense Department, it was commanded to drift westward at a controlled rate which put it by August 19, at 160°E. longitude to back up the SUNCOM III launch. After this successful move it continued its westward drift toward an eventual station over the Indian Ocean.

SYNCOM II has logged almost 4,000 hours for Army ground stations--more than all other satellites combined--and has provided an alternate defense communications link to the western Pacific, the Philippines, and Viet Nam.

ECHO--On January 25 a second, improved, and larger ECHO passive communications satellite was placed in orbit. Ejection and controlled inflation of the rigidized sphere were televised from the AGENA stage and received at Johannesburg, South Africa. The spacecraft was also tracked by stations of the Soviet Academy of Sciences. Through an international agreement tracking photographs and communications results were later forwarded to this country for analysis.

On February 21, communications research began between the British Jodrell Bank station operating on behalf of NASA, and Zimenki Observatory, Gorki University, east of Moscow. U.S. efforts consisted of Air Force experiments between Rome, New York and Puerto Rico, and NASA-sponsored experiments between a contractor facility near Dallas, Tex. and a U. S. Navy station at Stump Neck, Md. A facility of Ohio State University also participated in the latter.

Observation of the signals from ECHO II's radio beacons indicated that it was spinning at about p.6 rpm. The cause of this spin-up was under investigation and should add to knowledge of the physics of space.

ECHO I has completed its fourth year in orbit. Somewhat wrinkled, it is still being observed periodically to assess the properties of space and for some geodetic purposes. Present orbital computations predict at least two more years of life for this 100-foot diameter sphere. In choosing an appropriate sphere to be launched for further orbital investigations, geodesists have selected the ECHO I design.

#### LIGHT AND MEDIUM LAUNCH VEHICLES

Launch vehicle used for NASA's unmanned missions are SCOUT, THOR-DELTA, THOR-AGENA, ATLAS-AGENA, and ATLAS-CENTAUR. Of these only CENTAUR is in the development stage. However, minor improvements continue on vehicles already developed to insure reliable and effective support for planned missions.

SCOUT was used by NASA, the Air Force, the Navy, and the Atomic Energy Commission for research experiments including probe, reentry, and orbital missions. Increased flight reliability and performance were achieved during 1964 and ten of the eleven missions launched by the Scout vehicles were successfully completed.

Performance of THOR-DELTA was also significantly increased and a program initiated to obtain still greater performance. After 22 consecutive successes DELTA failed in an orbital attempt, but it has launched SYNCOM III and a scientific satellite since that one failure. Additional launches of meteorological, communications, and scientific satellites were planned.

RANGERS VI and VII, the first Orbiting Geophysical Observatory (OGO-I), and MARINERS III and IV, were launched by NASA's ATLAS AGENA vehicle systems

during 1964. With the exception of the MARINER III launch, all vehicles performed flawlessly. The MARINER III launch was unsuccessful because the fiberglass shroud failed to separate from the spacecraft as planned.

In addition, ECHO II and NIMBUS I were launched by THOR-AGENA vehicles. In these launches orbits varied from the predicted but allowed successful spacecraft operations and completed missions. Improvements were incorporated to increase THOR-AGENA reliability performance.

An ATLAS vehicle was successfully launched in April to study high reentry velocity into the earth's atmosphere (37,000 feet a second) in Project FIRE.

Development of the ATLAS-CENTAUR continued satisfactorily. The third development vehicle was launched on June 30 and achieved 95 percent of its planned flight test objectives.

The fourth launch on December 11 was primarily successful although the attempt to restart the CENTAUR engine in flight failed. The launch vehicle placed a metal model of the SURVEYOR spacecraft into a precise orbit. Development will continue through 1965.

## ADVANCED RESEARCH AND TECHNOLOGY

### BASIC AND APPLIED RESEARCH

During this year, NASA's Advanced Research and Technology activities continued to extend the store of new knowledge which serves as the basis for our airborne and space flight programs.

Applied Mathematics--The aerodynamic and corresponding inertial properties of a wide variety of shapes possibly applicable to future air- and spacecraft were expressed mathematically and compiled by computer in extensive tables where information is available for use in the design of aircraft and spacecraft bodies.

Fluid Physics--A newly developed ultrasonic technique was used to measure viscosity of monatomic gases up to 10,000° K (Kelvin) and was being extended to higher temperatures and to diatomic gases. Chemical kinetic data on gases were obtained to temperatures above 10,000° K, particularly carbon dioxide which is of interest because of its indicated presence in the atmospheres of Venus and Mars and its potential temperature and radiation effects on space probes entering these planetary atmospheres.

Development continued on electromagnetic gas accelerators for aerothermodynamic model testing under simulated reentry heating conditions. A prototype accelerator produced a velocity of 20,000 feet per second and a gas density equivalent to that at an altitude of 45 km in the earth's atmosphere, conditions representative of the critical stage of orbital reentry. Methods developed for calculating high speed flow fields about blunt bodies included one which allows rapid and accurate calculations for vehicles such as the APOLLO reentry capsule even at relatively high angles of attack and hypervelocities.

A new technique, utilizing a special paint which reliquifies in regions of high heating

rate, was developed for heat-transfer measurements on models in hypersonic test facilities. Used to study heat transfer near irregularities on the normally smooth surfaces of reentry vehicles, the technique may represent a simpler method to determine surface temperatures of full scale vehicles.

Electrophysics--Irradiation of solid and liquid materials by exceptionally intense pulsed laser beams was found to generate coherent hypersonic sound waves of greater intensity and higher frequency than previously obtained. These hypersonic waves provide a new tool for probing the structure of matter and for non-destructive testing of materials.

Materials--Power systems for extended space voyages of the future will utilize metal vapors heated above 2,000° F in place of steam. Progress was made in preventing the severe corrosion of container materials by these vapors. Changes in container materials to compensate for the deleterious effects of minor impurities resulted in an alloy which withstood 2,000 hours of exposure to potassium at 2,200° F. In a related program, NASA-developed solid lubricants prevented seizure of moving parts in liquid sodium at temperatures up to 1000° F.

The continuous deformation, or creep, of metals subjected to stresses at relatively high temperatures restricts the use of certain metals in many applications. Theoretical and experimental investigations indicated that a drastic reduction in creep rate could be achieved by adding a suitably distributed second phase in the metal. In a particular aluminum alloy, finely dispersed aluminum oxide drastically lowered the creep rate at 500° C and 1,000 psi stress.

The application of very high pressures can produce advantageous changes in certain substances. In investigations on methods of fostering the retention of improved characteristics at atmospheric pressure, it was demonstrated that the addition of sufficient indium to thallium results in the retention of the high pressure phase at atmospheric pressure. In the space environment, the optical properties, and hence the energy absorption, of metals can be affected by the bombardment of high energy particles. These effects must be understood to permit optimum design of space vehicles. Laboratory investigations of the absorption properties under hydrogen ion bombardment indicate different behavior for a titanium alloy, commercially pure aluminum, and high purity copper.

The temperature control of spacecraft can be aided by optimizing the reflectance of the sun's energy. For this purpose, studies were made of the scattering of light by pigmented coatings; it was found that a white paint coating of several layers of pigment particles, each layer consisting of particles larger than in the previous layer, will reflect a high percentage of solar radiation.

### Biotechnology and Human Research

Life Support--A partially regenerative life support system was successfully tested for thirty days with five men in a sealed chamber. The system supplied oxygen from chemicals stored within the chamber and processed all forms of water for reuse by the inhabitants. Also, an advanced physical-chemical regenerative life support system was fabricated; designed to operate for up to a year, with expendables resupplied at 90-day intervals. Through a series of steps, it can completely reduce man's exhaled carbon dioxide to water and reduce water by electrolysis to hydrogen and oxygen.

Man-Machine Relations--An advanced controller which responds to voice input was designed for use in extra-vehicular stabilization and control systems. It will allow freedom of hands for performing maintenance tasks and scientific experiments outside the spacecraft.

### Electronics and Control

Computers and Logical Devices--The feasibility of micropower logic devices was demonstrated, and negotiations were under way to obtain prototype devices for test and evaluation. Research also continued in an effort to develop active devices immune to the space radiation environment.

Research on high capacity digital computer memory systems for use in spacecraft advanced with the construction and testing of a prototype of a memory unit using thin coatings of a magnetic alloy on fine wires, known as "plated wire." Memory units of this type were being designed to store millions of "bits" of information in a very small volume. Preliminary tests of a laboratory model of an entirely different memory utilizing both the magnetic and mechanical properties of materials were also completed.

A research program to develop control and logical systems using certain special properties of gas streams was initiated. Although such systems do not appear to be as fast as other types, they are largely immune to shock and radiation effects and can operate over an extremely wide range of temperatures.

Instrumentation--Advances were made in developing scientific instruments for atmospheric, ionospheric, and celestial observations, including devices for measuring density and composition of planetary atmospheres. Improved methods of simulating space environmental conditions served as the basis for designing more accurate instruments better adapted to extended space flight. A program was initiated to develop instruments to detect extraterrestrial resources indicated by transient events on the lunar surface. The objective is the automatic detection and analysis of lunar phenomena such as red colored spots which were sighted in 1963. Scientific analysis of such phenomena may indicate energy sources on the lunar surface which could be exploited.

Controls--The basic feasibility of the cryogenic gyroscope was demonstrated. A passive attitude spacecraft control system developed at Ames Research Center was chosen for use in the Applications Technology Spacecraft project. The simple configuration of this system should improve reliability and lower spacecraft weight and cost.

Simulation--Recent advances in the development of refined computer analysis techniques for manual control experiments promised to reduce by one-third the time required in piloted simulation studies. The techniques will permit an experimenter to select from a wide range of data during the course of an experiment, to alter the experiment to bring out conditions of greatest interest, to detect anomalous results while still running the experiment, and to repeat conditions immediately to determine the nature of these anomalies.

### Chemical Propulsion

Liquid Propellant Engines--Research continued on space storable engines, capable

of firing after months or years of travel into deep space and needed for such purposes as orbit transfer or departure, attitude control, vehicle maneuvering, midcourse corrections, braking into orbit, and landing.

The RL-10 hydrogen-oxygen engine was operated with liquid fluorine-liquid oxygen. Following a minimum number of modifications to engine components to assure compatibility with the highly energetic liquid fluorine, two complete engine systems were fired for a total of seven minutes. Further engine modifications were being made to produce higher performance levels. Many mixtures of light hydrocarbons were screened to develop fuel blends with cryogenic characteristics matching those of liquid fluorine-liquid oxygen (flox) mixtures; such compatible blends could be stored at the same temperatures as the flox and thereby enhance space storability without sacrificing engine performance.

Development of technology for high pressure engines continued. These engines-- lighter, more compact, and more efficient than conventional rocket engines-- are highly suitable for first and second stage launch vehicle applications. Investigations were made of cooling, combustion instability, and high pressure pumping; thrust chamber elements were subjected to hot firing tests for the discrete multichamber and the continuous toroidal chamber approaches to advanced large engines; and design studies based upon test information were under way to determine the best combination of such features as chamber design, nozzle type, engine cycle, and turbo-pump arrangement.

For the M-1, a 1.5 million pound thrust high performance oxygen-hydrogen engine, the first gas generator tests were successfully completed and thrust chamber tests were in progress.

Solid Propellant Engines--NASA defined the characteristics most desirable for space applications, developed experimental advances in technology for improved systems, broadened operational capabilities of solid systems, and improved propellant mechanical characteristics. For hybrid propellants, research indicated superiority in high performance, space storability, and variable thrust potential. The solid propellant technology program conducted research on materials development and application, engineering analysis methods, instrumentation, and nondestructive testing procedures for quality control.

In the joint NASA-DOD large solid-propellant motor program, which is developing the technological base for motors in the 1-10 million-pound-thrust range, NASA completed highly successful full scale tests of 156-inch diameter motor at a thrust level of over a million pounds. Tests were planned for mid-1965 of engines at a thrust level of over 3 million pounds as the next step in demonstrating the feasibility of a 260-inch diameter motor.

#### SPACE NUCLEAR PROPULSION

The joint NASA - AEC Nuclear Rocket Program is a two-pronged effort. The first consists of two projects (KIWI and NERVA) aimed at developing components and subsystems for an experimental nuclear-rocket engine. The second is a research and technology effort on advanced reactor research, conceptual design and evaluation, mission applications and requirements, technology development and safety.

## KIWI

Major tests under the KIWI program for the development of a non-flight reactor were virtually completed during 1964. Two successful tests, one cold flow and the other at power, were conducted with the B4D reactor. All major test objectives were realized in these tests. The B4E reactor was run under power for approximately 8 minutes on August 28. On September 10 the reactor was restarted and operated about 2-1/2 minutes near design power. Plans were made to conduct a Transient Nuclear Test to evaluate safety aspects of the reactor under unusual operating conditions.

## NERVA

The objective of the NERVA project is to develop a flight-weight reactor. Cold flow tests on the NRX-A1 reactor were highly successful. The NRX-A2 reactor was tested under power for more than 6 minutes on September 24; it was restarted and run for 20 minutes in additional testing on October 15, 1964. These tests were also completely successful. Major continuing effort was being devoted to non-nuclear components and engine system technology by the engine contractor.

The KIWI and NERVA tests demonstrated for the first time numerous attributes bearing on the suitability of hydrogen-cooled graphite reactors for nuclear rockets. Among the objectives realized in these tests were the attainment of design power, satisfactory control of the reactor, maintenance of structural integrity during powered operation, and the capability for restart. All these achievements are critical to the successful application of nuclear rockets to space flight.

## Research and Technology

KIWI and NERVA reactor work is supplemented by work on advanced graphite and tungsten reactor types. At the Lewis Research Center studies on a thermal, water-moderated, tungsten-reactor concept were being conducted. Emphasis was being placed on fuel-element and materials research--the critical areas determining the feasibility and performance of these systems. Preliminary work was continuing on more advanced gaseous and liquid fueled reactors.

Non-reactor components were being experimentally ground-tested; these components are necessary for the development of advanced nuclear rocket propulsion system technology. Typical of this effort were tests of a simulated nuclear rocket engine, using some KIWI subsystems; these were conducted at the Plum Brook Station of the Lewis Research Center.

## NUCLEAR SYSTEMS AND SPACE POWER

NASA continued its efforts to develop nuclear electric power generators; it also pushed ahead with its electric rocket engine and space power generation programs.

### Nuclear Electric Power Generation

An electrical prototype of a 50-watt isotope generator intended to augment the power for the 1966 Nimbus B spacecraft was built and delivered to Goddard Space Flight Center for integration testing. Other electrical prototypes are under test for a

variety of other missions.

SNAP-8, under joint development by NASA and the AEC, is intended to provide 35KW of nuclear electrical power for use in advanced space missions. In 1964, the reactor accumulated over 6,000 hours of testing time, including 4,000 hours at rated power and temperature. First generation components for the power conversion system were fabricated and performance verification tests were started.

The NASA advanced nuclear power program (to provide electric power ranging from kilowatts to megawatts) is concerned with two energy conversion concepts, the Rankine turbogenerator system and the thermionic direct conversion system. During 1964, as part of the Rankine cycle work, turbine-generator and other test facilities were completed and put into operation; measurement of the basic thermodynamic and transport properties of the potassium and sodium working fluids was completed; long time materials tests, such as high temperature creep, fatigue strengths of alloys, and boiling alkali metal corrosion were started; much boiling and condensing heat transfer data were accumulated; hundreds of particle impact tests were performed to investigate space meteoroid protection methods; and testing of the first potassium vapor turbine in the Free World (a 200 kw design) began July 13, 1964, and was continuing.

#### Electric Rocket Engines

During 1964, NASA's electric rocket engine program progressed in the research and technology area. Various electrothermal (arc jet and resistojet) and electromagnetic (plasma or MHD) concepts were being evaluated to determine their performance capabilities and problem areas.

On July 20, an electrostatic (ion) engine of 0.006 pounds thrust was successfully operated in space for approximately 30 minutes during a suborbital flight. This test proved that the ion exhaust beam could be neutralized and thus permit production of a net thrust. Tests in ground vacuum facilities had been inconclusive because of the automatic beam neutralization by electrons emitted from the facility walls.

#### Space Power Generation

The weight of silicon solar cells was reduced to one-half that of cells used in the past, and packaging and deployment techniques were under development to make lightweight multikilowatt solar cell arrays feasible.

Feasibility of a dry-tape battery concept was proven. The concept offers long shelf life, high energy-to-weight ratios, and the ability to use materials that are otherwise chemically incompatible.

Numerous improvements were made in fuel cell technology. The feasibility of removing static moisture from capillary membrane hydrogen-oxygen cells was demonstrated, and development of multikilowatt evaluation units was initiated. High performance hydrogen-oxygen fuel cell electrodes were developed; when combined with capillary membranes, these electrodes would provide high power output for unit weight. A system comprised of such electrodes is attractive for space missions lasting one to two weeks.

## AERONAUTICS

### Aircraft Aerodynamics

Advanced supersonic configurations with efficiencies approaching those of the best subsonic aircraft were developed, stability and control research indicated a probable need for damping augmentation devices for acceptable longitudinal and lateral handling characteristics in supersonic flight at high altitudes, and various configurations and design parameters were investigated for hypersonic cruise aircraft and winged recoverable boosters.

### Structural Studies

Two structural models embodying design concepts applicable to the fuselage of a hydrogen-fueled hypersonic aircraft were being constructed for testing at 1500-2500°F--temperatures likely to be encountered in hypersonic flight. Equipment was developed for inducing angular ascillations in the test section flow of a large transonic wind tunnel and will be used to obtain the dynamic response of wind tunnel models.

### Air-Breathing Propulsion

In research on a light-weight, high-performance propulsion system for the supersonic transport, NASA continued efforts to improve engine component performance, emphasizing higher turbine-inlet temperature and reduced engine weight. The agency was also conducting a research program to build a hydrogen-fueled ramjet engine capable of Mach 8 flight which will be evaluated on the X-15 airplane. Such an advanced air breathing engine has potential advantages for advanced military and civilian global transportation systems as well as in certain launch systems.

### V/STOL Aircraft

Initial flight tests with the NC-130B boundary-layer-control airplane equipped with a stability augmentation system verified simulator predictions of considerably improved low speed turn entry and landing approach maneuvers. For smaller STOL aircraft, low speed stability and control characteristics of a two-propeller deflected-slipstream STOL model were studied in wind-tunnel tests, and simulator studies, using the characteristics of a similar aircraft, were conducted to determine pilot preference as to stability requirements. Flight tests with a deflected-slipstream STOL aircraft, a tilt-wing test bed, a vectored-thrust jet airplane, and a variable-stability helicopter were used to aid in establishing more reliable criteria for V/STOL aircraft flying and handling qualities. Finally, wind-tunnel studies were conducted on models of the Tri-Service tilt-wing transport, the Navy tilt-duct aircraft, and the Army fan-in-wing and augmented-jet aircraft.

### Supersonic Transport

Aerodynamic refinements were applied to the SCAT 15 concept and verified by wind-tunnel tests. The modifications produced better flight characteristics at supersonic speed and a range increase of more than 15 percent.

## X-15 Research Airplane

The 100th flight in the X-15 program was made in January. The X-15-2 was modified for Mach 8 flight, for the study of stellar ultraviolet radiation, and for testing advanced air-breathing hypersonic propulsion systems; in June, it made its first flight following these modifications. The NASA-USAF-USN Research Airplane Committee decided that the X-15 aircraft should be utilized to obtain research data in aerodynamics, air-breathing propulsion, and structures by means of flight tests lasting through 1968.

## Aircraft Operating Problems

Additional data collected on clear air turbulence supported earlier findings of a pronounced decrease in the occurrence of turbulence above 50,000 feet as compared with its occurrence between 20,000 and 50,000 feet. An airborne instrument package able to measure clear air turbulence at high altitude was being assembled, and the feasibility of a laser turbulence detection system and its possible evaluation in flight were under study. In a comprehensive NASA-FAA program on jet transport operation in severe turbulence, NASA measured turbulence characteristics and structural response, made piloted simulator studies of thunderstorm penetration and of the effects of cockpit vibration and instrument and control malfunction, and analyzed subjective reports.

NASA continued theoretical and experimental investigations of sonic boom. A method of calculating the location and strength of the ground shock wave patterns of maneuvering aircraft was developed. Predictions calculated by this method compare favorably with experimental data from maneuvering flights. Also, NASA participated in the instrumentation and data analysis of the sonic boom tests conducted by the FAA.

## SPACE VEHICLE SYSTEMS

### Aerothermodynamics

Research on the problems of stability, control, performance characteristics, base heating, aerodynamic heating during launch and exit, and landing and recovery of space vehicles contributed new information applicable to present and future space vehicle systems.

A flight research program using a lightweight manned glider to simulate a lifting-body reentry vehicle was successfully completed and the subsonic flying qualities and landing characteristics of two heavier lifting-body gliders more representative of the actual weight of spacecraft were being investigated. A new testing technique to simulate the rocket exhaust of large launch vehicles was developed which makes it possible to obtain base heating information by using simple wind-tunnel models; significant savings in time and money resulted. A Ringsail parachute 123 feet in diameter and weighing only 200 pounds, designed for recovery of spacecraft weighing up to 100,000 pounds, was tested. Results indicated that such high strength-to-weight parachutes may significantly reduce weight and storage volume of recovery devices for heavy spacecraft. A flight experiment, conducted in cooperation with DOD, provided additional information on the radar detection (signature) of objects reentering the earth's atmosphere. And the first Project FIRE reentry flight test experiment, launched from Cape Kennedy, provided a substantial number of measurements

of radiative heating on the spacecraft as it reentered the atmosphere at a speed of 25,834 miles per hour.

### Structures

In research on lighter, more efficient space vehicles, analytical methods were developed to predict the stiffness and strength properties of composite materials. Application of these methods to the production of materials resulted in the development of filaments with increased strength and stiffness properties. Studies showed that use of these improved materials in reentry missions could result in substantial weight saving. Among structural concepts for lifting and ballistic entry vehicles studied were lifting entry concepts in which ablative and radiative surfaces were combined to achieve acceptable structural weights. Materials for a refurbishable ablator-type heat shield were flight tested on the X-15, and a SCOUT reentry heating experiment provided information which will aid in the evaluation of lightweight heat shield materials.

In studies of advanced analytical methods for spacecraft structural design, material parameters which govern penetration by high speed particles were established and combined into scaling laws for the prediction of penetration by micrometeoroids. Findings that the effects of atmospheric damping of a spacecraft structure can be appreciable indicated that vacuum simulation rather than the normal atmospheric testing may be necessary during dynamic qualification tests. Preliminary fuel slosh studies showed that flexible baffles can give higher damping as well as weigh much less than rigid baffles. In efforts to predict more accurately the loads on space vehicles, development of a radar-balloon system for measuring details of atmospheric winds, a major source of flight loads acting on a space vehicle, progressed satisfactorily.

### Environmental Factors

In research to obtain definitive data on the characteristics of meteoroids and their hazard to spacecraft, a Meteoroid Penetration Probe was launched during a meteoroid shower; it confirmed the existence of a momentary increase in the meteoroid flux. Other flight projects included the EXPLORER XXIII meteoroid satellite (launched November 6) to supplement data from the EXPLORER XVI experiment, and Project PEGASUS (to be launched by SATURN SA-9) to add data on the meteoroid hazard by counting actual penetrations in large areas of relatively thick materials.

Laboratory and flight studies of the effects of the effects of weightlessness on liquids and gases in space vehicle propellant tanks were continued, the behavior of liquid fuels was more precisely measured to provide data on the importance of surface tension, and an ATLAS piggyback experiment provided about 25 minutes of zero-gravity test data on heat transfer and temperature characteristics of a cryogenic fuel.

In space vacuum research, more realistic simulation and measurement techniques were developed for laboratory testing of space vehicle systems and materials, very low pressures similar to those of the lunar atmosphere were achieved, and refinements were made in ion gauges to determine vacuum more accurately. Research on spacecraft temperature control indicated the need for better standardization of ground thermal testing techniques, and the National Bureau of Standards cooperated with

NASA in developing better measurement standards. Also a prototype of an automatic skin-temperature control system was fabricated; it is designed to stabilize spacecraft temperatures under changing environmental conditions.

### Design Criteria

In keeping with the objective of improving flight worthiness of NASA space vehicles through the uniform application of design criteria formulated from the latest technology, NASA made available to industry three criteria monographs on the structural design of space vehicles.

## TRACKING AND DATA ACQUISITION

The NASA tracking networks continued to provide excellent support in tracking, telemetry, command, and data processing for the NASA and DOD programs during 1964. Key missions supported during the period included the first GEMINI unmanned launch; three SATURN launches for continued development of the SATURN booster; two RANGER launches, including the successful RANGER VII to the moon; two planetary launches; and 31 scientific satellites.

During this period, the networks were expanded by the addition of new facilities and equipment to support the increased requirements of the various NASA programs.

### Manned Space Flight Network

The Manned Space Flight Network stations were augmented with new and more complex tracking, telemetry, command, processing, and communications equipment during this period. This equipment provides the network with the dual capability to support both the GEMINI spacecraft and the AGENA target vehicle. The new station in northwest Australia, Carnarvon, was completed in this period; it became operational in June 1964.

Planning continued for station and ship requirements, and advanced electronic systems were being procured for the APOLLO tracking and data acquisition throughout this period.

### Satellite Tracking and Data Acquisition Network

The Satellite Network includes the electronic Space Tracking and Data Acquisition Network (STADAN) and the Smithsonian Astrophysical Observatory (SAO) optical camera tracking stations. This network has been steadily improved by the addition of automatic tracking, telemetry, and command antennas at selected stations and with the completion of three medium-gain antenna installations with 40-foot parabolic dishes. Installation of the first two was completed at Quito, Ecuador, and Johannesburg, South Africa, in May; the third was completed at Santiago, Chile, in July.

The second 85-foot antenna system in Alaska (the Weather Bureau Facility) became operational in March. Construction was continuing on the second 85-foot antenna system at Rosman, North Carolina, and ground was broken for the 85-foot Data Acquisition Facility at Canberra, Australia. This will complete the Data Acquisition Facilities currently planned to provide support for the advanced observatory-type satellites.

The capability to process data was expanded this year by the procurement of the Satellite Telemetry Automatic Reduction System (STARS). This system provides data for the experimenters earlier and at lower cost per data point than was previously possible.

### Deep Space Network

The Deep Space Network consists of a control center at Pasadena, Calif., and 85-foot antenna facilities strategically spaced around the world in Australia, California, South Africa, and Spain.

This program to provide dual simultaneous planetary or lunar mission support with 85-foot antennas at three evenly spaced longitudes will be completed during calendar year 1965.

During the year, the major flight programs supported were RANGER VI, RANGER VII, and the early phase of the MARINER Mars flyby missions. Photographs of the lunar surface taken by RANGER VII were hailed as a major scientific accomplishment.

### UNIVERSITY PROGRAMS

NASA's Sustaining University Program is designed to increase university participation in the space effort. Through this program, the Agency awarded 43 special purpose research grants to 37 institutions during 1964. These grants support and encourage multidisciplinary research activity, help fill gaps between existing project efforts, stimulate new and creative approaches to research problems, and develop new research capabilities.

During this year, 1071 students entered training under the predoctoral training program. This brought to almost 2,000 the number of students receiving training in space related science and technology at 131 universities. (NASA continued to aim at an annual yield of about 1,000 Ph.D.'s.)

Also, NASA moved ahead in its effort to help create adequate university research laboratories. Twelve more facilities grants were awarded to institutions heavily engaged in scientific and technical activities supporting the national space program. These grants will provide over 400,000 gross square feet of critically needed laboratory space.

### INTERNATIONAL AFFAIRS

During the year, NASA's joint efforts with other countries in the peaceful uses of outer space brought about the launching of another international scientific satellite, agreements for the launching of six more cooperative satellites, wide ground-based support abroad for NASA missions, and an expansion of cooperative sounding rocket experiments and personnel exchanges. These programs have involved personnel and activities of 68 foreign political jurisdictions.

### Satellite Projects

In December, an Italian crew successfully launched the first SAN MARCO satellite on a SCOUT vehicle from Wallops Island. This was the second phase of the U.S. -

Italian SAN MARCO project. Earlier in the year (March), the Italians tested the operation of their towable ocean-going platform by launching sounding rockets from it in coastal waters off Kenya. In the third and final phase of the project, an Italian satellite similar to the one launched in December is to be launched directly into an equatorial orbit from a platform in the Indian Ocean. This is expected to take place in 1966 or 1967.

The second cooperative U.S.-U.K. scientific satellite (ARIEL II) was launched by NASA from Wallops Island in March. British scientists provided the experiments aboard the U.S.-built spacecraft, which has been transmitting data regularly on galactic radio noise, vertical distribution of ozone, and micrometeoroid flux.

The French National Center for Space Studies (CNES) this year began fabrication of a satellite to be launched by NASA in late 1965 to study very low frequency radio wave propagation. This work followed successful sounding rocket test of the satellite's instrumentation (in October 1964).

The European Space Research Organization (ESRO) officially came into existence on March 20. On July 8, ESRO signed a Memorandum of Understanding with NASA which provides for a cooperative project to build and launch two satellites in the 1967 period.

After two years in orbit, ALOUETTE, the Canadian-built topside sounder satellite launched by NASA in September 1962, continued to perform well. As a follow-on to this successful project, NASA and the Canadian Defence Research Board concluded a Memorandum of Understanding which was confirmed by an exchange of notes between the U.S. and Canadian Governments on May 6, 1964. Under this memorandum, Canada assumes responsibility for preparing four satellites in the NASA Ionospheric Research (ISIS) Program; NASA will launch these over the 1965 to 1970 period.

NASA also arranged with the British National Committee on Space Research (BNCSR) to include two British experiments--a special ion mass spectrometer and a planar electron temperature probe--on the Direct Measurement EXPLORER satellite. This satellite will be launched on the same booster with the first ISIS spacecraft.

In July, experiments proposed by four foreign scientific groups were approved by NASA for inclusion aboard the fifth Orbiting Geophysical Observatory (OGO-E), to be launched in 1967. Selected in competition with U.S. and other foreign proposals, the experiments include two from Great Britain, and one each from France and the Netherlands. They will be prepared and financed by the respective cooperating foreign agencies.

#### Support for Satellite Projects

Extensive international interest focused on the Automatic Picture Transmission System (APT) for direct read-out of cloud cover pictures, flown for the second time on NIMBUS, which was launched in August. Pictures are known to have been received and utilized by 17 foreign civilian stations abroad. All but two of these stations were designed and built by the countries involved, using information supplied by NASA.

NASA's Polar Ionospheric Beacon Satellite (S-66), successfully launched in October, evoked the broadest international participation of any single satellite project. Scientists in 27 foreign countries plus stations in Antarctica, Greenland and Hong Kong participated in this project (including laser tracking experimentation by scientists in France and the U.K.), with a total of 61 foreign stations making observations. The Goddard Space Flight Center is to collect the data obtained and make it available to the world scientific community.

Spain and India became the eleventh and twelfth countries to arrange with the United States for testing experimental communications satellites launched by NASA. An inaugural demonstration with the Spanish ground station was conducted on May 27.

Plans for the Italian ground station are under active consideration.

Through SYNCOM III, positioned over the equator at the International Meridian, live television coverage of the 1964 Olympic games (held in Tokyo) was brought to audiences in the United States, Mexico and Canada. Also, tape coverage was provided more rapidly to countries of Western Europe.

NASA and the Radio Research Station (RRS) of the U.K. Department of Scientific and Industrial Research arranged for continued RRS support of U.S./Canadian ionospheric satellite studies. NASA is to extend the loan of telemetry equipment in use by RRS at a South Atlantic station. For its part, RRS is to staff and operate the telemetry stations at Winkfield (U.K.), Singapore and in the South Atlantic; make the data acquired available to the joint NASA/Canadian Working Group; and share in the work of data analysis.

#### U.S. -Soviet Cooperation

Between February 21 and March 9, the Soviet Academy of Sciences cooperated with NASA in a series of joint satellite communications tests via the U.S. passive reflector satellite ECHO II. These experiments represented the first specific performance under the terms of the Bilateral Space Agreement between NASA and the Soviet Academy. The facilities of the Jodrell Bank Observatory in England were used during these experiments to transmit radio signals to the Zimenki Observatory of the Gorky State University in the U.S.S.R. The Soviet Academy supplied data on its optical observations during the injection of the satellite into orbit; it also supplied data on the test transmissions.

On November 5 NASA and the Academy of Sciences of the U.S.S.R. reached agreement on a Second Memorandum of Understanding to Implement the Bilateral Space Agreement of June 8, 1962, clearing the way for the exchange of conventional and satellite weather data, when available from both sides, over a special communications link between Moscow and Washington. The regular exchanges of conventional data began November 16. The Second Memorandum of Understanding also includes additional details relating to the complementary use of satellites by both countries in mapping the earth's magnetic field.

#### Sounding Rockets

Through both bilateral and multilateral arrangements, NASA continued to share with other countries costs and results of space research conducted by sounding rockets.

Over 60 rockets were launched in cooperation with Argentina, Denmark, France, Germany, India, Japan, New Zealand, Norway, Pakistan, Sweden, and the United Kingdom from foreign and U.S. ranges. These rockets were used to investigate the ionosphere, the upper atmosphere, and geomagnetic and auroral phenomena.

Joint projects developed by NASA to supplement the atmospheric studies of the International Indian Ocean Expedition resulted in coordinated launchings of meteorological rockets by India, Pakistan, and Australia. In India, cooperative projects with NASA led to development of the Thumba range, located on the geomagnetic equator. Other countries responded with contributions of equipment, and late in the year, Thumba became the first U.N. -sponsored range, open to all nations.

In April, the first launching of a NASA payload on a foreign vehicle in a cooperative experiment took place. Instrumentation prepared by the Goddard Space Flight Center was launched from the French range in Hammaguir, Algeria, on "Dragon" sounding rockets supplied by the French National Center for Space Studies (CNES).

### Opportunities for Further Cooperation

In an information brochure titled "Opportunities for Participation in Space Flight Investigations," NASA renewed invitations to the world scientific community to submit experiments for flight on NASA's manned and unmanned spacecraft. Copies of the brochure went to all foreign space committees, to scientific attaches in Washington and in U.S. embassies abroad, and to interested scientists in the U.S. and abroad.

### Tracking Network Stations

An international agreement was concluded with Spain in January for the establishment and operation of an 85-foot tracking and data acquisition station west of Madrid.

Other developments with regard to the tracking network abroad included the following: renewal of the agreement for the station at Kano, Nigeria; expansion and relocation near Tananarive of the station formerly located at Majunga in the Malagasy Republic; and installation of telemetry and control equipment in Australia to support Project SYNCOM. The NASA station in Zanzibar was withdrawn at the request of the new Government of Zanzibar (which came into office through the revolution in January 1964).

### Personnel Exchanges

In 1964, 75 scientists from 23 countries participated in the post-doctoral theoretical and experimental research program at NASA centers. During the same period, under NASA's International Fellowship program, 75 graduate students were enrolled at U.S. universities in space research studies. These students were co-sponsored and supported by their national or regional space committees.

Some 74 technicians from three countries and ESRO were trained at NASA centers in payload engineering, telemetry, tracking, radar, meteorology, launch procedures, and range safety operations. Eighteen foreign students, sponsored by their national or regional space committees, attended a summer institute in space physics at Columbia University. And during the year about 2,900 foreign visitors--representing

scientific and technical organizations, governments, and overseas news media--toured NASA Headquarters and the Agency's field installations.

### NASA ORGANIZATIONAL CHANGES

The Electronics Research Center was established at Cambridge, Mass. This major new field installation will provide NASA with the greater competence in electronics research needed for the continued success in the Nation's space exploration program. Its activities will include basic studies and research in instrumentation; communications; data processing; navigation, guidance, and control; and it will also absorb the activities of NASA's North Eastern Office in Cambridge.

A Deputy Assistant Administrator for Technology Utilization was appointed and was assigned full-time operating responsibility for NASA's Technology Utilization program. This program identifies data on scientific and technical innovations resulting from NASA's research and makes it available to industrial and other potential users.

An Assistant Administrator for Management Development was appointed to review and develop recommendations concerning major management matters of specific interest to the Administrator.

A NASA European Representative was appointed to handle NASA relations with Western European regional and national space organizations in cooperative projects and other joint international space activities. This Representative is stationed in the U.S. Embassy in Paris and reports to the Assistant Administrator for International Affairs in NASA Headquarters.

### PROCUREMENT

During 1964, NASA continued its efforts to improve the management of procurement activities throughout the Agency. Greater use was made of incentive contracting than in any previous period; by the end of the year, the total value of outstanding incentive contracts was over \$500 million.

Procurement policies and procedures were consolidated and codified in a separate set of regulations known as the NASA Procurement Regulations, available for sale to the public. Existing policies were reviewed, updated, and revised to meet the operating needs of the NASA field installations.

Field procurement activities at a number of installations were reviewed by a Headquarters team of specialists as part of a continuing effort to determine the effectiveness of such field operations. As a result of these reviews, improvements were instituted by field personnel in their procurement organization and operation.

### TECHNOLOGY UTILIZATION

During the past year, NASA placed strong emphasis on increasing the flow of technical information to potential users in both aerospace and non-aerospace industries. With the cooperation and financial support of local industry and some state governments, this Agency continued a program of diverse pilot projects to encourage the transfer of space research information on a regional basis. New dissemination and applications centers were established at the University of Pittsburgh, the North Carolina Research Triangle, and the Southeastern State

College (Oklahoma).

Prior to this year, centers had already been established at Indiana University, Wayne State University, the University of Maryland, and the Midwest Research Institute. These centers, while still very young, are now dealing with several hundred companies. These companies are increasing their own use of the services almost on a weekly basis. They range from the very smallest proprietorships to the largest, most sophisticated industrial corporations.

Along the same line of increasing the flow of technical information, an innovation this year was the issuance of one- to two-page technological bulletins called "Tech Briefs." These were designed to acquaint industry more quickly with promising technological developments stemming from NASA's R&D effort. Over 220 Tech Briefs were issued during the year and were distributed to the trade press and news media. They were also issued through a special mailing list consisting of companies and individuals who have requested information concerning all technology utilization publications.

Other Federal programs were also benefiting from NASA's Technology Utilization program. Through the listing of selected technology utilization publications in the Small Business Administration's "facility inventory," over 8,000 separate publications requests for small businessmen were filled. The Food and Drug Administration might use a NASA-developed, extremely sensitive listening device to measure the effect of drugs on chicken embryos. The Bureau of Public Roads in its safety program is now publicizing the potentially dangerous tire hydroplaning phenomenon which NASA's Langley Research Center discovered.

DEPARTMENT OF DEFENSE



# CHAPTER IV

## INTRODUCTION

Continued progress was made during 1964 in military aeronautics and space endeavor. Three new high performance aircraft, the YF-12, XB-70, and the F-111 were publicly revealed and promise to enhance United States capabilities. In the area of space operations, there were three systems to reach operational status. These were the military Navigation Satellite and two defensive Anti-Satellite Systems. In addition, the TITAN III space launch vehicle achieved two successful flights and should, in the coming years, be a most valuable and versatile member of the national launch vehicle family. The GEMINI launch vehicle, a man-rated version of the TITAN II ICBM, successfully demonstrated its capability to perform the NASA two-man GEMINI mission. Two more VELA nuclear explosion detection satellites were injected into identical orbits from a single ATLAS AGENA launch vehicle. Another important milestone reached in 1964 was the decision to proceed with a military communications satellite system, planned for operational status in 1966.

The Department of Defense involvement in space activities has grown steadily in scope since its earliest identification in 1955 as a \$3 million effort. Today it represents about 25% of the funds spent for all Defense research and development programs. It is the largest single program grouping in the Defense Department Research, Development, Test and Evaluation category.

The military space effort is classed under two headings. First are those projects which are directed at clear, identifiable military needs and requirements such as navigation, communications, space tracking and detection, anti-satellite systems and observation systems. About half of the Defense effort falls under this heading.

The second area of endeavor embraces the development of broad competence in space technology. It includes vehicles, subsystems and systems concepts likely to be important for possible future military application. It is in this grouping that is found the Manned Orbiting Laboratory (MOL) to determine how man can be exploited usefully in a military space system, the TITAN III space booster, gravity gradient stabilization systems, space electrical power supplies, bioastronautics and similar important research and development efforts.

## SPACE DEVELOPMENT ACTIVITIES

### Manned Orbiting Laboratory (MOL)

The Manned Orbiting Laboratory (MOL) is conceived as a national program to provide knowledge of manned space operations for 30 days duration. Emphasis will be given to those activities which contribute to an understanding of man's usefulness

in performing military missions. Scientific and technological experiments of general merit will also be included in the flight program.

The MOL program was in the Pre-Program Definition Phase during 1964. The purpose of this phase was to define the experiments to be conducted in the MOL, and to determine the configuration details for the MOL system.

To arrive at the best possible program of experimentation for the MOL, the Air Force and the Navy let contracts to a number of companies for studies, in addition to conducting in-house investigations. The efforts to determine system configuration proceeded in a similar manner. Study contracts were awarded for investigations in such areas as spacecraft and booster interface matters, environmental control subsystems, and electrical subsystems. The Manned Orbiting Laboratory will provide a valid and major augmentation to the national space effort and specifically accomplish the following objectives:

- a. provide a multi-purpose space laboratory for conduct of significant scientific, technological and bioastronautic experiments.
- b. utilize the GEMINI spacecraft for ascent and descent, the TITAN IIIC booster for propulsion and a laboratory module making maximum use of APOLLO subsystems to provide an early, minimum cost capability of at least 30 days manned flight.
- c. accomplish a series of progressively more sophisticated experiments which will contribute to the understanding of man's ability to operate military equipments in space, of his ability to work outside the spacecraft to assemble and service large objects such as telescopes or radio antennae.
- d. provide a vehicle with flexibility for a wide range of activities of national importance and follow-on potential for military operational utilization of required or additional experimentation, perhaps to include rendezvous and coupling.

### TITAN III

During the last quarter of 1964, the TITAN III Standard Space Launch System completed the second year of its development phase. Most of the major subsystem components successfully completed development testing and the delivery of the flight test vehicles was well underway. The program entered the Research and Development flight test phase with the advent of the first TITAN IIIA launch September 1, 1964. Objectives of the maiden flight were to confirm system performance and design and place a dummy payload of 3,750 pounds in a low altitude circular orbit. Launch was achieved within 3 seconds of scheduled liftoff time. Performance of all systems through third stage ignition was well within design specifications and all engine and staging sequences were confirmed by telemetry. Although orbit was not achieved because of a pressurization system malfunction in the third stage, the flight demonstrated that the launch vehicle would meet its performance criteria.

"On December 10, 1964, the second TITAN IIIA was launched and all stages and systems performed as designed. The TITAN IIIA third stage (transtage), which is designed to provide a space maneuvering, start and restart capability, demonstrated its agility by performing a planned somersault in orbit, restart and injection of a 3750 pound boiler-plate spacecraft into a precise 100 nautical mile circular orbit."

The remaining fifteen R&D vehicles will be launched at regular intervals over the next 18 months, with the first flight of the TITAN IIIC configuration with two "strap-on" five segment, 120 inch diameter solid motors scheduled for the second quarter of 1965.

In early November, a successful firing of the sixth full-scale development 120 inch diameter solid motor took place. This was the first motor to be tested in the flight configuration and incorporated a new improved nozzle design. Test objectives were satisfied and performance was close to that predicted.

#### Defense Communications Satellite Program

The immediate objective of the Defense Communications Satellite Program (DCSP) as reoriented by the Secretary of Defense in May 1962, was to provide a world-wide communications system utilizing active, medium-altitude, random-spaced, satellites to be launched into polar orbits by the ATLAS-AGENA booster combination with ground stations so located as to satisfy the operational requirements of the Defense Communications System. Under the integrating direction of the Defense Communications Agency, the Army has responsibility for the surface environment comprised of fixed, transportable and shipborne terminals and the Air Force is responsible for the satellites and launch vehicles.

On October 11, 1963, the Secretary of Defense requested the Communications Satellite Corporation to advise him as to whether satellite services could be provided to the Department of Defense with a stated degree of confidence. Subsequent negotiations between the Department of Defense and the Communications Satellite Corporation for development and use of a joint or shared satellite system revealed that, although such a system was technically feasible, concern over the extent of control the international consortium would have over the system precluded reaching an agreement with the Corporation.

On July 15, 1964, the Secretary of Defense announced that the Department of Defense would proceed with the development of an independent Defense system designated the Initial Defense Communications Satellite Program (IDCSP). Three research and development TITAN IIIC launch vehicles will be used to place twenty-four satellites into near synchronous, near equatorial orbits.

The basic objectives of the International Defense Communications Satellite Program are to:

- a. Conduct system research, development, testing and evaluation to determine the operational compatibility, capability and utility of the system to meet user requirements.

- b. Provide an emergency capability for supplementing the Defense Communications System and improving the assurance of provision of the minimum essential survivable communications for National Military Command and Control purposes.
- c. Establish a research and development communications satellite system in being, designed to lead eventually into an operational system through integration with the Defense Communications System and thereby capable of providing service to specified users of the National Communications System.

The IDCSP promises to give good coverage to the communications links of military interest. With only one TITAN IIIC multiple launch, of eight satellites, outage times for most of the communication links would be less than ten percent. With two launches, outages would be less than one percent for most links.

The capability will gradually degrade due to normal satellite failures, but should provide an acceptable capability for some two to three years.

Studies are now underway for an advanced system characterized by long life in orbit. In addition, the military departments are studying the development of a capability for tactical communications via satellites.

The Department of Defense TRADE POST test program was successfully completed in March 1964. The purpose of the program was to obtain test data and experience factors with respect to technical capabilities of transportable terminals to operate with communications satellites. Both military and commercial ground terminals and all available communications satellites such as SYNCOM, TELSTAR, and RELAY were employed in the test program. In addition, requirements for operation, maintenance, personnel and logistical support were accumulated to aid in planning ground terminals for tactical use with future military communications satellite systems.

The Department of Defense provided ground terminals in support of the NASA SYNCOM II and III programs and test results have been promising. Through the cooperation of DOD and NASA, SYNCOM III and a receiving antenna at Point Mugu, California, were made available to the Communications Satellite Corporation for trans-Pacific telecasts of the 1964 Olympic games in Japan.

#### Project WEST FORD

The Massachusetts Institute of Technology, under Department of Defense sponsorship, completed Project WEST FORD in 1964, an experiment on the use of passive dipoles in orbit for communications. Some 480 million fibers, each 1.8 centimeters long and .0018 centimeters in diameter were placed in a 2000 mile orbit to provide an artificially created ionospheric belt which was used to reflect radio signals over-the-horizon. The communication links created by this belt of needles tested the concept of orbital scatter communications.

Several conclusions from this experiment were reached and reported during 1964. It is now possible to predict reasonably accurately the characteristics of orbiting dipoles. The belt exhibited a physical behavior that is in general agreement with

predictions. Of considerable significance was the fact that the dipole belt as distributed, did not interfere with radio and optical astronomical observations. A complete technical assessment of Project WEST FORD has been published by the National Academy of Sciences. As a result of this experiment, the design of future orbital scatter communications systems can now be studied with better understanding of their potential advantages and disadvantages.

#### Spaceborne Nuclear Detection (VELA)

The purpose of the VELA Satellite Program is to develop a satellite-based nuclear test detection capability for high altitude and deep space nuclear tests. This Advanced Research Projects Agency research and development program is jointly conducted by the USAF and AEC.

The performance of the nuclear test detection satellites launched into orbit about the earth has been outstanding. The four VELA spacecraft launched during 1963 and 1964 continue to remain in operation, providing radiation background data and information on the operation of various nuclear test detection sensors in space as well as providing a capability for detecting clandestine nuclear test detonations conducted in outer space. Test data are providing DOD with a clearer concept of the costs and capabilities of an operational space test detection system as well as design characteristics for a satellite-based world wide nuclear test detection system. The radiation background data are also of general scientific value for the study of solar and galactic radiation and trapped particles in the earth's magnetosphere. In addition to the accomplishment of their R&D objectives, the four VELA satellites in orbit are providing an interim monitoring capability particularly significant because of the Nuclear Test Ban Treaty.

Future launches in the program are planned to permit the incorporation of improvements in sensors and to conduct related experiments.

#### Anti-Satellite Systems

The Air Force and the Army have developed and tested systems which are capable of intercepting and destroying armed satellites. Both the Air Force system which employs the THOR missile and the Army system which employs the NIKE ZEUS have been tested against satellites in space and have demonstrated the capability of intercepting a target within the destruction radius of the warhead. Both systems utilize data from our global space detection and tracking networks.

The Air Force is currently conducting exploratory, advanced and engineering development effort plus conceptual studies, to improve the present anti-satellite system capability and to provide the design concept and technological base for follow-on systems.

#### Geodetic Satellites

The Department of Defense is continuing to participate in the National Geodetic Satellite Program which is under the overall project management direction of NASA. All three military services are contributing satellite subsystems as well as providing a world-wide network of tracking and readout stations.

An Army Corps of Engineers Sequential Collation of Range (SECOR) geodetic satellite successfully achieved orbit in January 1964. This event initiated a series of tests with SECOR an electronic distance measuring system designed to make use of the intermediary space positions of artificial satellites for determining geodetic positions on earth. A three month test period was successfully completed on May 1, 1964. The preliminary results of data reduction indicate that SECOR, the first weather independent system to be developed for the extension of control over multiples of hundreds of miles between stations, has the accuracy of a first order geodetic tool.

The NASA Beacon Explorer Satellite launched on October 9, 1964 contained both the Navy doppler transmitters and the Air Force flashing light system.

The data resulting from the doppler tracking of satellites in the past year have been analyzed extensively. As a result of this analysis, additional knowledge of the earth's gravitational field has been obtained and a refined shape of the earth (geoid) has been defined. This knowledge will assist in the prediction of the perturbations in the orbits of near-earth satellites to be launched in the future.

Further refinements in the shape of the geoid will result from additional reduction of data received from the tracking of satellites in polar orbits. The absolute locations of points on the earth's surfaces are now known to at least an order of magnitude better than when the program started. As the program continues, it is expected that this knowledge will improve to about another order of magnitude. More precise mapping and charting of the earth's surface will result.

#### Navigation Satellite Program

The DOD (Navy) Navigation Satellite System has been in operation for more than one year, and reached operational status in July 1964. During this time, the system has demonstrated an accuracy and reliability equivalent to LORAN "C", but on a world-wide basis. At the present time the Navy is equipping selected ships and submarines with satellite navigators. The Navigation Satellite System is the first operational space system that has been employed in day to day direct support of fleet operations. Additional research and development effort will be continued by the Navy to improve the lifetime of satellites and the cost effectiveness of the system. Recently, the USS LONG BEACH, a nuclear powered Cruiser, completed a round-the-world cruise during which satellite fixes provided the only accurate navigation fixes available during most of the journey due to bad weather.

During the course of this development, the Navy has demonstrated the feasibility of employing passive gravity gradient stabilization and the employment of nuclear isotope electrical power in operational space systems.

#### Large Solid Propellant Motor Program

In May 1964 the first 156-inch diameter solid propellant rocket successfully completed a full-scale static firing. The motor produced a maximum thrust of a million pounds and averaged approximately 900,000 pounds thrust during its two-minute firing. This major milestone in the Air Force large solid motor

technology program also demonstrated the integrity under firing conditions of a segmented motor case rolled and welded from maraged nickel-steel.

After hydro-testing, the motor case sections were refurbished and reloaded for a second firing. The second firing in September also met all test objectives and confirmed the advanced state of motor case technology.

These firings are significant because 156-inch motors are the largest transportable overland by existing methods. The case used was transported by truck from New York to California for loading. The fully loaded segments were then trucked to the firing site by way of the California highway system with no serious difficulty. One additional 156 inch diameter motor employing a large single movable nozzle for thrust direction control was successfully fired in December 1964.

### SPACE GROUND SUPPORT

#### Department of Defense National Ranges

The National Range complex within the Department of Defense consists of the White Sands Missile Range and the Kwajalein Test Site managed by the Army; the Pacific Missile Range managed by the Navy; and the Eastern Test Range, the Western Test Range, and the Satellite Control Facility managed by the Air Force.

In accordance with direction provided by the Secretary of Defense in November 1963, the management aspects of the Department of Defense missile test ranges were realigned. The creation of the National Range Division within the Air Force and the realignment of the DOD test facilities have been effected to provide more efficient and economical support for the Nation's space program and for the DOD's ICBM and AICBM development efforts. Specifically, the reorganization of the Nation's range complex is aimed at bringing about operational savings resulting from standardization of equipment and procedures. The principal changes effected by this action include:

- a. the establishment on May 15, 1964 of the National Range Division, a single manager within the Air Force, to coordinate and conduct planning of ICBM and space tracking activities involving the Eastern Test Range, the Western Test Range, and the Satellite Control Facility.
- b. the transfer of Navy managed facilities at Point Arguello in California, South Point and Kokee Park in Hawaii, Canton Island, and Eniwetok to the Air Force. This action will be completed before July 1, 1965.
- c. the transfer on July 1, 1964 of the Navy managed Kwajalein Test Site to the Army. While Kwajalein range management and operations are to be responsible to the requirements of the ZEUS testing and NIKE X programs, operation of the Atoll facilities for all range users will be in accordance with the established national range policies.

The total capability of the national range complex is growing at a pace set by the ever-increasing data needs of the DOD missile programs and the expanding space program. During the past year the ranges have upgraded portions of the metric tracking instrumentation to meet more stringent accuracy requirements imposed in the test and evaluation of the various short range missiles, IRBM, ICBM, and space vehicles. Specifically, the Eastern Test Range has added a new launch area telemetry facility to its resources. This new facility houses the latest in telemetry data receiving, recording, and separation equipment. Additionally, the installation of a real time computer system at Cape Kennedy materially improves the ETR range safety capability by permitting the display of real time position and projection impact location derived from the sensors available to the system.

The Pacific Missile Range has established a computer center to extend the utilization of equipment procured to support its real time data handling system. This facility, in operation since March 1964, assures more effective coordination of the support activities association with the 158 separate projects presently assigned to the range. The PMR, too, has enhanced its capacity for downrange support with the acquisition of the USNS WHEELING (AGM-8). This mobile station, equipped with C-band radar, telemetry, communications, and a helicopter recovery capability is a valuable complement to the shore based instrumentation. Although not tied directly to space or missile development programs in this instance, the TAA2 radar installation at PMR provided communication support with the successful video transmission of the Japanese Olympic games via SYNCOM III.

The White Sands Missile Range modernization efforts during the past year have been directed towards establishing and maintaining a modern and efficient test laboratory. Instrumentation designed specifically to improve trajectory measurements as well as to provide an increased real time and quick look capability is being emphasized for procurement. Command and control facilities are being installed to provide more efficient range operations and to reduce turn-around time.

The NASA operated APOLLO propulsion development facility is under construction at WSMR, and two successful tests of the APOLLO abort system have been carried out in the LITTLE JOE program. The capability of the WSMR has been expanded to permit off-range launches such as those associated with the reentry physics research program. In addition to the space oriented experiments, WSMR is responsible for supporting more than 170 separately managed air and missile programs that are currently assigned to the range.

In consonance with the current program to develop the most effective use of available resources, national range instrumentation ships have been pooled into a single national fleet. The Military Sea Transport Service is responsible for ship operation, while the Instrumentation Ship Project Office (ISPO), under the Chief of Navy Material, is charged with the requirements for reconditioning, modifying, equipping and checking out the vessels. Technical operations, scheduling and central ship planning have been assigned to the Air Force National Range Division.

The merits of central planning and pooling of resources were demonstrated earlier this year with the completion of the joint DOD/NASA study of instrumentation ship needs. The data produced by this study showed that the combined needs of the Air Force, Navy and NASA can be met with three less vessels than if the Agencies had conducted separate instrumentation ship operations. This combining of effort resulted in a capital investment saving of about \$30.0 million and eliminated the need for an additional outlay of \$6.0 million a year in operations and maintenance costs. Centralized scheduling will make inter-ocean deployment possible and will ultimately allow the deactivation of two instrumentation ships which will result in an additional annual saving of about \$2.6 million.

In February 1964, the Air Force implemented an operations plan for its meteorological rocket network. The new network provides for synoptic coverage of the atmosphere above balloon-sensing altitudes and is used to support the missile test ranges. Data are collected on upper atmospheric density and winds, and are used to evaluate booster performance and to support range safety operations. The current operation provides for measurements of temperature and wind and computation of density up to 200,000 feet altitude from six sites of the Eastern Test Range plus a far-north site at Fort Churchill, Manitoba, Canada. The range instrumentation ships used to support the ranges in tracking and meteorological data gathering have also been outfitted for the launching of meteorological rockets in support of the Meteorological Rocket Network.

#### Space Detection and Tracking System (SPADATS)

SPADATS is a system designed to provide the North American Air Defense Command (NORAD) with a capability for detecting, tracking, identifying, and maintaining constant surveillance of all man-made objects orbiting the earth. The system also provides the basic ground elements for defensive systems to cope with any threat that may be posed by hostile space vehicles. SPADATS consists of the Navy operated Space Surveillance System (SPASUR), the Air Force Spacetrack System, and an Air Force operated computer at CINCNORAD. The information acquired by both Spacetrack and SPASUR is fed into the Air Force operated computer at NORAD where position of satellites is updated and predictions of future track locations made.

The Spacetrack system is a globally deployed network of conventional radars and optical devices which first detect a satellite then lock on to the target and follow it to determine its location in space. Radars are located in the continental United States, Alaska and the Aleutian Islands, Trinidad, United Kingdom, and Turkey. Optical devices are located in the United States, Canada, Norway, and Johnston Island. During 1964 the capability of the system was enhanced by the addition of new long-range Spacetrack radars in Alaska and Turkey.

SPASUR consists of three transmitting and four receiving stations located on a great circle extending from Savannah, Georgia, to San Diego, California. These stations use antennae that form narrow beams in the north-south direction and broad beams in the east-west direction. These stations permit SPASUR to determine the position of the detected object, calculate its direction of travel, and predict its future position.

## AERONAUTICS DEVELOPMENT ACTIVITY

### XB-70 Development

The XB-70 program consists of two experimental flight test vehicles. The objectives are to determine problems and behavior relating to a large aircraft designed to fly up to Mach 3. Many new design features are represented in this aircraft.

The first vehicle was completed in May 1964 with first flight September 21, 1964. A total of four flights have been made. Maximum speed and altitude attained to date is 46,200 feet and Mach 1.42. A series of proof-loading tests are being conducted prior to making further flights to prepare for higher speed tests.

The second vehicle is expected to fly before the end of 1965.

NASA has provided funds for special instrumentation in the XB-70 to gather flight test data for specific value to support the National Commercial Supersonic Transport program and for the supersonic aeronautical research activity conducted by NASA. FAA and NASA participation in the flight test program has been provided by joint agency agreement.

### Advanced Manned Strategic Aircraft

The Air Force continues to study potential candidates for a replacement aircraft to the B-52. A strategic version of the F-111 and a new proposal, Advanced Manned Strategic Aircraft (AMSA), are currently the two most promising alternatives.

The F-111 modified to accommodate a third crew member, external fuel, extended fuselage, improved avionics and other changes required for strategic missions is being studied and compared with the AMSA. It would have about the same speed and dispersal capabilities as the AMSA; however, for strategic coverage, it requires aerial refueling.

The AMSA would have sufficient unrefueled range for strategic missions. As presently envisioned, the aircraft would require substantial propulsion and avionics development in order to fulfill the projected mission. Both of these areas are being funded in FY 1965 and FY 1966. Advanced development work now underway will provide, in about 2 years, a more valid basis upon which to make a decision for the development of a new aircraft.

### YF-12A Interceptor

The development of the YF-12A and its associated armament system offers a significant advance in interceptor capabilities for manned bomber defense. In addition to the great operational potential of the YF-12A, the system represents major advances in technology in the fields of aeronautics, propulsion and avionics. The development of the aircraft was made possible by major achievements in aircraft technology and metallurgy. These accomplishments resulted in an aircraft capable of sustained speeds of more than 2000 miles an hour.

The high thrust engine, the only engine flight tested at more than three times the speed of sound, has been qualified at the required high operating temperatures. The engine project included the successful development and application of several new high-temperature alloys.

The YF-12A incorporates the Air Force Advanced Armament System, which includes the ASG-18 pulse doppler fire control system and the AIM-47A air-to-air guided missile. This system has demonstrated radar detection ranges appreciably exceeding those obtainable with current interceptors.

The performance of the aircraft and the increased radar and missile capabilities offer one of several sets of possibilities for technological improvement and new concepts of interceptors for air defense should a decision be made to develop a new interceptor force. The technical achievements of the program also have major significance for other military and commercial aviation applications.

### X-15A Research Aircraft

Last year the Air Force modified one of the X-15 Research Aircraft to increase its speed capability from Mach 6 (4100 mph) to Mach 8 (5400 mph). The modified aircraft made its first flight in June 1964. The first flight was at a relatively modest supersonic speed and altitude to verify the predicted flight characteristics of the aircraft. During the coming year the NASA-Air Force test team will gradually approach the design top speed and increase our knowledge of the manned hypersonic flight regime.

### F-111

The F-111A is being developed as a fighter weapon system for Air Force use in either limited or general war. The F-111B will perform fleet air defense missions for the Navy.

The F-111A and B basic aircraft configuration was released to the public in May of 1964 and on October 15, 1964 the roll out ceremony took place at Fort Worth, Texas. First flight of the F-111A took place successfully in December 1964 and the F-111B is scheduled for first flight within a year.

The configuration of the F-111A was changed during the year to include automatic terrain avoidance, computing optical sight, an alternate gun installation, SHRIKE missile and penetration aids.

### Helicopter and V/STOL Development

DOD is continuing a development program oriented toward improving helicopter performance and handling qualities and developing vertical and short take-offs and landing (V/STOL) aircraft.

The joint Army-Navy rigid rotor program and the XH-51 flight tests have produced technical data leading to improved stability and control, handling qualities, vibration levels, and high speed performance. A high speed helicopter research program has made excellent progress to date in increasing helicopter speed capability to the 200 knot class. The modifications include the installation

of wings to unload the rotor at high speeds and auxiliary propulsion systems for improved high speed thrust.

An advanced research helicopter employing the hot cycle propulsion system was constructed and flew for the first time in November 1964. The hot cycle system employs the principle of piping hot gases through the rotor hub and rotor blades and exhausting the gases out at the blade tips, thus eliminating the requirement for heavy and expensive gear drives now used in conventional helicopters. The objective of this program is to determine the feasibility of lighter weight heavy lift systems for air mobile operations.

Operational suitability testing is continuing on 6 CH-54 flying crane helicopters which have a payload capability of 8-10 tons. The future of the various design approaches to the flying crane is being studied by the Department of the Army.

### Tri-Service V/STOL Program

The three military services continued the development and flight test of V/STOL transport type aircraft following three different V/STOL concepts. The tilt wing XC-142A V/STOL transport program under Air Force management accomplished its first flight in the conventional mode on September 20, 1964. In late 1964 the aircraft is scheduled to undergo hover flight testing and transition from vertical to horizontal flight. Of prime importance to the overall program will be the operational suitability testing to be accomplished in 1965.

The tilt propeller X-19A V/STOL research vehicle also under Air Force management completed the hover phase of the flight test program. The transition from vertical to horizontal flight and conventional mode flight testing was accomplished in the latter part of 1964.

The Navy managed X-22A rotating ducted propeller V/STOL research airplane is progressing through the design and fabrication phase. The first flight of the X-22A is now currently scheduled for the Spring of 1965.

The Department of the Army's interest in a V/STOL surveillance aircraft would be to provide the Army with an integrated system for performing tactical aerial surveillance and target acquisition that would substantially improve Army capability to perform the intelligence function of land combat. Three programs in progress will provide technical and operational data to definitize military characteristics for such a V/STOL surveillance aircraft. These programs are the XV-4A "Hummingbird" which uses the jet pump principle, the XV-5A "Fan-in-Wing" which uses fans in each wing to augment the thrust from the engine for vertical lift, and the XV-6A (P. 1127) which utilizes the vectored thrust principle. In tests of these aircraft to date, the XV-5A's fan-in-wing principle has shown a thrust augmentation of up to 300%. All three programs are in flight status and XV-6A operational suitability testing begins in the United Kingdom in the spring of 1965.

### X-21A Laminar Flow Control Aircraft

The Laminar Flow Control Demonstration Aircraft program has not yet proven in practice the concept of drag reduction by suction through a large number of very fine slots in the wing. During the year it became clear that optimum results were not going to be achieved with the current wing leading edge. Wind tunnel tests and a modification to a small part of the leading edge of one X-21A showed that increased laminar flow could be achieved by making the leading edge sharper. If current wind tunnel tests of the refined design are sufficiently promising, the Air Force may modify the entire leading edge of one of the two X-21A's next year. The operational utility and value of this technique remains to be demonstrated.

### C-141A Transport Aircraft

The C-141A program to develop and produce a high speed, jet powered, cargo transport aircraft for both military and commercial use has continued into the flight test phase. Following the first flight in December 1963, eight aircraft entered an intensive test program during 1964. The Number 9 aircraft was delivered to the Military Air Transport Service on October 19, 1964. This aircraft and the next thirteen C-141's delivered will be used for transition training of flight and ground crews. The first operational squadron will be completely equipped in July 1965, followed by a rapid build-up in squadron strength. The introduction of this aircraft into the military-civilian transport fleet will greatly extend the speed, range, and versatility of the Nation's airlift capability.

### COIN Aircraft

The counterinsurgency aircraft program continues the dual approach philosophy aimed at the ultimate achievement of developing a relatively low cost versatile aircraft for use in limited war.

The Air Force completed its evaluation of modified T-37 and T-28 aircraft and is formulating its position on the use of these aircraft for counterinsurgency missions.

A light Armed Reconnaissance Aircraft (LARA) is based on a requirement expressed by the Marines. It is to have a limited capability to transport people and cargo. An optional configuration would provide an amphibious capability. COIN is now specified as a twin engine 600-650 horsepower turboprop aircraft of short wing span, with short take-off performance, capable of austere operation off unimproved fields, roads, large amphibious landing craft (LPH) and aircraft carriers without the use of arresting gear. The DOD envisions COIN as a Military Assistance Program Aircraft in the counterinsurgency role with applications as well for the Marine Corps, Army and Air Force in limited warfare. An R&D contract for the development and delivery of seven aircraft was signed on October 15, 1964.

## Short Airfield for Tactical Support

This system has been developed and delivered to the Marine Corps in response to a requirement for close air support of Marine assault and amphibious forces soon after a landing. It permits a complete airfield to be air transported into an unimproved site and quickly assembled to allow operation of first line fighter and attack aircraft within three days after arrival of the equipment. The system completed operational evaluation in 1964 and deliveries have commenced.

## SUPPORTING RESEARCH AND TECHNOLOGY

### Over-the-Horizon Radar

The Department of Defense has demonstrated the feasibility of detecting aircraft and missiles over the radar or line-of-sight horizon. These new over-the-horizon radars eliminate a serious limitation inherent in present day conventional radars. It will now be possible to detect aircraft and missiles at longer ranges and lower altitudes than previously possible, thereby providing earlier warning to defense agencies. This new capability was achieved by a comprehensive research and development program carried out over the past decade by the Navy, Air Force and the Advanced Research Projects Agency. A program to improve and exploit this new technology will be continued.

### Lifting Reentry Technology

The current reentry technology programs are known as START and ASSET. Employing small unmanned test vehicles, they are adding to the background technology and developing the means of maneuvering spacecraft during the extreme speed of reentry into the earth's atmosphere, followed by a precision landing.

The START program is developing a small reentry system, based upon a particular lifting-body shape known as the SV-5, with the objective of returning instruments and data from orbit. Many experiments produce results and records which are not susceptible to transmission by telemetry. The START program will provide a flexible and accurate system for placing experimental results in the hands of the experimentors where direct examination is necessary.

The ASSET program is investigating radiative cooled vehicle configurations and the START program ablation-type maneuvering lifting body reentry configurations. Both programs have related design studies to assess the merits of aerodynamic shapes. The objective of the DOD reentry technology program is to determine the performance improvements which could be realized by exploiting advanced component or subsystem design concepts. To date only the ASSET reentry vehicle has reached flight test status. The overall program is expected to contribute significantly to the development of lifting reentry technology of potential importance to both military and civilian space activities.

Several ASSET flight tests were successfully accomplished during 1964. The most notable of these took place on July 22 when ASV-3, the third ASSET flight

test vehicle, was launched by a two-stage THOR DELTA booster and recovered after a 1400 mile flight down the Eastern Test Range to impact in the ocean east of Antigua. This marked the first time a glide reentry vehicle had been successfully flown and recovered.

The actual flight trajectory of this vehicle was very close to the planned trajectory. Booster separation and glide insertion occurred at an altitude of about 213,000 feet and a velocity of 18,000 fps (mach 15.5). All vehicle subsystems performed extremely well and the vehicle was sighted by an Air Rescue Service search plane a few minutes after impact. Pick-up of four par divers, dropped to attach an additional buoy, and the 1100 pound flight test vehicle was complete some 12 hours later.

Recovery of the ASV-3 vehicle satisfied a prime objective of the ASSET program. Correlation of in-flight data with the excellent condition of the recovered vehicle was validated. Theoretical considerations, as well as testing and predictive techniques, of considerable importance to the future development of aerodynamic configurations, radiative materials and structural concepts for future lifting reentry applications were also confirmed.

In May 1964, under the aegis of the Aeronautics and Astronautics Coordinating Board, a special review of all significant USAF and NASA research and development programs in the field of lifting reentry was undertaken. The purpose of the review was to ensure that present and planned programs in this field were complementary rather than duplicative and directed to the attainment of objectives of maximum value to both agencies.

#### Advanced Ballistic Reentry Systems Program

The Advanced Ballistic Reentry Systems Program (ABRES) is the DOD program for advanced development of reentry technology and devices for operational ballistic missile systems. This program provides the technology for increasing the accuracy and effectiveness of missile reentry systems and to assure that these systems will penetrate a defended target. Significant progress was made in both areas of endeavor.

Laboratory experiments and flight tests were conducted on various penetration techniques and tactics. Flight tests of experimental reentry body shapes and materials were flown from both the Eastern and Western Test Ranges. These experiments have greatly enhanced understanding of the phenomenology of reentry bodies and the test results have provided an essential input to continued improvement of ballistic missile operational effectiveness.

#### Cesium Contact Ion Engine in Space

An important scientific milestone was achieved late in the summer of 1964 on the behavior of a cesium contact ion engine in space. Test data review revealed the following:

- a. neutralization of the positively charged ion beam was successful.

- b. there was nothing to indicate that the ion engine interferes in any way with communications.
- c. although measurement of in-flight engine thrust was not accomplished because the power supply inverter to the reference system failed, beam power measurements indicated a thrust of 2.08 millipounds.
- d. electrical measurements of performance in space verified laboratory data previously obtained. The thrust time was 17 minutes with 9 minutes at a full regulated thrust of 2.09 millipounds and a specific impulse of 7,370 seconds.

Ion engines inherently are capable of small thrust, long duration, and extremely good fuel economy. Because of these factors the potential value of this engine lies in long duration near earth missions for sustaining satellite orbit, satellite attitude control and orbit transfer. Additional evaluation tests of ion engines in the space environment are planned in conjunction with the space nuclear power program.

#### Space Power Equipment

The DOD continued to examine various concepts for meeting anticipated high electrical power requirements of future satellites. For possible requirements of more than several hundred watts, careful consideration has been given to both nuclear and solar powered generators. In 1964, the Atomic Energy Commission and the DOD reached agreement on the funding and management of SNAPSHOT, a flight test program of the SNAP 10A nuclear electric space power unit. The design and development of radiation hardened electronic components for the power distribution, and the command and telemetering circuits of the AGENA spacecraft were initiated by the Air Force in 1961. All of the specially designed components have been subjected to qualification tests and are undergoing a 9000-hour life test as part of the USAF technical effort to prepare them for launch of the SNAP 10A in April 1965. Commencing in FY 1965 all funds for the USAF prime contract and for the ATLAS and AGENA are provided by the Atomic Energy Commission.

#### Restartable Solid Rocket Motor

Rocket thrust termination, restart and throttling, formerly available in liquid propellant systems, is now attainable with solid propellant systems. A solid propellant rocket motor was successfully operated through five cycles of command thrust termination, restart, and thrust modulation control. The time between motor operations was varied to as long as several hours to simulate actions required in some space maneuvering trajectories. These tests represented the first of this type in solid propellant rocketry. This increased flexibility added to the inherent simplicity and reliability of the solid rocket motor will make it more attractive in such applications as terminal guidance for advanced military weapon systems and future propulsion systems.

## Materials Research

The Air Force is developing a new material for possible use in aerospace craft, missiles and other devices requiring lightweight-high strength structures. The key to the program, which may prove to be a great advance in materials, is the discovery of a way to produce continuously very thin filaments of elemental boron. Measurements show these filaments have been produced in laboratory quantities with a tensile strength of 400,000 pounds per square inch and a modulus of elasticity (stiffness) of 60,000,000 pounds per square inch.

The filaments can be formed into a plastic composite material as glass fibers are now used where they act much like steel rods in concrete or the cords in rubber tires. The resulting material would be as rigid as beryllium and light as aluminum. Potential applications are to make missile rocket cases lighter and stronger, for use in the cool portions of turbojet engines to increase their thrust-to-weight ratio, or to provide lighter aircraft structures.

Work is just beginning on composite materials using three filaments and considerable work must be done to study effects of fiber orientation, per cent volume of fiber to resin matrix (plastic), bond integrity between fiber and matrix, environmental effects, cost reduction, process speeds and other production and design problems.

## Gravity Gradient Stabilization for Satellites

The Navy has performed the major pioneering effort in this field. This technique is currently stabilizing a constellation of navigation satellites using a system designed by the Applied Physics Laboratory (APL), John Hopkins University. Four satellites have been stabilized using the APL gravity gradient system of which 2 were placed in orbit in 1964.

In January 1964, the Naval Research Laboratory launched a gravity gradient experiment employing a different system than the APL approach. The test satellite was a 20 inch sphere weighing approximately 70 pounds. The stabilization system hardware weighed an additional 15 pounds. This gravity gradient stabilization system operated entirely as predicted and passively oriented the satellite to within  $\pm 6^\circ$  of the vertical.

Three more gravity gradient stabilized satellites are scheduled to be launched by NRL in early 1965. One satellite will use a magnetically anchored eddy current damper. It will be of a dumbbell configuration employing a 41 foot boom. The second satellite will stabilize around all three axes. It will use a magnetically anchored viscous fluid damper. This system will be configured in a skewed "Y" with three, 60 foot booms. The damper will be extended at the end of the leg of the "Y" and a 2.9 pound mass will be extended at the tip of each arm. The third satellite will have a two axis stabilization system of the dumbbell configuration.

The tip mass will be the boom deployment mechanism which will be extended from the satellite by an 18 foot boom. The damper will be an eddy current damper which will act as a hinge between the satellite and the boom-tip mass structure.

The tests previously mentioned have all been conducted in relatively low orbit (about 500 miles). During 1964 an agreement with NASA was reached whereby a joint DOD/NASA gravity gradient experiment will be conducted in 1966 at an altitude of 6,000 miles utilizing one of the NASA Advanced Technology Satellites as a platform. This experiment is being performed for the Military Communications Satellite Program. In addition, the DOD plans an experiment at synchronous altitude (22,000 miles) during the same time frame for the purpose of establishing the practicality of using the gravity gradient technique at that altitude to stabilize the future advanced military communications satellite system during the 1967-1970 period.

#### General Support, Research and Development

Effort continued in 1964 in the area of astrophysics, astronomy, bioastronautics, entry physics, lasers, space power and propulsion systems, solid state physics, aerodynamics, stability and control, materials research, and advanced structures.

The following accomplishments are worthy of highlighting:

- a. an aircraft was illuminated and tracked by a pulsed laser beam. It is anticipated that the outgrowth of this development may be the tracking of orbiting satellites to ascertain their precise orbits.
- b. in the materials area, recent efforts have resulted in the ability to form new improved non-melting fibers intended for reinforcements of thermally protective composites which are used in rocket exhaust and in high shear force reentry environments.
- c. on June 16, 1964 the Naval Research Laboratory in a follow-up x-ray astronomy experiment to one conducted in June 1963, revealed 2 discrete x-ray sources in Scorpius and the Crab Nebula. The rocket probe experiment also revealed several strong new sources and these results have important bearing on present theories of the nature of gravitational collapse of massive stellar objects and of peculiar galaxies about which man knows very little. Further survey experiments with improved detectors promise that a full map of the sky may reveal a substantial number of x-ray sources. Neutron stars have been postulated as one means by which these x-rays may be generated. However, on July 7, 1964, a lunar occultation of the Crab Nebula was observed with an inertially pointed aerobee rocket probe experiment during 4.5 minutes of the occultation of the central region of the Crab. The x-rays decreased gradually during the occultation, which apparently disproves the possibility that this source is a neutron star.

The U. S. Naval School of Aviation Medicine, Pensacola, Florida, dedicated on July 22, 1964, a vestibular laboratory, jointly supported by DOD and NASA for the study of the effects of complex directional forces on the orientation of men operating in the space flight environment.

The Aviation Medical Acceleration Laboratory, U. S. Naval Air Development Center, Johnsville, Pennsylvania, completed in 1964 a major modernization of the human centrifuge. This unique research tool, presently the most advanced man-rated flight simulator in operation, is supporting DOD programs as well as the NASA GEMINI and APOLLO flight programs.

## COOPERATION WITH OTHER GOVERNMENT AGENCIES

### General

The close interaction and relationship between DOD and NASA as well as other government agencies has required continuous coordination with them. This has been achieved by direct and frequent contact at all staff levels.

### Joint NASA-DOD Review of National Space Program

A series of critical joint reviews was conducted in each of several categories of the respective DOD and NASA space programs. Examinations were made of the (1) Launch Vehicle Program (2) Manned Earth Orbital Program (3) Communications Satellite Program (4) Weather Satellite Program and (5) Instrumentation Networks, Control Centers and Instrumentation Ships. As a consequence of these reviews, it was expected that substantial cost savings would accrue through the pointing up of objectives, mutual support and joint utilization of resources.

### NASA-DOD Agreement on Research and Technology Exchange

An agreement was concluded between DOD and NASA which provides for procedures and a common format for the reporting of the research and technology efforts of the respective agencies. Such action will significantly enhance the ability to interchange information and coordinate projects. It is estimated that the exchange of 100,000 DOD documents and 4,000 NASA documents will be involved. The information is to be prepared in a manner suitable for machine processing. An exchange of data, in the form of resumes and magnetic tapes will occur twice within each fiscal year starting February 1965. It is expected that these procedures will result in more meaningful inter-agency decisions regarding program goals and balance.

### Establishment of a National Program in Satellite Geodesy

In accordance with Congressional recommendations, a national program in satellite geodesy was established to fulfill requirements of the Department of Defense, NASA and the Department of Commerce. It also allows for the necessary international cooperation. During 1964, a program plan was prepared and adopted which consists of essentially three phases involving (1) Beacon Explorers containing doppler transmitters (2) Active Geodetic Explorers containing flashing light, minitrack beacon, doppler transmitters, satellite clock, range and range rate system and SECOR and (3) Passive inflatable spheres.

## Early Gravity Gradient Test for Defense Communications Satellite Program

As presently planned, the Interim Defense Communications Satellite Program will employ spin stabilized satellites at near synchronous orbits. If gravity gradient stabilization could be achieved at such altitudes, it would have a significant impact on the design of the Advanced Defense Communications Satellite system. In recognition of the importance and urgency of demonstrating gravity gradient stabilization at such altitudes, agreement was reached and management plans developed to conduct an early test for the purpose. Such test would assess the feasibility of the technique and provide data for the selection of design parameters not only for the advanced system but for possible upgrading of the interim system. The details of the experiments are to be jointly determined by DOD and NASA with procurement of the system assigned as a responsibility of the Air Force.

## Launch Vehicle Requirements

The Launch Vehicle Panel of the AACB has been engaged in a comprehensive study of various alternatives by which those launch vehicles in existence or under development may meet existing and projected mission needs of DOD and NASA for the 1965-1975 time period. Several options are being examined to meet requirements, costs, reliability, safety and response time criteria.

## Joint Navigation Satellite Committee

An ad hoc Joint Navigation Satellite Committee was established by agreement between DOD and NASA, Departments of Commerce, Treasury, Interior and the Federal Aviation Agency. The purpose of this committee is to review the potential capability of space technology to contribute significantly to the improvement of air and sea navigation, air and sea traffic control and coordination, and air-sea emergency activities of the signatory departments and agencies. As a result of this review, it is expected that the committee will be able to determine and evaluate the requirements of such a system and assess the economic feasibility, desirability and cost effectiveness of selected systems to perform the outlined missions.

## Other AACB Directed Efforts

In addition to the above agreements, joint studies and examinations were conducted under the AACB on:

- a. Launch Vehicle Improvement Requirements and Range Safety Considerations.
- b. XB-70 Research Program.
- c. Procedures for Reporting Reliability of Space Systems.
- d. Lifting Reentry Vehicles.
- e. Use of TITAN III for NASA SURVEYOR missions.

## DOD/NASA FY 1966 Facilities Coordination

The Department of Defense and the National Aeronautics and Space Administration have established formal procedure for coordinating each year's proposed in-house facilities construction programs. Each project in the proposed FY 1966 construction programs of the two agencies has been thoroughly and jointly reviewed under these procedures.

## DOD Participation in the GEMINI Program

The objective of the DOD GEMINI program is to raise the DOD experience level by evaluating techniques and equipment on NASA GEMINI flights which will contribute to potential manned military missions. Although the space available in the GEMINI capsule to house DOD experiments is severely limited, the experiments planned are expected to be applicable to the Manned Orbiting Laboratory program.

DOD participation in the GEMINI program is also providing the mechanism for timely flow of data from the NASA manned space flight activities to DOD agencies.

DOD program approval and FY 1964 funding release were given in February 1964. During 1964 the Air Force continued to refine the design of the thirteen Air Force and three Navy experiments and to contract for flight hardware design, fabrication and integration of equipment into the GEMINI spacecraft. This work is proceeding on a schedule compatible with the NASA GEMINI flight dates. All sixteen DOD experiments are scheduled for at least one mission on GEMINI flights 4 through 12.

Joint DOD/NASA GEMINI Program Planning Board meetings were held to assure that the DOD experiments and the development efforts, on the modified TITAN II GEMINI launch vehicle were progressing in an effective and coordinated manner.

## Range Instrumentation Aircraft

The Air Force is taking action to consolidate DOD and NASA requirements and develop a national aircraft fleet in support of the National Missile and Space effort. Procurement of aircraft instrumentation to meet NASA APOLLO requirements as well as DOD needs is presently in the program definition stage at the Air Force System Command's Electronic Systems Division. The combined fleet will be under the control of the National Range Division.

## DOD Use of the NASA THOR/DELTA Space Vehicle

A joint NASA/DOD study of the use of an improved NASA developed THOR/DELTA space booster has been conducted by the Launch Vehicle Panel of the Aeronautics and Astronautics Coordinating Board. The improved DELTA launch capability has been determined and negotiations with the NASA for a management agreement on use of the DELTA at the Western Test Range are presently being completed. The improved DELTA vehicle was developed as a versatile two or three stage standard launch vehicle for missions at Cape Kennedy and the Western Test Range. When THOR/DELTA has demonstrated adequate

performance and reliability, DOD will use THOR/DELTA for payloads falling within this vehicle class.

#### Personnel Support of NASA

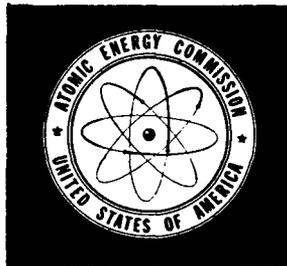
The Air Force and the NASA reached mutual agreement on guidelines regarding NASA requests for Air Force officers. The formal agreement, signed on September 15, 1964 sets forth specific criteria governing the terms of the NASA requests, the Air Force evaluation of the positions requested and the selection of nominees.

In general, the NASA requests are restricted to positions requiring education experience or skills especially developed by the Air Force in the fields of technical program management, engineering, and physical or life sciences.

There are a total of 266 military officers assigned throughout the NASA organization. Of this number, 120 are from the Air Force, 105 from the Army, 36 from the Navy and 3 from the Marine Corps.

#### General Support, Construction

The Army Corps of Engineers supports the national space program by providing real estate acquisition and management services, engineering services, and design and construction of facilities. Major projects in 1964 included facilities at NASA's Manned Spacecraft Center, Clear Lake, Texas; test complexes at NASA's Mississippi Test Facility; and Air Force and NASA launch facilities at Cape Kennedy. Master planning was initiated for the NASA Electronic Research Center, Boston.



INTRODUCTION

In 1964, the Atomic Energy Commission phased out its PLUTO Project, but continued to make steady advances in its programs to develop:

- a. nuclear systems for supplying power for spacecraft and satellites (SNAP);
- b. the technology for using nuclear rocket propulsion for space missions (ROVER); and
- c. satellite-based detection instruments and associated systems.

PROJECT PLUTO

Having completed repairs to the TORY IIC test facility at the Nevada Test Site, the Lawrence Radiation Laboratory resumed pre-nuclear air blowdowns and tests of the facility in January 1964. In mid-February the TORY IIC reactor was shipped from the Laboratory in Livermore, Calif. to the test site, and on March 25 achieved criticality for the first time while assembled in the test vehicle.

On May 12 the reactor was operated at an intermediate power level which simulated flight at a 10,000-foot altitude and a speed of Mach 2.8 (2.8 times the speed of sound). The initial full-power ground test of the TORY IIC was conducted on May 20 at test conditions which simulated nuclear ramjet engine flight at sea-level and design speed of Mach 2.8. Both tests were unqualifiedly successful.

The Department of Defense notified the AEC on July 1 that it had decided against pursuing a flight test objective with the PLUTO program. In response to this guidance, additional planned tests of the reactor were cancelled and the TORY IIC program was phased out. PLUTO test facilities at the Nevada Test Site were mothballed.

Investigations of possible alternate applications of the very high temperature gas-cooled PLUTO reactor technology are currently in progress.

SNAP PROGRAM

SNAP Radioisotope Units

In April, the third 25-watt plutonium-238-fueled SNAP-9A generator designed to supply all of the power needs of a Department of Defense navigational satellite was launched from Vandenberg Air Force Base, Calif. It did not achieve orbit because of a failure of the launch vehicle. All available evidence confirms that the generator

burned up at high altitude upon its re-entry into the earth's atmosphere and that its fuel was dispersed in very fine particles over an extremely wide area at the edge of space as it was designed to do. Two identical SNAP-9A generators had been successfully launched into orbit in 1963.

An electrically heated SNAP-9A generator was delivered to the NASA's Manned Spacecraft Center, Houston, Texas, for performance testing and familiarization purposes.

A SNAP-11 electrically-heated prototype thermoelectric generator, developed to power the instruments in NASA's soft-lunar-landing SURVEYOR spacecraft, was delivered to the Jet Propulsion Laboratory, Pasadena, Calif., early in May for environmental testing.

Two electrically-heated prototype SNAP-13 thermionic generators, developed as back-up units for the SNAP-11, survived hot dynamic testing without suffering any degradation in their power output.

The initial design phase of the SNAP-17 program, to develop a 25-watt strontium-90 fueled thermoelectric generator and associated ground handling equipment, was completed, and plans have been formulated for continuation of this development program. Preliminary studies were completed for integrating Strontium-90-fueled generators into several long-lived satellite applications for the DOD and NASA. Design studies were completed by four contractors on various Sr-90 fueled thermoelectric power system concepts at a power level of 250 watts.

In response to a request by NASA in January, 1964, the AEC is developing an isotopic power source for the NIMBUS-B advanced weather satellite. These SNAP-19 generators are to be fueled with plutonium-238, have a five-year design lifetime, and an electrical output of 30 watts. The first fueled generator is scheduled for delivery to Goddard Space Flight Center by early 1965. A study was performed for the Weather Bureau's National Satellite Center to determine the suitability of using SNAP-19 on the advanced TIROS Operational Satellite System (TOSS).

A system integration and design study was completed in September by two contractors for a 40-50 watt Plutonium-238-fueled power supply for the NASA's SURVEYOR Lunar Roving Vehicle. This information has been provided to NASA in support of program planning for the SURVEYOR Program.

### SNAP Reactor Units

SNAP-8--The SNAP-8 Experimental Reactor (S8ER), the first power reactor of the SNAP-8 series, had by the end of August accumulated more than 2,000 hours of continuous operation at full design power conditions of 600 thermal kilowatts and 1,300° F. coolant outlet temperature. The S8ER has subsequently been operated under various test conditions; all tests have confirmed the adequacy of the SNAP-8 reactor design for 450 kilowatts of heat output.

Another reactor of the SNAP-8 generation, the SNAP-8 Developmental Reactor Mockup (S8DRM-1), is a flight-design reactor and shield assembly containing un-enriched "dummy" fuel elements. This device was built to check the operation of the various components, as a complete system, under conditions closely simulating

the space environment. The S8DRM-1 completed shock and vibration and startup reliability testing during the year, and started long-term test operation in a vacuum and at high temperature.

SNAP-10A --In the Spring of 1964 the Joint Committee on Atomic Energy authorized reinstatement of the SNAP-10A flight test. Throughout the balance of the year development and detailed planning for a 1965 flight demonstration continued.

A mockup SNAP-10A flight system completed a continuous 90-day endurance ground test operation early in 1964. The test unit used electrical heaters to simulate heat which in the flight system would be produced by the nuclear reactor. The first nuclear-heated test of a complete SNAP-10A flight qualified system is scheduled to begin in January 1965. Testing will be directed toward obtaining performance information for at least 90 days of continuous operation. A second non-nuclear test was initiated in December. This test differs primarily in that it uses completely flight-qualified hardware.

### SNAP Systems Improvement

Mercury Rankine Power Conversion - An early flight-design power generator (CRU-IVM), currently used as a workhorse test machine, accumulated 6,295 hours of steady-state operation at design conditions. The machine is being disassembled so that internal components such as bearings, turbine wheels, etc., can be examined.

Over 7,500 hours have been accumulated on the current flight-design version (CRU-V) of the power generator. The most time accumulated on one machine (CRU-V-IA) was 2,560 hours, and the longest continuous run, accomplished on the same machine, was 2,344 hours. Failure of the test rig superheater precipitated a series of events which caused a seizure of the turbine bearing and terminated the continuous run.

Total accumulated operating time on CRU machinery since September 1962, when the CRU-IVM type was first tested, is now more than 15,500 hours (almost two years).

Other SNAP Systems Improvements--Operation of a dummy (non-fueled, electrically heated) SNAP-10A/2-class reactor mockup was started in 1964. This operation will demonstrate the unit's capability to operate in the thermal and vacuum environment required to produce about 125 thermal kilowatts at about 1,200° F. Development of advanced thermoelectric elements of the SNAP-10A type proceeded to the point of selection of final module design for 1,300° F. operation.

Safety Tests of Aerospace Nuclear Systems--Two major safety tests were carried out in 1964 on SNAP systems. The first was conducted in April to determine the consequences of an accidental nuclear excursion with a SNAP-10A reactor. Such an accident could be induced by the inadvertent water immersion of the reactor if a launch abort should occur in such a way that the reactor were thrown into the waters offshore of the launch pad or into the deluge water flume or catch basin. The reactor destroyed itself, as expected, and the fission product release and radiation levels were found to be very low.

Another safety test involved launching of an inert isotopic thermoelectric generator from the NASA Wallops Island Range in October. The purpose of this re-entry flight demonstration (RFD-2) was to demonstrate that the generator, similar to one

to be used on the NIMBUS-B satellite, would disassemble during re-entry so that the Plutonium-238 fuel could burn up and disperse safely in the upper atmosphere. Although data has not yet been fully analyzed, preliminary results indicate the generator disassembled as predicted and that the fuel encapsulating material burned through as predicted.

SNAP-50--During 1964, a reference design of the SNAP-50/SPUR high temperature refractory-metal power plant was continued in order to provide realistic design considerations for the power plant and its components. The experimental development program concentrated on selected key components of the reactor core, the reactor reflector and drive system, the turbo-alternator, the boiler, system pumps, advanced materials, and instrumentation and controls. One of 1964's more significant SNAP-50/SPUR program accomplishments was operation of a 5-megawatt liquid-metal heat transfer system which transfers heat from lithium in a columbium (with one per cent zirconium) loop to sodium-potassium in a stainless steel loop. This system, using an electrical heater to simulate the reactor, completed a 10,000-hour test at design temperatures of 2,000° F. Also in 1964, several large liquid-metal loops for testing power conversion subcomponents were fabricated and testing was begun on stainless steel models of a multi-tube boiler and a liquid-metal-cooled generator.

#### ROVER PROGRAM

The year 1964 was one of major progress in the nuclear rocket program. On February 13, a KIWI-B4D cold-flow reactor, containing no fissionable material and therefore producing no power, was tested. This reactor is a Los Alamos Scientific Laboratory re-design of the KIWI-B4A reactor that had been damaged by flow-induced vibrations in a November 1962 power test. No evidence of the damaging core vibrations was encountered in the cold-flow run, and the overall design and operation of the B4D were excellent.

On May 13, a major ROVER program milestone was achieved when the KIWI-B4D reactor was tested at power and temperature conditions that met or exceeded all planned test conditions except for duration of operating time at the power plateau which was less than planned. The reduction in operating time was necessitated by a hydrogen leak in the jet nozzle. Sufficient time at power was achieved, however, to provide a significant proof-test of the structural integrity of the reactor, as well as many other reactor features.

The KIWI-B4E, the eighth and final nuclear rocket reactor to be fabricated and tested in the KIWI phase of the ROVER program, was power tested on August 28. The test ran at planned reactor power and temperature for more than eight minutes, the maximum time possible with the available liquid hydrogen propellant supply. On September 10 the B4E reactor underwent an unprecedented "re-start" test and operated smoothly for approximately 2.5 minutes near design power. Again the reactor's performance was excellent. The analysis of data from this test will complete the KIWI project with the exception of the Transient Nuclear Test, a safety test yet to be conducted. The Los Alamos Scientific Laboratory will then concentrate its nuclear rocket efforts on design, applied research, and fabrication work under the advanced graphite reactor technology program known as PHOEBUS.

During March and April, the first experiment in the NRX (NERVA Reactor Experimental) test program was successfully conducted on the NRX-A1 cold flow reactor, with all test objectives being met. The NRX reactors are an industrial team's adaptations of the KIWI reactor for application to the NERVA (Nuclear Engine for Rocket Vehicle Application) nuclear rocket engine. On September 24, the second experiment in the NRX test program was successfully run on the NRX-A2 reactor. This first power operation of a NERVA nuclear rocket reactor lasted for more than six minutes at levels ranging from 50 per cent to near-full design power. On October 15, the NRX-A2 reactor was restarted and operated in a stable and reliable manner for 20 minutes.

Throughout 1964, work continued on developing major non-nuclear components for the experimental, ground-based nuclear-rocket engine; on evaluating how these components will function in the heat and radiation environment of the reactor; and on examining the operation of the reactor and non-nuclear components as an engine system. As presently conceived, the NERVA engine will stand 22 feet high from the top flange to the exhaust exit of the jet nozzle, with the reactor to be located in the central portion.

#### SATELLITE-BASED DETECTION OF NUCLEAR EXPLOSIONS IN SPACE

In support of the Department of Defense, the Los Alamos Scientific Laboratory and Sandia Corporation are cooperatively developing instrumentation for the ATLAS-AGENA-launched satellites for detection of nuclear explosions in space. Satellite-borne radiation detectors for neutrons, gamma rays and X-rays, and the associated electronic logics, have been developed and fabricated by the two laboratories.

The first pair of AEC-instrumented VELA satellites were successfully placed in orbit by a single ATLAS-AGENA launch in mid-October 1963. (See 1963 report.) The instrumentation systems continue to perform essentially as planned, and have demonstrated the feasibility of satellite detection systems. After 14 months in orbit, they have accumulated valuable operational and background radiation information. No unexpected backgrounds have been observed that would nullify the basic detection concepts.

A second ATLAS-AGENA launch was successful in mid-July 1964, placing two more AEC-instrumented satellites in orbits similar to the first two, making a total of four R&D detection spacecraft now in orbit and functioning. The two new spacecraft have essentially the same detection systems as the first two, plus new detectors for measuring "solar wind" proton fluxes, low energy solar X-ray fluxes, and the characteristics of plasma clouds observed by the first pair of spacecraft.

The currently authorized program contains a third launch in 1965 for placing two additional satellites into orbit. The detection systems for the third launch are being modified on the basis of information obtained from the first two launches, and some new detection concepts will be explored.

In addition to the currently authorized ATLAS-AGENA launchings, AEC-developed instrumentation systems are being included on other space launchings to measure background radiation at various altitudes above the earth.

DEPARTMENT OF STATE



# CHAPTER VI

## INTRODUCTION

In 1964, international cooperation in the outer space field kept pace with expanding outer space technology. On July 24, 1964, 19 nations joined together to conclude Interim Arrangements for a Global Commercial Communications Satellite System. In satellite meteorology, the World Meteorological Organization (WMO) pushed ahead with its plans for a world weather system.

As a result of bilateral discussions between the United States and the Soviet Union, final agreement was reached for the exchange of conventional and satellite weather data, when available from both sides, over a special communications link between Moscow and Washington. The results of these discussions between representatives of NASA and the Academy of Sciences of the U. S. S. R. were recorded in a Second Memorandum of Understanding to Implement the Bilateral Space Agreement of June 8, 1962. Discussions continued on the preparation of a joint review of space biology and medicine, although no agreement was reached on the means of carrying out this project.

A number of international bilateral governmental and inter-agency agreements, involving tracking stations or scientific experiments, were initiated or renegotiated. Ranking well with the numerous spectacular events of the year was the relay of television pictures of the Olympic games held in Tokyo in October to the United States and Europe by two satellites of different design and orbital characteristics.

Films and still pictures, of the successful RANGER VII flight, which were provided by NASA were shown to large and interested scientific and lay audiences abroad by the Department's 16 scientific attaches.

These developments were matched by progress in cooperative activities through the U. N. Committee on the Peaceful Uses of Outer Space. The Committee increased its activities in the scientific and technical area, and gave detailed attention to drafts of international agreements on assistance to and return of astronauts and space vehicles and on liability for damage caused by objects launched into outer space.

## ACTIVITIES WITHIN THE UNITED NATIONS

On December 13, 1963, the Eighteenth General Assembly unanimously adopted resolution 1963 (XVIII) which made specific recommendations on the work of the U. N. Committee on the Peaceful Uses of Outer Space for this year.

The Scientific and Technical Subcommittee of the U. N. Outer Space Committee, which met in Geneva from May 22 through June 5, agreed upon a number of

recommendations for consideration by the full Committee including the following:

- a. publication every two years of reviews on national and cooperative international space activities and on activities and resources of the United Nations, the specialized agencies and other competent international bodies in relating to the peaceful uses of outer space.
- b. establishment of a clearing house within the United Nations Secretariat of information on education and training in order to foster the growth of cooperative space arrangements and the spread of scientific and technical knowledge.
- c. compilation by the Secretariat of information on international conferences and symposia in order to keep Member States periodically informed.
- d. sponsorship by the United Nations of the first international sounding rocket facility, the Thumba International Equatorial Sounding Rocket Launching Facility in India.
- e. endorsement of the concept that Member States undertaking experiments in outer space should give full consideration to the problem of potentially harmful effects, and should, where they consider it appropriate, seek a scientific analysis of the qualitative and quantitative aspects of those experiments.

In addition, the Subcommittee recommended that the Secretary General be asked to consider, in the light of existing material, the usefulness and possibilities of publication by the United Nations of new material to ensure popular understanding of the purposes and potentialities of space activities, possibly in a series of pamphlets or a handbook.

The Legal Subcommittee met from March 9 to 26 in Geneva and again from October 5 to 23 in New York to frame international agreements on assistance to and return of astronauts and space vehicles and on liability for damage caused by objects launched into outer space. On the question of liability, there was a full and useful exchange of views. The United States presented a draft text at the March session and a revision of that text at the resumed session in October. Other texts were presented by Hungary and Belgium. On assistance and return, there was greater progress, based in part on the greater simplicity of the subject. The United States and the Soviet Union presented full texts, and Australia and Canada presented joint texts on the substantive articles.

The resumed session of the Legal Subcommittee was immediately followed by the meeting of the full Committee in New York from October 26 through November 6. The Committee noted with satisfaction that substantial progress was made in the Legal Subcommittee, although there was insufficient time to draft the international agreements, and decided that work on the two agreements should be resumed as soon as possible. The Committee also adopted the recommendations of its Scientific and Technical Subcommittee, and invited it to study the possibility of establishing a civil worldwide satellite system on a non-discriminatory basis. In addition, the Committee considered the usefulness of holding a conference in 1967 under U. N. auspices on the exploration and peaceful uses of outer space. The Soviet Union and

a number of other Members supported such a conference. The United States opposed it on the grounds that a conference would be expensive and unnecessary in view of the large number of conferences on outer space already being held in other international bodies. Instead, the U.S. Delegation suggested a meeting in 1967 of the U.N. Outer Space Committee to commemorate the passage of the first decade of space exploration. In the end, the Committee decided to set up a working group of the whole to examine the desirability, organization and objectives of an international conference or meeting to be held in 1967 on the exploration and peaceful uses of outer space.

The Committee also commended the WMO for the further development of the world weather watch concept. In addition, acting on a recommendation of the Scientific and Technical Subcommittee, the Committee commended the ITU for its contribution to the successful conduct of the Extraordinary Administrative Radio Conference held in October - November 1963. This Conference allocated frequency bands for space communication, telemetry, radio astronomy, meteorology, navigation satellites, aeronautical amateur services and scientific research.

During the Committee session, the United States in association with other signatories, submitted a progress report to the Committee concerning the Interim Arrangements Establishing a Global Commercial Communications Satellite System. The Soviet Union and several other Eastern European countries criticized the Arrangements as being discriminatory and contrary to United Nations resolutions. The United States and other countries observed that the Arrangements were in fact fully consistent with United Nations resolutions on outer space. They noted that the agreements remain open to adherence by all states which are members of the ITU and that access to the proposed Commercial Communications Satellite System would become available on a non-discriminatory basis to all.

#### BILATERAL AGREEMENTS AND OTHER INTERNATIONAL ACTIVITIES

During 1964 two actions were completed under the Bilateral Space Agreement of 1962 between NASA and the Academy of Sciences of the U.S.S.R., i. e.: one under the cooperative space project involving the experimental relay of communications via the ECHO satellite and the other under the cooperative project for the exchange of weather data from meteorological satellites. In January, with the cooperation of the United Kingdom, experimental communications were passed from the United States to the U.S.S.R. via the ECHO II passive satellite, the space relay being from Jodrell Bank in England to the Zimienki Observatory near Gorki. Studies of the technical aspects of these experimental communications have been exchanged, along with visual observations of the inflation of the ECHO II balloon during its post-launch phase which were made by the U.S.S.R. at NASA's request. A direct communication link between the Soviet Hydro-Meteorological Service in Moscow and the U.S. Weather Bureau in Washington was established in late September and, commencing in late October, is being tested through the exchange of weather data acquired by conventional means. This circuit has been established for the mutual exchange of satellite data and will be used for this purpose as soon as Soviet data from meteorological satellites becomes available.

In addition, a senior NASA official met with a senior representative of the Academy of Sciences of the U.S.S.R. in the spring and fall of this year to discuss further steps in the implementation of the agreed cooperative space projects involving the coordinated launching of meteorological satellites, the exchange of data from these satellites and the program to map the magnetic field of the earth by means of

coordinated launchings of geomagnetic satellites and related ground observations. These meetings resulted in a Second Memorandum of Understanding to implement the 1962 agreement; this memorandum specifies further details of these projects and was approved by NASA and the Soviet Academy on November 5, 1964. During these meetings there were initial discussions of an additional project looking to the mutual exchange and publication of information in the field of space biology and medicine. Agreement has not yet been reached on the details of this new project.

At the request of the National Aeronautics and Space Administration negotiations were commenced by the Department of State with the British in 1959 for the establishment of a data acquisition and communications station to be located either in Tanganyika or Zanzibar. The station was to be used for the Mercury and Gemini flight series. Prior to the exchange of notes signed on October 14, 1960 in London permitting the establishment of the station on Zanzibar, leases were signed on June 3, 1960 by NASA with the Government of the Sultan of Zanzibar providing for two station sites at Tunguu and Chwaka. The original agreement ran for three years, until April 30, 1963, with an option for an extension for an additional three year period to be negotiated on a year-to-year basis.

After NASA indicated its desire to extend its option, on January 28, 1963, the Department undertook negotiations with the Zanzibar authorities which agreed to an extension only through December 31, 1963. This period being unsatisfactory to NASA to meet its Gemini requirements, the Department pressed for a continuation for an extension for the full period. On January 11, 1964 the Department was advised that the Sultan was agreeable to negotiate an extension of the agreement as requested. The day after this advice was received, the Government of Zanzibar was overthrown and a new regime took over. Due to an element of hysteria created by extremist elements which charged that the tracking station was a "missile base", the United States was subsequently asked to dismantle and remove the station. Removal of the equipment was completed on April 28, 1962, two days before the deadline set by the Government of Zanzibar. It is to the credit of the U.S. diplomatic representatives stationed at Zanzibar at the time that all American personnel and dependents were evacuated without injury or loss of life.

Ironically, First Vice President Karume, speaking at the opening of a new Afro-Shirazi party branch office, at Kizimkazi, Zanzibar, on September 5, 1964, cautioned the people against believing false stories that are spread about certain nations. He said, "We are friendly to all nations and have no ill will towards anyone." He made special mention of the United States and said he knew that the Project MERCURY tracking station formally based in Zanzibar was for peaceful and scientific purposes only.

During mid-1964 arrangements were made with the Government of the Malagasy Republic for the installation near Tananarive of a tracking facility which will assist in tracking the GEMINI flights scheduled for early 1965. The station will also include a minitrack facility for support of scientific satellites as well as automatic picture receiving equipment capable of receiving photographs from the weather satellites as they pass near Madagascar. These several facilities are being added to a small, mobile facility which has been moved from its earlier location near Majunga.

Arrangements have been made with the Government of Australia for the installation of a facility to be used for communication at lunar distances in the APOLLO program.

At the request of the Smithsonian Astrophysical Observatory in Massachusetts an agreement in principle was reached with the Government of Ethiopia to locate a Baker Nunn optical tracking camera in that country. For technical reasons this camera will be relocated from Shiraz, Iran.

Negotiations were continued with the Government of Mexico for the extension of the agreement permitting NASA to maintain a tracking and communications facility for both the manned and unmanned flight series at Guaymas, Mexico. The original agreement established by exchange of notes, signed at Mexico on April 12, 1960, was extended by exchange of notes in May, 1963. On an interim basis, agreement was reached continuing the agreement until November 30, 1964. Subsequent agreement was reached for a further extension until January 31, 1965. It is anticipated that the newly elected Government of Mexico will concur in a further extension to the agreement.

The Department negotiated on May 21, 1964 an extension until June 30, 1966 of the agreement with the Nigerian Government permitting the continued operation of the NASA tracking station at Kano, Nigeria. The new agreement provides for the use of the station both for manned space flights and for scientific satellite tracking.

In further support of the NASA APOLLO program the Department obtained an agreement for the location of a second deep space instrumentation facility to be located near Madrid.

In addition to the bilateral governmental agreements, the Department lent its assistance to the negotiation of bilateral agency agreements between NASA and foreign entities in outer space projects involving satellites, sounding rockets, experiments in communication via satellite and ground station observations of U.S. satellites.

#### GLOBAL COMMUNICATIONS VIA SATELLITES

An important objective of the Communications Satellite Act of 1962 was realized on August 20, 1964 when the following countries signed the Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System: Australia, Canada, Denmark, France, Italy, Japan, Spain, the Netherlands, the United Kingdom, the United States of America and Vatican City. Subsequently, Norway, Switzerland, the Federal Republic of Germany, Sweden, Belgium, Ireland, Portugal and Israel signed, bringing the total signatory countries to date to 19.

Most of the countries who have signed to date have designated national communications entities to participate in the ownership and operation of the system. These entities are in most cases governmental, however, in some cases they are of a private nature. The Communications Satellite Corporation is the designated entity for the United States of America.

Representatives of these entities, except in the case of Italy where an entity has not yet been designated, have signed a "Special Agreement" which is concerned with such matters as financial contributions, design and development of the global system,

approval of the locations and technical capabilities of earth stations, rates and charges and management of the enterprise. Both agreements have been published in the "Treaties and Other International Acts Series" (TIAS 5646) which is available for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.

The first agreement establishes an Interim Communications Satellite Committee to give effect to the international cooperation envisaged in the Communications Satellite Act of 1962. The agreement is open for signature for six months from August 20, 1964, and after that by accession, by any state which is a member of the International Telecommunications Union.

The agreement names the Communications Satellite Corporation, which was established pursuant to the Communications Satellite Act of 1962, as manager of the proposed global commercial system. A more detailed statement of these arrangements is contained in the Annual Report of the President on Communications Satellites which is required by the Communications Satellite Act of 1962.

#### INTERNATIONAL TELEVISION VIA SATELLITE

When the Secretary of State was in Japan in January 1964 he was asked by the Japanese Government if he would use his good offices in facilitating the transmission of television pictures of the 1964 Olympic games to be held in Tokyo via satellite to the United States. The Department, being aware of obvious benefits from a foreign relations aspect as well as the extension of the technological and scientific experiments which had been carried on in previous years, immediately began an exploration of the practicability of the suggestion.

At the Department's suggestion the Communications Satellite Corporation, acting on behalf of the Department of State and other interested government and commercial entities, became the coordinating agent and operating entity for the United States. The Corporation in making the necessary technical and financial arrangements, on its own initiative, went one step further and arranged for the extension of the television transmission via satellite to Canada and Europe.

After the transmission facilities in Japan and the receiving facilities at Point Mugu had been modified, the President and the Secretary of State together with the Japanese Foreign Minister and the Japanese Minister of Communications inaugurated the opening of the facility on October 7, 1964, by a successful transmission of a 15-minute television program which originated in Tokyo. The statements of the President and the Secretary of State were previously recorded on video tape and flown to Tokyo for the inaugural transmission since no transmission facilities to Japan were available at that time.

Technical arrangements for the television transmission via satellite were indeed unique. The video signal which originated in Japan was relayed via the SYCNOM III satellite to an existing U.S. Government-owned facility at Point Mugu, Calif. Because the satellite was not originally designed for television transmission, the combined transmission of the video and the audio via the satellite would have reduced the size of the video image. Therefore, the audio transmission was accomplished via the trans-Pacific cable. From Point Mugu where the video was synchronized with the audio the hour long program was relayed via microwave relay to Montreal where it was transcribed on video tape and then flown to Europe for viewing by the Western

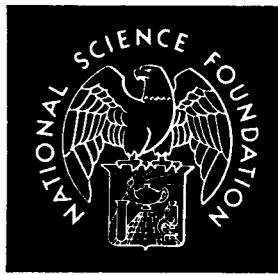
European countries and to a limited extent countries in Eastern Europe.

Television viewers in the United States were able to see the opening ceremonies of the Olympic games broadcast live from Tokyo. However, due to prior commercial arrangements which were concluded well in advance of the known availability of a usable satellite for the purpose, U.S. viewers saw the Olympics via video tape which was flown to the United States from Japan.

Shortly after the Olympics started, representatives of the European Broadcasting Union arranged to prepare a condensed 15-minute version of the hour long program, relayed to Montreal for almost "real time" transmission to Europe. The condensed package was then relayed via microwave to the AT&T earth terminal at Andover, Maine, which in turn relayed it via the RELAY I satellite to Europe where it was viewed the same day during "prime" evening hours the same day the events took place. The hour long program was seen at good time but later in the evening of the same day Tokyo time.

The net benefit to the United States in the conduct of this unique breakthrough in very long distance international communication was noteworthy in that it added further credibility to the feasibility of global communication via satellites. The picture quality both in the United States and in Europe was excellent and the interest of the viewing audience both in North America and Europe was widespread and enthusiastic.

The technical arrangements made prior to and the actual transmission of the television pictures from Tokyo were accomplished at no cost to the government.



# CHAPTER VII

## INTRODUCTION

The National Science Foundation has as its chief responsibilities the stimulation and support of basic research, promoting improved education in the sciences, and facilitating exchange of scientific information. Most of the work sponsored by the Foundation is carried on at colleges and universities and nonprofit research institutions in the United States.

The Foundation also has special responsibilities with respect to certain national laboratories, which it funds and sponsors, and certain national research programs. It is in the latter areas particularly that the Foundation's efforts are identified with those of the overall national space effort.

### The National Radio Astronomy Observatory (West Virginia)

The 300-foot diameter telescope, the world's largest moveable parabolic radio antenna, was used for more than 1200 hours during 1964 on a sky strip survey, with 4 receivers operating simultaneously. Observation of H II regions was also made and normal galaxies were studied. A 100 channel auto correlation hydrogen-line receiver, with magnetic tape output, was installed. H I radiation from discrete sources was measured, and the program of polarization measurements of external galaxies was resumed.

The construction schedule for the 140-foot precision radio telescope has been maintained, with all steel and aluminum in place at the end of the year. Addition of the electronics in the early months of 1965 will be the next step toward full operation by the middle of the year.

The second 85-foot dish antenna for the two-element radio interferometer, completed in June, was used at a wavelength of 11 centimeters both as a separate instrument and, with the first element, in interferometer form.

Final engineering studies are nearing completion for a 36-foot diameter, high precision radio telescope to operate at millimeter wavelengths and to be located at a high, dry site in the southwestern part of the country, perhaps at the Kitt Peak National Observatory.

### Kitt Peak National Observatory (Arizona)

The 84-inch stellar telescope was completed and available for staff and visitor use after September 15. Already equipped for direct photography and photoelectric photometry, spectrographs are under construction both for low dispersion work with faint objects and at higher dispersion for the brighter stars. A second 36-inch reflector is being built to fill the need for observing time at moderate

aperture. Automatic readout systems to increase the efficiency of these stellar telescopes when used for photoelectric work were constructed during the year.

The 60-inch solar telescope continued in demand for both daytime and night observations. Solar work included studies of depth dependence of physical properties in the sun's atmosphere. At night the telescope was used for lunar mapping and planetary photography, also for spectra at very high dispersion of bright stars.

In the Space Division, AEROBEE rocket flights in April and June secured further spectra of the daytime airglow in the program of planetary atmosphere studies. To extend this work to other planets, a fine attitude control system for the AEROBEE rocket is being developed. It will be further adapted for work on stellar spectra from above the earth's atmosphere. An expedition to Mount Chacaltaya, Bolivia secured intensity and polarization measurements of the zodiacal light from an altitude of 17,600 feet. The 16-inch telescope used to test the remotely controlled telescope system was moved to the mountain and set up in the dome already prepared for the planned 50-inch remote control telescope.

Plans for a 150-inch reflecting telescope at the Kitt Peak site moved ahead during the year. The fused quartz blank for the telescope mirror will be acquired during 1965.

#### Cerro Tololo Inter-American Observatory (Chile)

Inauguration of the access road to the mountain site late in 1963 and its completion in early 1964 permitted moving heavy equipment to the summit of Cerro Tololo to level its top for the planned 60-inch and 36-inch telescopes now under construction. During this work photoelectric observations with the 16-inch telescope were continued on the three-color photometry program for southern standard stars, and by visiting astronomers on two other researches requiring observations from the southern hemisphere.

#### The E. O. Hulburt Center for Space Research (Washington, D. C.)

Continued support by NSF of the Hulburt Center at the U. S. Naval Research Laboratory has broadened the research team in rocket and satellite astronomy at this laboratory to include visiting university faculty members and graduate students. A university scientist was assisted in the development of cryogenic rocket-borne photometers to use in the study of infrared celestial radiation from point sources and extended objects. Another is preparing instrumentation for rocket observations of possible interstellar absorption by hydrogen molecules.

#### STRATOSCOPE II Balloon-Borne Telescope

The second scientific flight of this 36-inch telescope system was launched on November 26, 1963, and its outstandingly successful results announced in 1964. As in the first such flight (both were to about 80,000 feet), an infrared spectroscope was used, this time to observe water vapor bands and other features in the atmospheres of six cool red giant stars as well as the spectrum of the moon, Jupiter and two hot stars.

In the STRATOSCOPE II project scientific ballooning has reached new capabilities for lifting heavy instruments above the greater part of the atmosphere. A ballooning test flight in the late spring of 1964 prepared for the added weight and ballast required for the first flight for direct photography with extended exposures on night sky objects.

#### The International Years of the Quiet Sun (IQSY)

The IQSY, one half of it occurring in 1964, is a coordinated effort to study the geophysical and interplanetary environment of the earth during the period of sunspot minimum. Federal coordinator for this national research program is the National Science Foundation.

The program for the IQSY consists of projects in meteorology, geomagnetism, aurora, airglow, ionospheric physics, solar radio astronomy, solar activity, the interplanetary medium, cosmic rays, trapped particles, and aeronomy.

In the field of meteorology, daily maps of the stratosphere up to the ten-millibar level are being produced through an objective analysis of available data by the U. S. Weather Bureau. The output of this computer program has also been used for predicting stratospheric warmings, first in the Arctic during the spring of 1964 and second in the Antarctic in the fall.

Ozone observations at a number of stations distributed in the Western Hemisphere from the North to the South Pole have been made on Regular Geophysical Days under the supervision of the Air Force Cambridge Research Laboratories.

Water vapor sounding techniques for the high atmosphere are being improved under the developments at both Naval Research Laboratory and the U. S. Army Ballistic Research Laboratory. Improved water vapor soundings in equatorial regions, combined with the ozone measurements, should provide important information relative to the energy balance of the upper atmosphere.

In the field of geomagnetism, the Coast and Geodetic Survey has established special stations for the study for the daily variation of the magnetic field on Midway, Koror, and Adak Islands in the Pacific Ocean. In addition, a computer facility has been established to facilitate rapid reduction and exchange of data among magnetic observatories throughout the world and correlation with data obtained from satellites; this project involves effective cooperation between the Coast and Geodetic Survey and Goddard Space Flight Center. Magnetic micro-pulsations are being observed and studied at a chain of stations from the Arctic to the Antarctic under the direction of the Central Radio Propagation Laboratory of the National Bureau of Standards; this program involves detection of pulsations in the range of 0.004 to 2 cycles per second, using magnetic tape for recordings instead of the former pen and ink charts. A cooperative network of observatories recording rapid variations of the magnetic field has made major progress in the coordination of observing techniques so as to increase the usefulness of the individual observations.

Studies of the aurora have been heavily concentrated in chains of stations established by the Geophysical Institute of Alaska, involving all-sky cameras, scanning photometers and spectrographs, as well as radio studies of the

absorption of cosmic noise by the ionized particles in the aurora. A study by the University of California on the precipitation of electrons into the aurora zone, measured by balloon-borne equipment, is under way. Airglow measurements, specifically high quality coverage of the whole sky with well calibrated photometers, under a program of the Central Radio Propagation Laboratory, has been extended to Kitt Peak, Arizona, in addition to the home station at Fritz Peak, Colorado, under NSF support.

Ionospheric studies have been in progress at a number of institutions. The Pennsylvania State University has made excellent progress in the construction of equipment for continuously monitoring profiles of electron density in the D-region of the ionosphere. It is now possible to produce daily electron density profiles from the data being secured. Stanford and Dartmouth each operate a chain of complementary stations for whistler studies. These studies of very low frequency phenomena are leading to increased knowledge of the magnetosphere, and the distribution of electrons along the magnetic field lines, uncovering a host of new phenomena at the boundaries of the earth's atmosphere.

Radio studies of the sun are in process at the University of Michigan where equipment for study of solar bursts has been improved in sensitivity. At Stanford University a large antenna array has been more sharply tuned to produce each day maps of the sun at radio wavelength of improved definition.

The solar flare patrol network reported through the Central Radio Propagation Laboratory has provided information for the system of alerts operated by the World Warning Centers. Several periods of extreme solar quiet have been identified. The flare patrol complex on Mt. Haleakala, Hawaii, has been improved by the addition of equipment and the construction of an observatory dome, providing an important link in the coverage of solar activity from the middle of the Pacific. Modifications of the Baker-Nunn cameras of the Smithsonian Astrophysical Observatory's satellite-tracking network have been supported to make possible the study of comet tails, which display changes presumed to be in response to solar activity. Continued operation of radar probes of the space between the earth and moon during the World Geophysical Intervals is supported by an IQSY grant to Stanford University.

In the field of cosmic radiation, a chain of new, high counting rate, super neutron monitors has been established. The chain runs from Thule, Greenland, to Dallas, Texas, and includes stations in Antarctica. The high counting rate enables variations to be measured with higher statistical certainty, so that real events can be distinguished from random noise. The data from this chain of stations will lead to improved detail in the mapping of the progress of solar plasma through the interplanetary magnetic field into the earth's field. Plans are being implemented by ten different organizations for a balloon-borne cosmic ray expedition to take measurements near the geomagnetic equator in India. The geomagnetic field of the earth acts as a filter for removing the lower energy solar components, a separation which can be made most successfully during the IQSY. Balloon studies of cosmic rays in northern latitudes have been pursued by the University of Minnesota.

DEPARTMENT OF COMMERCE



# CHAPTER VIII

## INTRODUCTION

The Department of Commerce supports and makes use of the Nation's space program. The principal activities of the Department in space and aeronautics are conducted by the Weather Bureau, the Coast and Geodetic Survey, the National Bureau of Standards, and the Office of the Secretary.

## WEATHER BUREAU

Responsibility for carrying out the space activities of the Weather Bureau is delegated to its National Weather Satellite Center in Suitland, Md.

As 1964 opened, some 50 weather forecasting stations around the world were receiving cloud pictures directly from the recently launched weather satellite TIROS VIII. This experiment marked an historic first in direct utilization of a space satellite by operational field stations with relatively simple receiving sets. As the satellite passed overhead, each station could tune in to a broadcast from the Automatic Picture Transmission (APT) system and receive a television picture of the clouds and weather conditions covering an area 1000 miles square around the station. The experiment continued successfully until the end of April, when deterioration of the camera system aboard the satellite made the pictures unusable.

The significant scientific advance which made this experiment possible is a special camera system which records a picture instantaneously aboard the satellite, then immediately broadcasts it much more slowly by television to enable ground stations to pick up the transmission with relatively inexpensive and compact equipment. The hundreds of thousands of pictures heretofore obtained by the TIROS satellites were transmitted much more rapidly to three or four specialized Command and Data Acquisition stations with highly sophisticated ground equipment. The high speed transmission enables these specialized stations to acquire a large number of stored pictures from around the world, while the slow transmission of the APT system allows reception of only two or three pictures covering the general vicinity of the individual receiving stations.

The TIROS VIII experiment was in reality the first flight test of the APT system, which originally had been designed for the NIMBUS satellites. Stations participating in the experiment included 12 major Weather Bureau forecast centers in the United States, 22 U.S. Air Force and U.S. Navy stations mostly overseas (including Antarctica) and about 12 stations built or purchased by foreign countries. The United States distributed advance information on the system to all member nations of the World Meteorological Organization, a United Nations agency.

An APT camera was flown again in September on the NIMBUS I satellite with spectacular results. The pictures contained far more detail than did the TIROS VIII APT pictures, and were again received and used at stations around the world. United

States east coast weather stations equipped with APT receivers tracked five different Atlantic hurricanes during the 1964 season. NIMBUS APT pictures received at the Weather Bureau's National Meteorological Center in Suitland, Md., were used by analysts of the Center to confirm or adjust routinely produced weather analyses. The pictures were also used to prepare nephanalyses (schematic cloud maps) for transmission on national facsimile networks.

Single stations received as many as four NIMBUS APT pictures during one overhead pass, each picture showing an area approximately 1000 miles square. Several APT picture sequences received by the Weather Bureau station at Suitland, Md., extended from the north coast of South America northward to eastern Canada.

Other 1964 highlights of the Weather Bureau's space activities, to be briefly reported below, include:

- a. successful launch by NASA of the first NIMBUS satellite, and limited operational use of its data by the Weather Bureau.
- b. emergence of a clearly defined concept of the TIROS Operational Satellite (TOS) System, to be established in late 1965 or early 1966 as the first implementation of the National Operational Meteorological Satellite System.
- c. continued support to meteorological operations by two conventional TIROS satellites, both of which operated excellently throughout the entire calendar year 1964.
- d. continued progress in satellite data research programs, and in development of new meteorological satellite sensors including particularly the successful balloon test flight of an infrared spectrometer.

#### Launch of NIMBUS I

NIMBUS I, the first flight model in a second generation of meteorological satellites, was successfully launched by NASA on August 28, 1964. It operated successfully until about September 22, when a mechanical malfunction in its solar paddles prevented proper absorption of solar radiation and cut power supply well below the minimum level required to operate the sensory and stabilization systems. At the end of 1964, the NASA was still receiving sporadic radio signals from NIMBUS I.

In addition to the APT pictures, NIMBUS I provided a large volume of data from its Advanced Vidicon Camera System and from the High Resolution Infrared Radiometer. The advanced vidicon pictures show far more detail than is contained in the standard TIROS television pictures, and the nearly 12,000 of them received are being archived for use by research meteorologists. The radiometer data were received in the form of pictures showing clouds, land forms, and oceans over the night side of the earth. The high quality of the radiation data points toward eventual operational use. Despite its short operational lifetime, the NIMBUS can be considered a highly successful experiment from the meteorological point of view.

## The TIROS Operational Satellite System Concept

The TIROS Operational Satellite (TOS) system is planned to fill the need for a relatively low-cost, fully operational weather satellite. The TOS system, based on proven TIROS technology, will use TIROS "wheel" satellites of a design to be tested with the launch of the next TIROS in the first quarter of 1965. The orbits will be nearly polar and sun-synchronous, to provide worldwide photographic and infrared coverage of the earth and its atmosphere at the same local time each day.

The distinctive feature of the "wheel" TIROS is that in orbit the spin-axis will be perpendicular to the plane of the orbit so, in effect, TOS will "roll" along the orbit on its edge. With its two cameras mounted 180° apart and looking out through the rim, instead of through the base plate as in the standard TIROS, the earth will come into view directly below each camera once each revolution. The camera will thus be able to view the earth from all parts of its orbit in contrast to the limited viewing capability of the present space-oriented TIROS.

The TOS system initially will consist of two types of satellites in orbit simultaneously. One will be equipped with two advanced vidicon cameras with associated tape recorders to store pictures for later high speed transmission to two specialized Weather Bureau Command and Data Acquisition stations. The other will have two APT cameras to provide direct transmission to all ground stations having suitable APT receivers. A heat balance radiation sensing system is also included for the advanced vidicon satellite. Launch of the first TOS is planned for late 1965 or early 1966.

The planned launch of the next TIROS R&D satellite will provide tests of the wheel satellite configuration, the attitude and camera control mechanisms, and the overall feasibility of the orbital system. This satellite is designed for a minimum life-time of six months.

The TOS configuration and system includes all features agreed upon by the NASA, the Department of Defense and the Department of Commerce.

## TIROS VII and TIROS VIII Operate Continuously Through 1964

On December 31, 1964 TIROS VII completed 561 days of continuously successful operation since its launch into orbit on June 19, 1963. Both its vidicon cameras and its medium resolution radiometer were still providing excellent data with no deterioration in quality. The previous record holder, TIROS VI, operated for 388 days before failing. TIROS VIII, launched December 21, 1963, had accumulated 376 days of operation by year's end, with its single recording vidicon camera still performing as well as on the day of launch. These records of operation confirm the dependability of the TIROS spacecraft which, with some modifications, will be used as the basic satellite for the new TOS system.

During 1964 the pictures from TIROS VII and VIII were used for direct support to a number of operational and research projects. The satellites were often programmed to take cloud pictures of specific areas at specific times to furnish the weather information requested.

One of the main operational projects was a tropical storm watch. Both of the TIROS, and briefly NIMBUS I, were programmed to maintain surveillance over areas of

potential tropical storm formation. When such storms were discovered they were tracked from day to day, and special meteorologically-coded advisories were sent to the weather services of all countries likely to be affected. Weather satellites were instrumental in initially detecting ten of the forty named storms that occurred in the tropics during 1964.

Other special projects, operations, and organizations that received direct support during the year included:

- a. Project GEMINI launches from Cape Kennedy.
- b. SATURN-APOLLO launch from Cape Kennedy.
- c. RANGER launch from Cape Kennedy.
- d. NASA Communications Satellite launch.
- e. Range support - Eastern Test Range and Western Test Range.
- f. The Galapagos Expedition.
- g. The International Indian Ocean Expedition.
- h. Trade Wind Zone Oceanography Program, Bureau of Commercial Fisheries.
- i. Ice Reconnaissance
- j. Desert Strike (Department of Defense).
- k. Mesoscale Meteorological Studies in the San Francisco Bay Region.
- l. Special USAF Operational Support.
- m. Anti-Locust Research Centre (London, Rome, Asmara).
- n. Navy Ordnance Test Station, China Lake, California.

#### Research and Development Programs

The Meteorological Satellite Laboratory is the research arm of NWSC. By analytical studies, research investigations, and experimental programs, it seeks (1) to extract the maximum possible weather information from satellite observations and (2) to find new ways to obtain information by satellite which will contribute toward improving the various services provided by the Weather Bureau.

During the year, the Meteorological Satellite Laboratory continued its work on the analysis of cloud pictures and infrared data received from the weather satellites. These data were used to study storms and atmospheric motions from the vantage point of space, and for extracting new information that can lead to greater understanding of atmospheric processes and improved weather forecasting. Among the more than sixty individual projects in the Laboratory are several of particular interest:

- a. a satellite infrared spectrometer designed to measure the vertical temperature structure of the middle and high atmosphere has been successfully tested on a balloon flying at 100,000 feet. The test took place on September 11 at Palestine, Texas. The instrument was recovered in working condition and the measurements obtained indicate that the spectrometer will work on-board a satellite. Construction of satellite hardware is now beginning.
- b. methods are being developed for improving numerical weather prediction models by using satellite data. Several tests have been made and results are promising.
- c. a method was developed for identifying the stage of development of tropical storms and maximum wind speeds in hurricanes by examination of the satellite photographs. The method was tested during the 1964 hurricane season with encouraging results.
- d. a special experiment has been designed to measure cloud heights from satellites by measuring atmospheric absorption of sunlight reflected from the tops of clouds. Spectral absorption in the oxygen "A" band at  $7621\text{\AA}$  is being studied in support of this program. Test measurements have already been made from aircraft using a specially designed 3.8 lb. hand-held spectrograph. This instrument will undergo additional testing aboard the first manned GEMINI flight prior to its use in weather satellites.
- e. Public Law 480 counterpart funds are being used to support research with meteorological satellite data at the Hebrew University, Jerusalem, Israel. The research will provide interpretation of meteorological satellite data obtained over the Middle East.

#### Other Progress in 1964

The Weather Bureau, in cooperation with the World Meteorological Organization and the United States-Japan Cooperative Science Program committee, arranged and furnished instructors for study-sessions and a workshop on satellite meteorology held in Tokyo from November 27 to December 15. Nearly 60 scientists from 15 nations attended these sessions.

The NWSC's Spaceflight Meteorology Group continued to provide climatological and forecast-development studies for many facets of the NASA's GEMINI and APOLLO missions. NASA Manned Spacecraft Center also received support in the form of operational forecasts needed for tests of aerospace systems and components. The test areas were in Texas and over the Gulf of Mexico. The Group also assumed new responsibility during the year for providing similar services pertinent to planning for the design, construction and maintenance of NASA facilities at Cape Kennedy and Merritt Island, Florida.

The Spaceflight Meteorology Group also was assigned responsibility for Weather Bureau support to the NASA Mississippi Test Facility, which included an expanded program in development of techniques for forecasting sound propagation conditions during rocket engine tests at the site.

The concept of a "World Weather Watch", which was developed in April 1963 during The Quadrennial Congress of the World Meteorological Organization, called for an intensive program to strengthen meteorological services and research with particular emphasis on artificial satellites, education, and training. Among its recommendations was the establishment of World Weather Centers in Washington and Moscow.

On October 25, 1964 a direct meteorological data link between these two cities was placed in operation as the first step toward implementing the World Weather Centers. Formal designation of the Weather Bureau's Suitland, Maryland, complex as "World Weather Center, Washington" followed on December 31, 1964.

## COAST AND GEODETIC SURVEY

### Geodetic Activities

The efforts conducted on Satellite Geodesy has, during this fiscal year, been almost exclusively concentrated in support of the geometric satellite triangulation method as part of the now established National Geodetic Satellite Program. The Coast and Geodetic Survey is developing the theoretical and practical tools for executing a worldwide geodetic satellite triangulation with an ECHO-type satellite which is to be launched during the first part of the calendar year 1966 by NASA.

A mathematical model of the contemplated 36-station net was derived and successfully tested. The corresponding electronic computer program will allow the study of the propagation of various observational errors, thus supporting the planning and logistics for an optimum field operation. Numerous auxiliary programs have been designed for the various steps in the data reduction, including programs for production control based on statistically significant accuracy tests. A fully operational prototype program for the execution of geodetic satellite triangulation for a seven station net was designed, tested, and applied to the first operational results on the 800-mile test triangle (Aberdeen, Maryland; Chandler Air Force Base, Minnesota and Greenville Air Force Base, Mississippi). The accuracy obtained is at least three times better than expected, and the results demonstrate that the method is capable of improving the basic first-order triangulation and to serve as a unique technique for the establishment of a worldwide geodetic reference frame. Furthermore, these results indicate that we will be able to draw significant conclusions about the validity of theorems in theoretical geodesy when the method is applied over a larger number of triangles. A new lens for the BC-4 has been designed to further enhance the metric quality of the data acquisition system.

### Geomagnetic Activities

The large coil facility at the Fredericksburg, Maryland Magnetic Observatory and Laboratory has continued to serve the needs of the national space program for the testing and calibrating of instrumental equipment designed for measuring intensity and direction of the magnetic fields encountered in space. The coil system, with fully automatic controls, can maintain a constant field of any specified intensity and direction (including zero field strength). The coils are large enough to permit generating other artificial physical conditions--high vacuum, intense sun-like heat and light radiation, and very low temperatures.

The analysis and interpretation of magnetic measurements made in orbiting vehicles and space probes must be correlated with the distribution of the magnetic field, and its changes, at the earth's surface. For this purpose, the daily records of changes in the magnetic field are currently obtained from some 35 to 40 magnetic observatories around the world and are being converted to digital form to permit correlation through electronic data processing techniques with the satellite recordings. This work is a 3-way cooperative effort supported by the Coast and Geodetic Survey, the National Aeronautics and Space Administration, and the National Science Foundation.

The magnetic charts of the world for epoch 1965 are being compiled as a cooperative project with the U. S. Navy Oceanographic Office using newly developed analytical techniques and the largest available electronic computer (the U. S. Weather Bureau's "STRETCH" computer). The results of these efforts will be a set of world magnetic charts of greater accuracy than any previous publication. Spherical harmonic coefficients of degree and order at least as high as the 18th--possibly the 36th--are being derived, which describe the geomagnetic field with higher definition than any previous analysis. A mathematical description of the magnetic field at any altitude, derived from this analysis, should be helpful in any space studies having geocentric references.

### Seismological Activities

The seismic effects of the intentional destruction of a TITAN III solid fuel motor with 80,000 pounds of propellant was monitored to determine the TNT equivalence to assess the potential damage from an explosion on the pad or abortive impact shortly after launch.

Two SATURN (SA-5 and SA-6) launches were monitored at the John F. Kennedy Space Center with seismic instruments to provide information relative to ground equipment design criteria for the control of hazards which could result from large-scale missile launches.

## NATIONAL BUREAU OF STANDARDS

The rapidly expanding national space effort has generated many demands for new and more precise measurement techniques, for reliable data on the basic properties of matter and materials, and for more accurate determinations of physical constants. The efforts of the National Bureau of Standards to meet these many and varied needs of science and industry contribute substantially, although sometimes indirectly, to the space program.

### Basic Measurement Standards and Techniques

Numerous improvements were made in the calibration services through which NBS makes its measurement competence available to science and industry.

In length measurements, for example, an important advance was the development of a line standard interferometer which uses automatic fringe-counting techniques. This instrument was devised for calibrating graduated length scales such as are used on many types of precision machinery. For such measurements, it makes possible a precision within a millionth of an inch, performing in 15 minutes a calibration procedure that previously would have required as long as 15 hours.

Very large weights are used extensively in the calibration of devices used to measure the thrust of rocket engines. Periodically the weights must be calibrated, and the equipment is out of service while the weights are shipped to NBS and back. The Bureau recently developed a comparative measuring technique which should permit any laboratory to use readily available equipment in the calibration of its own large weights. With a load cell used as a comparator in a double substitution weighing scheme, precisions of 5 parts per million have been achieved in the calibration of 10,000-pound weights. Over the next few years this technique should result in substantial savings in time and dollars by decreasing the downtime while weights are shipped to NBS for calibration.

The need for accurate temperature measurements below 20° K has increased greatly as cryogenic liquids find wide application in rocket propulsion systems and in numerous space-age research tools. During the year, the Bureau established a new low-temperature calibration facility covering the range 2 to 5° K. It is based upon germanium resistance thermometers that have proved especially suitable for use in this temperature region. Development of a new acoustical thermometer also was completed which will make it possible to provide calibration services in the range from 2 to 20° K in the near future.

Because of the enormous complexity of most hot gases or plasmas, it has been extremely difficult to develop accurate and convenient diagnostic techniques that might provide better measurements and understanding of the characteristics of the plasmas encountered in space, solar and stellar atmospheres. The Bureau recently has developed a new form of plasma-- the brush-cathode plasma--which is both stable and uniform, thus lending itself to precision measurement of its characteristics. As a result of this development, the reliability, compatibility, and useful ranges of various diagnostic tools such as Langmuir probes, resonant probes, microwaves interaction, and spectroscopic measurements can be studied in this well-behaved plasma medium.

#### Standard Reference Data and Properties of Materials

Reliable basic information on the properties and behavior of matter and materials is essential to the design and execution of the complex experiments, equipment, and systems involved in the space effort. In 1963, NBS accepted responsibility for administering and coordinating a National Standard Reference Data System to provide critically evaluated data in the physical sciences on a national basis. The first year of the NSRDS was devoted mainly to planning the extensive data compilation program. Surveys were made of existing data-compilation activities in seven broad technical categories, and a detailed appraisal of needs and priorities for new or expanded programs is under way. Operation of the well established NBS data centers in chemical thermodynamics, atomic transition probabilities, atomic cross sections, and cryogenics continued in close coordination with the NSRDS.

Properties of atoms with excitation energies in the intermediate energy range are of special significance to space programs since this type of excitation is normal in the hot gases or plasmas that exist in the upper atmosphere and in space. However, because of technical difficulties and the lack of adequate tools of analysis, only fragmentary studies of atomic properties have been made in this energy range. During the year, two powerful new techniques for such studies were devised at NBS. The application of a new high-resolution electron scattering apparatus and of

a far ultraviolet spectrometer employing light generated by the Bureau's 180-million electron volt synchrotron has already led to observations of hundreds of new atomic levels which exhibit properties that are absent or not relevant in other energy ranges. Many of these levels belong to previously unknown negative ions. Other atomic data can now be obtained which are of great importance to studies of the upper atmosphere and space.

The broad ranging programs at NBS on basic properties of materials produced much needed information during the year. Studies supported by NASA on the stability of polymers when exposed to ionizing radiation, and for determination of the rate of vaporization of high-melting-point metals used in the development of thermionic generators, were typical.

### Cryogenics

Cryogenic activities, centered at the NBS Boulder Laboratories, provide data on the bulk properties of materials in the environmental extreme of very low temperatures. Research is conducted at cryogenic temperatures to determine the physical properties of materials, the engineering properties of systems, and to develop methods for measuring these properties.

Since many advanced chemical and nuclear rockets use hydrogen as a fuel or as a monopropellant, the thermodynamic and transport properties of hydrogen need to be known with higher accuracy and over wider ranges of temperature and pressure. The Bureau, with the support of NASA, is engaged in an extensive experimental program to determine these data. Previously, P-V-T and thermal properties were determined, and extensive provisional tables of thermodynamic functions were published. During the past year, measurements of the viscosity of hydrogen were concluded covering the same pressure and temperature ranges.

Many of the problems associated with the use of hydrogen in liquid form as a fuel for space vehicles might be eliminated or greatly reduced by further refrigeration of the liquid to form a mixture of solid and liquid or "slush." These problems include short holding or storage time, pump cavitation, flight instability caused by sloshing liquid, and safety hazards associated with high hydrogen vent rates. With NASA support, the Bureau is conducting a broad study of "slush" hydrogen aimed toward an optimization of the concepts to be incorporated in a space vehicle launch facility. This study includes the evaluation and correlation of all known applicable properties of "slush" hydrogen, and investigation of production methods and flow characteristics. The results will assist in the establishment of specifications for instrumentation and production of flowable mixtures of solid and liquid hydrogen.

The Bureau continued its studies of fluid flow and heat transfer characteristics of cryogenic systems. Much needed data were produced on boiling heat transfer which is of concern to designers of a wide range of cryogenic systems. An analytical method was developed for predicting peak surge pressures to be expected when the cold fluids are introduced into ambient-temperature transfer lines. Another study was concerned with methods of predicting the rate of heat transfer from, and frost formation on, tubes or pipes containing cryogenic fluid and exposed to air.

## Radio Propagation

Through its Central Radio Propagation Laboratory (CRPL) at Boulder, Colorado, NBS has a central responsibility for radio propagation research, for prediction of radio propagation conditions, and for technical advice and assistance in the use and conservation of the radio spectrum. In addition to studies aimed at the specific needs and problems associated with space and aeronautic telecommunications, CRPL conducts broad research intended to improve understanding of atmospheric and solar phenomena. The examples which follow represent only a small portion of the total program.

The total eclipse of the sun in July 1963 provided an excellent opportunity for observation of the effects of the eclipse on the ionosphere. Vertical soundings of the ionosphere were made by several laboratories from a total of 22 locations across the continent, providing the most extensive set of ionospheric observations ever made for a solar eclipse. Analysis of the data by CRPL during the last year showed a well marked geographical pattern of variation in the F-region of the ionosphere with eclipse time. Maps of this variation are being prepared for use in testing theories of physical processes in the ionosphere. Studies using very-low-frequency radio signals received during the same eclipse provided valuable information about the response of the D-region of the ionosphere to ionizing radiation. Other solar studies during the year were concerned with the persistence of solar flare activity at certain locations on the sun, with sudden changes in the so-called "dark filaments" on the sun which have been found to be associated with bursts of radio noise, and with noise storms in the solar atmosphere.

CRPL has played an active role in planning, coordinating, and executing certain programs for the International Year of the Quiet Sun (IQSY). This is a period during 1964 and 1965 which is characterized by a lull in solar radio activity and hence permits studying phenomena which are obscured by normal solar activity. Scientists from more than 65 nations are making measurements, under this coordinated program, in a variety of disciplines concerned with solar and terrestrial physics. With partial support from the National Science Foundation, CRPL is operating World Data Center-A for Airglow and Ionosphere and participating in the operation of a Data Center for Solar Activity.

Success in some areas of the IQSY depends on making observations when the desired types of solar and geophysical activity are taking place, for which advance knowledge is needed. Notice of such events is distributed through the NBS Radio Warning Services. This group also assigns designations to all satellites and space probes for the International Committee on Space Research (COSPAR) and distributes satellite launching and orbit data internationally.

At the Jicamarca Radar Observatory operated by CRPL on the magnetic equator near Lima, Peru, studies are being made of various features of the equatorial ionosphere with a very powerful radar. Its basic function is to study the distribution of electron density by means of the incoherent scatter technique. Observations made during the year have yielded information not only on electron density, at heights from 200 to about 10,000 km, but also on electron and ion composition and temperature at heights from 200 to 1200 km. Protons were found to be the major ionic constituent in the magnetosphere, outnumbering atomic oxygen at some heights and certain times of day. Other radar measurements combined with

theoretical studies at Jicamarca show that acoustic-wave plasma instabilities are generated in the equatorial E-region by the flow of the strong equatorial electrojet. Radar echoes from the resulting ionospheric irregularities are similar to previously observed auroral radar returns. It is now believed that the auroral returns arise from essentially the same phenomena.

Study continued on the radio interference problems that might arise in the event space telecommunication services are operated on frequencies shared with systems on the surface of the earth. The effectiveness of antenna discrimination against unwanted signals is being investigated through both theory and measurement. Effects of beam or pattern orientation, polarization changes, and phase interference from multi-path propagation are being considered. In closely related work supported by the Air Force, experimental microwave measurements were made between a mountain top transmitter and several lower elevation receiving sites to determine the information rate or bandwidth limitations imposed by the atmosphere on satellite-to-earth communication systems at low elevation angles.

CRPL scientists used signals from the Ionospheric Beacon Satellite S-66 to chart the electron distribution below the satellite path. The electron density was found by determining the signal polarities, and thereby the Faraday rotation imposed during transit on the linearly polarized satellite transmissions at two closely spaced frequencies. Observations were made at several stations located on a line parallel to the satellite's path. Data from S-66 will be supplemented by data taken from OGO-A. These in turn will be compared with results of studies of SPUTNIK III. Study of these data from three different sources will enable the NBS scientists to obtain a more complete, overall picture of the electron density in the ionosphere.

New statistical techniques and the use of electronic computers produced improved methods for predicting the performance of high-frequency skywave radio systems. Such computations were used routinely to obtain optimum frequency utilization in the NASA ground communication system, in maintaining ground communications during mapping by the use of satellites, and in estimating the extended range of high-frequency communications during the APOLLO mission.

### Other Services

The broad competence of NBS was utilized by many other Federal agencies in meeting their responsibilities for aeronautic and space related activities. These consultative and advisory services ranged from the basic planning of a global-range information-processing and control system for future orbital and space programs of interest to the Air Force, to assistance given the Army in the selection of construction materials for the SATURN rocket installation at Cape Kennedy. They included such activities as consultation with NASA and DOD on corrosion problems, testing for DOD of the fatigue strength of various aircraft structures, examination for the Civil Aeronautics Board of service failures of aircraft, and mathematical studies for NASA on the theory of satellite orbits.

As a result of action by the Federal Council for Science and Technology, a Clearinghouse for Scientific and Technical Information was established at NBS in February 1964. The Clearinghouse provides a central point of contact from which industry and the technical community may obtain information on government activities in the physical and engineering sciences. This facility will be of major importance in assisting American industry to benefit from defense and space research.

## OFFICE OF THE SECRETARY

### Economic Analysis of the Supersonic Transport

At the President's direction, the Department of Commerce has directed a parametric cost-benefit analysis of various supersonic and advanced subsonic transport aircraft which could enter airline service in the United States during the next ten years. The study is directed at the impact of new aircraft types on the aircraft manufacturing industry, on U. S. exports, on U. S. airlines, and on the quality and cost of air transportation. A wide variety of factors were considered in estimating the demand which would be generated for each type of new aircraft in the various economic and international environments possible in the early and middle 1970's. These factors included: level of business activity; ticket price; trip time; comfort; safety; convenience of schedule; consumer income; the performance, costs and ticket prices of competing aircraft both foreign and domestic; attitudes and practices of airline managements; the nature and extent of interconnection between airlines; and, the attitudes and practices of governments in establishing route and fare structures.

The demand study was set up in the form of a large computer program which could simulate, essentially, the complete operation of the major world airlines, including the probable flow of passengers in virtually any competitive situation. This computer program, along with others, allowed the airline operating costs and airline revenues to be determined for any given period of time. Similar cost-benefit analyses were conducted on the operations of airframe and engine manufactures which might develop the new aircraft.

The results of this study were used to make a series of recommendations to the President regarding the proper goals and the best strategy for a national program to retain leadership in the manufacturing and use of modern, economical air transport equipment. Both subsonic and supersonic aircraft were considered in these recommendations as well as the competition potential of the British-French Concorde supersonic transport program. The findings framed to assist in answering basic policy questions, such as: the proper pace for SST development; the type of industrial competition which would yield the greatest return on investment in SST development, and, the the government-industry risk-sharing arrangements best suited to timely SST development while preserving the incentives of private initiative.

This study was conducted with broad cooperation and assistance from the Civil Aeronautics Board, the Department of Defense, Federal Aviation Agency, National Aeronautics and Space Administration, Department of Treasury, the Air Transport Association, Airport Operators Council, the aircraft and engine manufacturing industries, and the airline industry.

INTRODUCTION

The National Academy of Sciences, a private organization of scientists and engineers that serves as an official adviser to the Federal Government, is called upon to advise the government on scientific aspects of the space program. These advisory services are carried out on behalf of the Academy by its Space Science Board. In addition, the Board furthers space research generally by promoting the discussion of advances and opportunities in the field. Internationally, the Board, on behalf of the Academy, represents the U. S. scientific community on the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU), and has collaborated closely with that committee. The committee serves to encourage and guide international cooperation in space research, to facilitate the exchange of information, and to elicit the interest and participation of scientists throughout the world.

Committees

To accomplish its work the Board with an Executive Committee and a small number of standing committees holds regular meetings. The committees are: Surfaces and Interiors of the Moon and Planets, Life Sciences, Geodetic Uses of Navigational Satellites, High Altitude Rocket and Balloon Research, Potential Contamination and Interference from Space Experiments, and several ad hoc groups. The Board maintains continuous and close liaison 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 NASA, the Department of State, the FCC, the DOD and other interested government departments and agencies.

THE NATIONAL SPACE PROGRAMBoard Assistance to NASA

The National Aeronautics and Space Administration (NASA) requested the Board for assistance in reviewing NASA's future space exploration plans with the object of relating hardware and development programs to prospective missions. The main purpose of this review was to define those objectives of space exploration which might require new missions and the development of major new technologies.

NASA pointed out the need for balance in the space program among science, applications and technology, and manned space flight and urged the Board to consider the present state and the future direction. The Board submitted to NASA a broad statement on future goals and at the same time noted that the 1962 Iowa Study, A Review of Space Research, is now two years old and should be reexamined to bring up to date the views expressed there on problems of scientific interest.

In its Report to NASA the Board concluded that the exploration of the nearer planets will be the most rewarding goal for science, and will also serve as a focus of national attention, for the 10 to 15 years following the manned lunar landing, to capitalize on the achievements of APOLLO. The primary goal of the national space program should be the exploration of the planet Mars. (Full text of the Report was released to the public by the Academy on November 17, 1964).

The Board agreed unanimously that the national goals in space should be:

- a. the Mars program should be the major goal past 1970, starting un-manned with the SATURN class of vehicles with suitable decontamination.
- b. the lunar program should be continued but subordinated to the Mars effort, recognizing continued lunar scientific goals.
- c. a continued program of science in space is essential with respect to: earth itself; interplanetary space; solar physics and preliminary exploration of other space objects; and astronomical observations outside the atmosphere. This program is essential to the accumulation of basic information for manned programs. The development of standardized vehicles could reduce its cost.
- d. the manned earth orbital program should be developed for rescue, service of unmanned vehicles, and several military objectives such as inspection, but should be a secondary -- not a primary -- goal.
- e. flexibility should be provided in all these programs to permit exploitation of any major, unforeseen breakthrough or discovery. The Board agrees that our space program must satisfy all national objectives, but that to do this the scientific program must make a maximum of sense.
- f. obvious applications should be exploited quickly, as now planned.

#### Qualifications and Selection of Scientist-Astronauts

The Board, acting on the request of NASA, convened an ad hoc committee to develop scientific qualifications for scientist-astronaut selection. The Academy will make the initial selection of applicants on the basis of scientific qualifications and will recommend to NASA approximately 75 individuals. The committee agreed that no branch of science should be excluded a priori from consideration. Background in the physics and chemistry of rocks and meteorites is desirable. The ad hoc committee established minimum qualifications and aids towards arriving at certain special qualifications. The recommended minimum scientific qualifications are:

- a. a bachelor's degree; and
- b. a doctor's degree in a natural science, medicine or engineering, or the equivalent experience.

Final selection will be made by NASA on the basis of qualifications other than scientific.

## Biology and Man in Space

In April 1964, at the request of the government, a Working Conference was arranged at the University of South Florida to study the problems of nutrition and waste disposal on longer space missions. Actively participating in this symposium were many of the national authorities in the field of nutrition and representatives of the Department of Defense, as well as various elements of NASA. A report will be published late this year.

The Life Sciences Committee of the Board has a group of scientists looking into the problem of radiation hazards of longer space missions. This group will bring together the information that has been gained on the space radiation environment and relate this to planned missions.

The question of the optimum atmosphere for longer manned space missions is being reviewed by a Working Group. A Summary Report on Gaseous Environment for Manned Spacecraft was issued during the past year.

A review of proposed biomedical experiments for APOLLO-GEMINI missions is being conducted. The support for programs in space biology and manned spacecraft continues to be a matter of vital interest to the Space Science Board.

## Advanced OAO

The Board agrees that there is justification for placing in orbit an astronomical facility larger and more versatile than the Orbiting Astronomical Observatory. This question was raised by the 1962 Summer Study. Further discussions are necessary which should lead to some engineering studies for a large-aperture telescope in space.

## WEST FORD Experiment and Interference from Space Activities

The WEST FORD experiment involved the creation of an orbital belt of many fine wire dipoles and the testing of its properties as a reflector in a radio communications system. The experiment as conducted in May 1963 was designed to produce a belt with limited lifetime, to avoid causing interference to astronomical research. Established at the request of the government, a special Board committee has continued to follow this project, to compare its predictions with the results of the WEST FORD experiment.

The committee concluded that, with the observing techniques in use today, the present experiment has not been harmful to either optical or radio astronomy.

These conclusions were identical with those of the International Astronomical Union and concurred in by the COSPAR Consultative Group on Potentially Harmful Effects of Space Experiments (Florence 1964).

With the possibility that, during the next few years, increasing activity in space may lead to contamination of the environment in subtle ways or to interference with other scientific research, the Board has established a committee with broader responsibilities in this area of interest. The committee has first concerned itself, as has its international counterpart, COSPAR's Consultative Group, with a study of the

levels of accumulation of rocket fuel, exhaust, and chemicals released in the upper atmosphere. The conclusion is that all substances (except a few elements of scientific interest, present only as traces in atmosphere) would have to be injected at rates several orders of magnitude greater than the present rate to produce any but very temporary and local effects.

### Exobiology Summer Study

In response to a request from NASA the Board decided that a study to develop the aims of and the proper strategy and approach to the search for extraterrestrial life should be held this year. A Steering Committee was formed and agreed that a series of meetings rather than one extended meeting should be held.

The study is progressing satisfactorily. The main objective is to produce a document on the aims of exobiology and to outline a national plan for the pursuit of exobiology.

The latest progress report reiterates that the primary goal of the national space program after the APOLLO program should be the exploration of the planet Mars. The adventurous exploration of Mars will emphasize strongly the answers to biological questions; hence sterilization techniques will be necessary to avoid contaminating the Mars environment. Knowledge of the physical surroundings of Mars must be improved before any actual landing.

## INTERNATIONAL ACTIVITIES

### Potentially Harmful Effects of Space Experiments

The Board has long been concerned with the problems which might arise from the landing of unclean spacecraft on the moon and the planets before an adequate study of the existence of life or the chemical precursors of life on these bodies could be made. The Board has advised the government with respect to decontamination of lunar and Mars probes. The COSPAR Consultative Group on Potentially Harmful Effects of Space Experiments has also considered this topic, and has adopted some tentatively recommended interim objectives for the guidance of launching nations. COSPAR further encourages the exchange of information and cooperation between the two major satellite and space probe launching nations, to avoid the contamination of Mars by non-sterile spacecraft.

In other action, COSPAR at its meeting in Florence, Italy, accepted the findings of the Board's ad hoc WEST FORD Committee and concluded that no interference to optical or radio astronomy has resulted from the belt of orbiting dipoles launched in May 1963, but recommended to its members that any proposals for future experiments of this sort be evaluated by the scientific community in order to assess in advance their harmlessness to other scientific research.

### Seventh Meeting of COSPAR

The Board organized the attendance by U.S. scientists at the meeting of COSPAR in Florence, Italy, May 8-20, 1964, and prepared and presented the summary report of the year's activities in this country in space research. The attendance figures indicated a gratifying participation on the part of smaller countries.

Messages or reports were received from international scientific unions and special committees. Annual reports on space research done during the previous year, present activity, and plans for the near future were submitted by the national scientific bodies adhering to COSPAR. The yearly increase in the number and content of these reports shows a steady growth of interest and activity in space research in the countries that have no satellite program of their own, as well as those that do.

#### International Years of the Quiet Sun (IQSY)

The planning of the IQSY program is now complete, and observational programs are now in operation in 70 participating countries. IQSY work is in progress in at least two or three additional countries and it is hoped that these will agree to participate formally in the near future. Data in the IQSY disciplines (meteorology, aeronomy, aurora and airglow, geomagnetism, the ionosphere, solar physics, and cosmic rays) are collected at more than 900 stations, not counting the 700 engaged in more routine types of meteorological work. COSPAR's Working Group for the IQSY has planned and encouraged the rocket and satellite portion of the IQSY program. To stimulate the program eight manuals describing techniques of rocket experiments have been prepared and distributed to interested scientists, and a ninth is in press.

#### COSPAR Fifth International Space Science Symposium

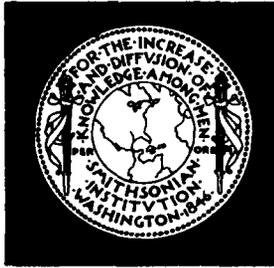
The Fifth International Space Science Symposium was held in conjunction with the Seventh Meeting of COSPAR in Florence, Italy, May 8-20, 1964. The U.S. delegation, organized by the Board, contributed more than 90 papers. The central theme of the sessions for papers in the physical sciences was The Interaction of Energetic Particles with the Atmosphere. Contributions were encouraged from countries that have only recently begun space research.

In the physical sciences sessions, the general impression was one of firming up results that had been only suggested in earlier work -- a general filling-in.

The life sciences are beginning to receive attention commensurate with their importance. The symposium this year was marked by a more nearly balanced presentation. There was a rather full presentation of biological and physiological results from the U.S.S.R. VOSTOK flights.

#### World Data Center A for Rockets and Satellites

The Board continued to support the operation of the World Data Center, which collects and exchanges the results of research with spacecraft and sounding rockets. The usual annual bibliography of reports and papers was submitted to COSPAR. Of particular interest was the transmittal of sets of original RANGER 7 photographs of the moon to the World Data Centers in other parts of the world.



INTRODUCTION

Established in 1890 as a center for research in solar astronomy, the Smithsonian Astrophysical Observatory pursues a broad program of research in astrophysics and related space sciences. Observational data are obtained from a satellite tracking network, field stations for the observation of meteors, satellite experiments, and similar projects. Research topics include the geopotential, geometrical geodesy, the upper atmosphere, meteors, meteorites, comets, the planets, and various solar and stellar phenomena. These activities are supported by private funds from the parent institution, by federal appropriations, and by foundations. For the space programs, major grants are received from the National Aeronautics and Space Administration.

More than fifty scientists carry out these research projects. Each year they are joined by consultants from other institutions in the United States and foreign countries, exemplifying the best tradition of the international spirit of science.

OPTICAL SATELLITE TRACKING PROGRAM

The optical satellite tracking program of the Observatory has a dual mission: it gathers data for investigations by staff scientists of the density and temperature of the upper atmosphere, the earth's gravitational field, and the geometrical relation between points on the earth's surface; and it provides preliminary coverage of new NASA launches and tracks satellites on special assignments from NASA and other agencies.

The network consists of 12 Baker-Nunn camera stations in 10 countries as well as of Moonwatch teams of volunteer observers. The Baker-Nunn stations made more than 40,000 observations in 1964--an increase of better than 30% over the previous year. Included were many simultaneous observations from two or more stations to support the world-wide geodetic measurements being made by the Observatory, and special films of the geodetic flashing satellite ANNA IB. Approximately 32,000 Baker-Nunn films were reduced to determine precise satellite positions relative to atomic time.

The camera stations also produced unique photographic data for SYNCOM II, CENTAUR (AC-2) and other objects on special assignment.

A model of the major temperature variations in the upper atmosphere has been prepared from analyses of Baker-Nunn observations of satellites. Recent observations of INJUN 3 and EXPLORER 17, have determined that atmospheric heating accompanying geomagnetic disturbances is greater in the auroral zones than at

middle latitudes. Also, the relation between atmospheric heating and the geomagnetic index departs strikingly from linearity on magnetically-near-quiet days, thus implying greater heating from this source than had been thought.

From 26,000 precisely reduced Baker-Nunn observations of 11 objects, new estimates have been made of the coefficients of zonal, tesseral, and sectorial harmonics of the geopotential. Related studies support the hypothesis that irregularities of the earth derived from satellite observations are correlated with uneven thermal expansion of the earth's mantle from some heating process, perhaps an inhomogeneous distribution of radioactive heat sources.

More than 45,000 Baker-Nunn films were used in a new analysis to derive the coordinates of the camera stations. The resulting information was used in determinations of the absolute deflections of the vertical for seven geodetic datums.

Other geodetic investigations employ simultaneous observations from two or more Baker-Nunn stations to define the directions of the lines connecting them to an accuracy approaching one second of arc. In time, these efforts will provide an independent determination of the relation of the major world datums.

As an adjunct to this expanded geodetic work, the International Union of Geodesy and Geophysics and the International Committee on Space Research have invited the Observatory to establish and maintain in Cambridge an international Central Bureau for Satellite Geodesy. The Bureau will collect and publish predictions, observations, and other data on satellite geodesy.

#### METEORITIC STUDIES

Through data obtained by several newly completed field systems, the Observatory's investigations in the meteoritic sciences have expanded.

By mid-1964, all 16 camera stations of the meteorite recovery program became fully operational. Shortly thereafter, double-station photographs were obtained of meteors whose luminosity far exceeded any on which data had previously been acquired. One set of photographs yielded data that will lead to a search for a possible meteorite.

The addition of large trough -antennas to all sites of the Harvard-Smithsonian radio meteor project greatly enhanced its capabilities. This multistation radar system has provided comprehensive data on meteors significantly smaller than previously studied by similar projects, and major results from the improved networks are imminent. In addition, members of the project are conducting an investigation of upper atmospheric wind by measurement of the drift of meteor trails.

Except for an additional camera station, instrumentation for the meteor simulation project was completed with the installation of four radar receivers and a shipboard transmitter. This program, conducted with the cooperation of NASA's Langley Research Center, makes possible simultaneous radar measurements and optical observations of the luminosity and ionization produced by artificial meteors.

The Observatory's program for the identification and analysis of micrometeoritic particles is continuing. The recently completed mass spectrometer is used to

ascertain the presence of material of extraterrestrial origin in deep sea sediments and in matter from Greenland ice.

Significant advances were made in the programs for the analysis of meteorites. Sufficient materials were separated from the recently fallen chondrite Peace River to permit measurement of the short-lived argon-37 in the whole-rock, magnetic, and nonmagnetic phases. Analyses have also been made of xenon and krypton from minerals and chondrules from the Bruderheim meteorite. Methods were devised for trace-element determinations by mass spectrometry of neutron-irradiated samples, as well as for potassium-argon dating.

The measurements of cosmic-ray-produced radioactive and stable isotopes in extraterrestrial material have established the time that various meteorites were exposed to cosmic rays. Similar measurements made on recovered satellites indicate that in addition to cosmic rays there are isotope effects produced by Van Allen and solar flare particles.

A metallurgical study of Widmanstätten patterns in metallic meteorites was made to establish the roles of pressure, temperature, and time in the formation of these patterns. A method of analysis using the method of finite differences was developed for the diffusion-controlled growth of the Widmanstätten patterns. Two alternative models have been proposed for the origin of meteorites in which the Widmanstätten pattern formed at low pressures.

#### COMETARY STUDIES

The Baker-Nunn network has been employed to make a series of observations of comets for analysis and study by the Observatory staff. It is known that the tail of a comet may oscillate about the line directed through the comet away from the sun; observations by the Baker-Nunn cameras are being used to investigate this phenomenon.

A photometric study is concerned with several other cometary features, including whether changes in comet magnitudes correlate with solar activity.

The Director of the Observatory has suggested the possibility that several periodic comets may disappear within a few years. This research should stimulate further studies of the actual decay processes of comets and efforts to rediscover old comets that have disappeared.

New research is being conducted on the theory that the head of a comet may be an icy conglomerate. After a re-examination of the theory of heat transfer in glaciers, laboratory work has been initiated to explain the transfer of heat and mass within substances like snow and frosty sand.

#### SPACE OBSERVATORIES

Project Celestee is the Observatory's satellite experiment to survey the stars in the ultraviolet ray region. The prototype instrument has been completed and is now undergoing extensive environmental testing. The flight instrument, for launch in an Orbiting Astronomical Observatory, is under construction. Procedures for the absolute calibration of the four ultraviolet television photometers have been estab-

lished, and a procedure for coordinating the reduction and analysis of the automated data has been defined.

In a continuing project, reduction of 1,000 orbits of data from the Orbiting Solar Observatory A has indicated no evidence of high-energy gamma rays from the sun, even during solar flares.

A new sensitive detector is being built for use in balloons and satellites to search for high-energy gamma rays from celestial sources. The device is a spark chamber used in conjunction with a television system. Preparations for a balloon flight test of the detector are being made. In a related project, in cooperation with the Army Quartermaster Corps, a converted large-area solar furnace is being used as a ground-based detector to search for extremely high-energy gamma rays.

#### OTHER SPACE STUDIES

In the field of planetary sciences the nature of atomic collision processes is being studied by an analysis of the phenomena of the aurora and airglow. Another study is concerned with possible atmospheric phenomena on Mars and Venus. A third, involving laboratory synthesis of molecules fundamental to biological processes, is attempting an answer to the key question of the origin of life on earth and possibly elsewhere. An analysis of Saturn's rings continues.

In solar studies, observations are being analyzed to correlate photospheric velocities and magnetic fields. Ways that neutrinos from the sun can be detected are being studied.

The Baker-Nunn cameras continue to be used to photograph flare stars nearly simultaneously with observations by radio telescopes. One result has been to show that the velocity of light is constant to better than one part in  $10^6$  over a range in wavelength exceeding a factor of  $2 \times 10^6$ .

The Smithsonian catalog giving the positions, magnitudes, and other data on more than 250,000 stars will be issued in early 1965.

FEDERAL AVIATION AGENCY



# CHAPTER XI

## INTRODUCTION

Along with new challenges typical of a dynamic technology, 1964 brought to the Federal Aviation Agency fresh opportunities to help advance aviation in the interests of the Nation's general welfare and security. Towards this end, the Agency's management processes and organizational structure were improved. FAA contributes to the advancement of the Nation's aviation through its major missions of promoting air safety, fostering civil aeronautics and air commerce at home and abroad, and assuring safe and efficient utilization of airspace for all users.

### NATIONAL AIRSPACE SYSTEM DEVELOPMENTS

FAA's evolutionary plan for a National Airspace System (NAS) capable of meeting with safety the demands of the supersonic era reached new and important stages during 1964. The NAS plan is based on general recommendations of the Project BEACON airspace utilization report approved by President Kennedy early in his administration. It was elaborated by FAA's Systems Design Team and is progressively updated to keep pace with continuing advances in technology and national needs. To assure timely, coordinated progress in the many programs making up the total system, the FAA Administrator in October established a NAS Special Projects Office, charged with overall responsibility for directing the NAS implementation efforts of various Agency components.

NAS design calls for use of an air traffic control radar beacon system (ATCRBS) to automatically give controllers discrete aircraft identification and continuous, three-dimensional, position information. The airborne portion of the system, an altitude and identity reporting transponder, is available commercially for large and medium aircraft. Developed by FAA's Project SLATE, a model for small aircraft is expected to be on the market in 1965. Rapid progress during the year on ground equipment paved the way for field trials of several ATCRBS components. The first trial is scheduled to begin at Atlanta airport early in 1965, testing the advanced radar traffic control system (ARTS) for terminal use. Another version SPAN (stored program alphanumeric) which uses the same basic hardware group--computer, digitizer, and alphanumeric generator--will begin trial operations about the same time handling en route traffic at FAA's Indianapolis air route traffic control center.

FAA also moved toward the follow-on stage of greater automation in the evolutionary construction of NAS. Contracts were let during the year for additional system components including a central computer complex and common digitizer. Developed by FAA and designed to meet FAA/DOD common system requirements, this digitizer translates primary radar echoes as well as transponder beacon returns into digital messages acceptable to the central computer complex. Installation of the equipment at Jacksonville air route traffic control center will begin in 1965. This prototype semiautomated system is scheduled to be fully operational by mid-1967.

Work continued on various devices that will continuously check essential system operations when the ATCRBS comes into nationwide use. During the report year, a beacon ground station performance monitor was developed at FAA's National Aviation Facilities Experimental Center (NAFEC). Development and trial installation of common digitizers (CD's) were further steps toward fashioning a National Airspace System. Besides making it possible to send radar and beacon data from field sites to control centers at costs greatly lower than by older methods, the equipment also converts data into the digital format required for processing in NAS computers.

While FAA pushed ahead with developmental work on the future National Airspace System, more immediate steps were taken to improve the present system from which it is evolving. Among these were:

- a. replacement under a joint FAA-USAF program of outmoded terminal radars with equipment better suited to handle high-performance jet aircraft.
- b. installation at five air route traffic control centers of the first transistorized, automated (real-time) computer system to be used by FAA in traffic control.
- c. completion of the first field installation of a newly developed antenna for instrument landing systems (ILS). A major achievement in design, the low-cost antenna used with standard ILS equipment can provide precise enough guidance for aircraft to land in weather minimums of 100-foot ceiling and 1/4-mile visibility.
- d. installation of greatly improved antenna systems on some 150 VOR's (very high frequency omnidirectional radio range), the basic source of radio navigational information for civil pilots and equip approximately 130 VOR's with improved dual-channel monitors for better on-the-air performance and about 60 with voice call signs--in addition to Morse code--for easier identification by pilots.
- e. development for use with airport approach lighting systems of a new high-intensity lamp applying the iodine-cycle principle. The cycle of evaporation of tungsten from and its return to the filament prolongs lamp life to about six times that of the present standard.
- f. commission of a new high-speed data interchange system handling air traffic control and flight movement information. Installed at 10 locations, the new system supplants relay operations previously performed at 55 locations.

To better serve user needs and at the same time make more efficient use of navigational aids for the Nation's skyways, FAA radically revised the basic U.S. airway/route structure. Effective September 17, 1964, the revision substituted a two-layer for the previous three-layer scheme. Short- and intermediate-range flights now take place at levels below 18,000 feet mean sea level, while long-range operations use a jet route structure at flight levels between 18,000 and 45,000 feet. Airspace above 45,000 feet is reserved for point-to-point operations on a random routing basis. The new structure is reducing pilot-controller workload by requiring fewer radio contacts and navigational checkpoints.

All 22 of FAA's domestic air route traffic control centers (ARTCC's) are now providing radar separation service for aircraft operating at high altitudes. Addition of the Boston and Great Falls ARTCC's to the program during the year put virtually all airspace in the continental United States between 24,000 and 60,000 feet under area positive control (APC). In contrast to nonradar separation, sometimes requiring as much as 100 miles, APC service permits jets to be safely separated by as little as 5 miles and thus expedites traffic flow.

The Agency program to consolidate air route traffic control centers (ARTCC's) and realign area boundaries kept on schedule with the target date for completion set for July 1965. ARTCC's at St. Louis, Detroit, and Phoenix were phased out during the year--their services taken over by the Kansas City, Cleveland, and Albuquerque centers, respectively. In a parallel move, FAA began a field test of proposals to reduce the number of flight service stations without adversely affecting services needed by the aviation public. These efforts are all part of a continuing process to keep FAA's facilities and services in line with technological advances and changing user needs.

In keeping with its statutory mandate to establish a common civil-military system of air traffic control, FAA, in cooperation with the Department of Defense, pushed ahead with programs to further this purpose. Where FAA's air traffic control and military air defense requirements can be met by the same facilities, a continuing program calls for joint-use arrangements. The close of the report period marked the first full year during which the SAGE direction center at Great Falls, Mont., did double duty, functioning also as an FAA air route traffic control center. At three Agency ARTCC's, radar indicator displays were installed during the year for air defense purposes. Six FAA centers--in addition to Great Falls--are now equipped for such joint-use operations. Seven more FAA-military long-range radars (LRR's) joined the common surveillance system, bringing to 57 the total serving in this dual capacity.

FAA and DOD also explored ways of reducing the overall LRR inventory of the two agencies through wider application of the joint-use concept. Plans were formulated to progressively reduce the current national inventory of 166 to a total of 145. Elimination of these 21 systems will produce annual economies in the neighborhood of \$17 million.

Actions begun in 1963 to consolidate FAA-DOD long-haul communications services are producing operational gains while furthering work underway to develop a National Communications System (NCS). Mid-1964 marked the first full year during which FAA's commercial leased-line requirements were combined with those of the Defense Communications Agency. The bulk-tariff arrangements have resulted in annual savings of more than \$6 million. A parallel project aims at incorporating FAA's command/control voice communications into the automatic voice network (AUTOVON), a component of the NCS, being installed in the Defense Communications System.

During 1964 joint FAA-DOD teams drafted plans for integrating communications systems and facilities in the Caribbean and Pacific areas. At year's end, the Pacific plan had been approved for implementation by the Secretary of Defense and the FAA Administrator; final details were being worked out for the Caribbean.

Highlighting a number of other common system achievements were those that:

- a. implemented an FAA-CONAD agreement (FAA Authorization for Interceptor Operations) under which air-defense interceptor activities are conducted within the same FAA traffic control system that controls all other aircraft operating under instrument flight rules.
- b. established procedures, similar to those above, covering interceptor and antisubmarine warfare operations in the Pacific area.
- c. furthered system standardization and operational effectiveness through joint FAA-DOD management of air traffic controller training programs and by integration of the USAF Communications Service (AFCS) evaluation program with that conducted in flight by FAA.
- d. established certification standards for bringing military facilities into the common system.

### AVIATION SAFETY PROGRAMS

The year 1964 witnessed broad-ranging government-industry investigations concerning turbulent air masses and their relation to the safe operation of turbojet transports. Beginning in 1963, one swept-wing jet accident and several dangerous upsets or uncontrolled dives, associated with severe turbulence at high altitudes, spurred precautionary actions pending precise pinpointing of possible causes. Aircraft manufacturers revised upward recommended rough air penetration speed to avert the possibility of stalls and loss of control; air carriers introduced as part of their pilot training programs concentrated instruction on jet penetration of turbulence; and FAA in its safety surveillance and advisory activities placed heavy stress on approved practices and procedures for bad-weather flying. Continued careful monitoring of the swept-wing airframes has revealed no pattern of fatigue problems, even though some of the jets have flown over 15,000 hours. A joint FAA-industry team worked during the year to validate the control systems of high-performance turbojets. Target date for completion of the project report is set for early 1965.

Research and flight test programs related to the turbulence problem were accelerated. Using specially instrumented Agency jet aircraft, FAA and NASA pilots flew into areas of known turbulence to obtain engineering and pilot performance data. This information was incorporated into the vertical motion simulator at NASA's Ames Laboratory, where pilots simulated flying under conditions of greater turbulence than would be prudent in actual practice. Additional tests to determine pilot reaction to such G-forces as might be encountered in rough air were conducted at the U.S. Navy's Aeromedical Acceleration Laboratory with airline pilots serving as subjects in the human centrifuge. Results of these human-factors tests will provide FAA with better information concerning the adequacy of cockpit instruments and airspeed margins.

In other projects, FAA explored new or improved techniques and equipment for identifying, tracking, and displaying turbulent airmasses. Tests were begun to evaluate the effectiveness of such devices as an electronic storm detector, a sensor for measuring at a distance temperature changes in airmasses, and improved airborne weather radar. Conclusions reached in studies of the turbulence problem underscored the FAA air traffic controller's need for suitable weather displays. During the year contracts were let for equipment to meet this requirement. Meanwhile, with the cooperation of the U.S. Weather Bureau, the Agency initiated a

program to remote USWB displays to selected FAA air traffic control facilities. These actions will help FAA controllers to assist pilots in flying around severe weather and to avoid unintentionally routing aircraft into such areas.

FAA's hopes for improving aviation safety depend heavily on aeromedical research efforts to obtain a broader understanding of man-machine relationships and the human factors in the aeronautical environment. Much of this research is carried out by Agency medical scientists at FAA's Civil Aeromedical Research Institute (CARI), Aeronautical Center, Oklahoma City, and at the Georgetown Clinical Research Institute of Georgetown University.

Special attention was given during the year to impact studies. Important new data were uncovered showing that the human body is many more times resistant to impact than previously thought. In collaboration with the USAF's Medical Research Laboratory, CARI prepared and published the most comprehensive compilation to date of existing biomedical knowledge on acceleration, impact, vibration, and restraint systems. The compilation is based on findings disclosed in some 20,000 scientific papers.

Another publication of special interest aimed more directly at serving general aviation was "Medical Facts for Pilots." An analysis of accident data gathered by FAA and CAB investigators, the booklet throws light on key human factors figuring as causes of light aircraft accidents in recent years.

FAA researchers studied the fatigue problem as it relates to the efficiency of airmen and air traffic controllers. The effect of rotating shifts worked by air traffic controllers was analyzed. To determine the effect on aircrew members of rapid time-zone changes--routinely experienced in current air carrier jet operations--detailed physiological and psychological studies were made on subjects flying to and from the Far East. Knowledge gained from these studies will be used to develop guidelines for scheduling procedures which minimize fatigue, thereby enhancing air safety.

Studies are also continuing on man's aging process and its relation to pilot proficiency. This work aims at developing better criteria than a standard physical examination and the subject's chronological age for determining when an airman, through aging, is no longer able to safely perform his job.

FAA made further progress in a number of programs which, though not interrelated, aimed directly at enhancing air safety. Some of these achievements were:

- a. establishing the feasibility of emergency arresting gear systems for large transport aircraft and spearhead a concerted government-industry undertaking to define comprehensively the use and characteristics of the proposed system.
- b. endorsing the use of crash locator beacons to speed search and rescue of downed civil aircraft.
- c. cooperating with the USAF to program single-frequency approach procedures for single-seater jets at 16 high priority airbases. These procedures will reduce the risk of accidents resulting from pilot vertigo.

- d. completion of an extensive field survey evaluating the accuracy of airborne radio navigation equipment and test new, low-cost techniques for calibrating altimeters. Along with greater air safety these programs aim at increasing the capacity of the Nation's airways through reduced separation standards achievable with more precise cockpit instrumentation.
- e. conducting the first turbojet safety seminar for general aviation pilots. Current plans call for additional seminars to keep pace with the growing general aviation use of jet aircraft.
- f. taking steps to assure the adequacy of emergency procedures and crew-member training of air carriers engaged in overwater operations.
- g. conducting research probing the potential hazards created by lightning striking an aircraft wing, and evaluate ignition, flammability, and explosive characteristics of fuels in this circumstance.

As technology moves onward, creating more sophisticated hardware, air safety hinges increasingly on competent maintenance specialists and effective systems for managing the complex aircraft maintenance processes. These aspects of aviation safety received continuing emphasis during the year. To better evaluate from a safety standpoint the systems and practices used by air carriers in directing and controlling all phases of aircraft maintenance the Agency developed an experimental "Maintenance Management Audit System." The new approach includes detailed appraisals of maintenance management in such critical areas as inspection, mechanical performance, production and quality controls, maintenance and performance analysis, and product modification. Conducted in cooperation with two air carriers, test programs confirmed the validity of the concept. In the next step various refinements will be incorporated to make the system suitable for industrywide use. FAA also began applying air carrier reliability control concepts to general aviation operations. Development of a maintenance difficulty reporting system will permit FAA to more effectively monitor maintenance trends and practices in this most rapidly expanding segment of U.S. aviation.

Work continued this year to improve and update the education, training, and licensing of aviation mechanics and other maintenance personnel. Of particular interest was a new study program conducted at five private and public aviation schools featuring a jet-age curriculum with specific teaching objectives and achievement levels established by FAA. Another objective of the program is to test the practicality of giving approved mechanic schools authority to examine and recommend for Agency certification their own graduates. Such examining authority is already delegated by FAA to certain flight schools.

In December national winners were selected in the second annual aviation mechanics safety awards program. A combined FAA, Flight Safety Foundation, and aviation community undertaking, the awards program recognizes aviation mechanics who contribute conspicuously to air safety through original ideas for maintenance improvements.

To lay a solid technological groundwork for improving safety standards and rules FAA is engaged in aircraft safety research and development. During 1964, the Agency launched major new programs to attack one of civil aviation's most pressing

problems--crash fatalities in survivable accidents.

The Flight Safety Foundation, under FAA contract, conducted an experimental program that promises to yield some of the most constructive and comprehensive information ever gathered from crash tests involving large transport aircraft. Simulating past accidents in which aircraft occupants might have survived with adequate protective devices, a weary DC-7 airliner, remotely controlled, was deliberately wrecked in April. A second full-scale crash test took place in September using a surplus Lockheed Constellation. The aircraft were thoroughly instrumented to record impact forces on passenger and crew seats, restraint and fuel containment systems, and other airframe components. In the September test, 130 separate items of crash data were successfully recorded. Test results will be used to define accurately the crash-load environment for typical survivable accidents, thus aiding design of crashworthy airframes and improved cabin safety features.

In a related project, the Agency sought to improve the odds of rescue from crashed aircraft that catch fire, through better techniques of suppressing fire and prolonging survival time. At FAA's National Aviation Facilities Experimental Center (NAFEC), Atlantic City, 22 scientific fire tests, which included burning five surplus USAF C-97's, highlighted these experiments undertaken in cooperation with the Air Force. Conducted with devices to measure internal and external temperatures, air velocity, and toxic gases, the experiments tested the effectiveness of both ground equipment and helicopters in applying dry chemicals and foam. Preliminary findings in the NAFEC tests indicate that the helicopter was not successful as a firefighter in large transport crashes. Nearing completion at year's end, a final report will be published for dissemination to the aviation community.

Prevention of in-flight structural failures is another objective of FAA safety investigations. In a project to determine the ability of aircraft structures to withstand collision with birds, tests were completed on Viscount and DC-7 horizontal stabilizers and evaluation begun on Boeing 707 stabilizers. Extensive flight tests are underway on a system to augment the stability of light high-performance aircraft. Such a system could provide protection against in-flight structural failure during recovery from high-speed dives--a common accident that often results from pilot disorientation under weather conditions.

#### AIRCRAFT DEVELOPMENT

The U. S. supersonic transport (SST) program moved through design and evaluation phases during the year. Important research was undertaken in the fields of sonic boom and economics. Twenty-one U. S. and foreign flag air carriers reserved 93 delivery positions for a U. S. SST when the airplane becomes available, submitting \$9.3 million to the Treasury in advance royalty payments.

Following President Kennedy's determination in June 1963 that the Government should proceed with a program of assistance to industry for development of an SST and request for congressional support, FAA prepared a Request for Proposals establishing aircraft performance objectives as a basis for design competition among industry. This RFP was prepared in a process that included close coordination of successive drafts with manufacturers, airlines, government agencies, and other aviation groups concerned. This was made available to industry, in final form, on August 15, 1963.

In mid-January 1964, three airframe manufacturers and three engine builders submitted initial design proposals in response to this Request for Proposals. Comprehensive evaluation of these designs was carried out by the Supersonic Transport Evaluation Group--a team of aviation specialists directed by FAA's Deputy Administrator for Supersonic Transport Development and including personnel from NASA, Air Force, Navy, CAB, and the Department of Commerce. Concurrently, 10 U.S. airlines independently evaluated the design proposals. Findings and recommendations emerging from the evaluation process were reviewed by the FAA Administrator and by President Johnson's Advisory Committee on Supersonic Transport, which the President established in April 1964.

On May 20, 1964, after receiving recommendations from the Committee and from the Administrator of FAA, the President directed the award of contracts for further design work. FAA awarded these contracts on June 1, 1964, to two airframe and two engine companies. The two airframe companies were directed to conduct wind tunnel testing, structural analyses, and other studies aimed at improving and refining designs to meet technical and economic objectives for a safe, operationally efficient, economically practical SST. Engine contractors were directed to develop detailed preliminary layout designs to satisfy criteria for performance, operation, reliability, safety, maintainability, and economy established in conjunction with airframe manufacturers to allow final engine sizing and design for further development at conclusion of these contracts. In each of the four contracts, which totaled \$22 million, the government provided 75 percent of costs and the contractor 25 percent.

Procedures for evaluating second-round designs paralleled the government-airline evaluation of initial SST proposals. The joint governmental Supersonic Transport Evaluation Group performed its task from November 1 to November 30, 1964, at FAA headquarters in Washington, the NASA Langley Research Center, Hampton, Va., and Wright-Patterson Air Force Base, Ohio. The President announced on December 3 that, on the recommendation of his Advisory Committee, he had directed FAA to extend the engine and airframe design contracts so the companies could "continue to study the problems associated with the airframe and engine of a commercial supersonic transport ..." "... keep together the skeleton teams they have been using to work on this problem."

In addition to authorizing contract awards for further efforts to achieve an optimum SST design, the President in May 1964 also (1) instructed the Department of Commerce to undertake economic studies, and (2) directed that sonic boom research continue with the guidance of the National Academy of Sciences. In progress at the time was a major study in the Oklahoma City area of public reaction to sonic boom. This study ran from February 3 through July 30, 1964. A report of preliminary data gathered in this study was published on August 3, 1964. A comprehensive program report was scheduled by the end of 1964. A study of structural effects of sonic boom began at White Sands Missile Range on November 18, 1964. It was scheduled to be concluded February 5, 1965.

Study and research in the fields of air traffic control, flight controls, and airworthiness continued during the past year. When NASA's SST flight simulator went into operation in May 1964 at Langley Research Center, Va., it was tied in with the FAA air traffic simulator at NAFEC for this purpose. The flight control program is being conducted by FAA and the Air Force in a simulator at Wright-Patterson AFB and in test-flights of T-39 aircraft equipped with experimental control and

display equipment at the Instrument Pilot Instructor's School, Randolph AFB, Tex. In the field of airworthiness, in which FAA published "Tentative Airworthiness Objectives and Standards for Supersonic Transport Design Proposals" last year following a preliminary publication in 1961, a number of informal conversations and formal meetings were held with officials of the joint Anglo-French Concorde SST program.

Requests for delivery positions for the U.S. supersonic transport continued to be received from the world's airlines during the year. Fourteen foreign flag and seven U.S. flag carriers, plus one aircraft leasing company, held these positions at year's end. In this connection, the Federal Aviation Agency acts in an intermediary role pending identification of the aircraft's manufacturer. A system of aircraft delivery priorities to meet this requirement was established in 1963.

Developments during the year proved disappointing in FAA's program to stimulate the design and production of a safe, economical, and efficient short-haul transport to succeed the 28-year-old DC-3. Preliminary proposals, submitted in design competition by seven U.S. and two French manufacturers, were evaluated by a 50-man team of government/industry aviation experts. None of the designs was considered to represent a sufficient advance in the state of the art to warrant award of a detailed design contract. Future FAA actions will depend upon continuing industry efforts to design an improved aircraft which meets local service and government needs.

To increase the commercial utility and availability of aircraft designed primarily for military use, FAA continued to participate in numerous development programs conducted by the armed services. During the reporting period, FAA completed extensive flight-testing and certificated for civil use all three entries in the Army's light observation helicopter competition as well as the Air Force's CH-3C helicopter. In the cargo-transport field, design improvements essential to meet civil airworthiness standards are in progress on the Air Force's C-141 STARLIFTER. Deliveries of the civil version to all-cargo carriers is expected to begin in 1967.

#### OTHER ACTIVITIES FOSTERING AERONAUTICS

In steps toward safe all-weather flying, FAA during 1964:

- a. established new standards for lowering landing minimums down to a decision height of 100 feet and runway visual range of 1,200 feet.
- b. continued to put high priority on programs having as their objective the development of ground and airborne systems needed to achieve safe, routine landings under zero-zero weather conditions.
- c. evaluated use of mapping radar for helicopter navigation.
- d. developed a recorder to accurately measure under all-weather conditions landing and departure profiles of civil transports.

In cooperation with the aviation industry and other Federal agencies FAA is seeking realistic solutions to the complex and difficult problems associated with aircraft engine noise. During the report period, new contracts were awarded and research

continued to investigate new techniques for compressor noise reduction, to analyze aircraft departure profiles in relation to ground noise effects, to develop better criteria for evaluating noise nuisance, and to study new methods for suppressing exhaust noise.

An Aviation Human Resources Study Board was created in February to undertake a comprehensive investigation of civil aviation manpower requirements over the next 20 years. Findings and recommendations of the study establish guidelines for improved government-industry planning to prevent a shortage of skills in the Nation's expanding \$7 billion civil aviation industry.

FEDERAL COMMUNICATIONS  
COMMISSION



## CHAPTER XII

### INTRODUCTION

The Commission participated in the drafting of the two historic international agreements for the operation of the global commercial satellite communication system. The regulatory activities of the Commission in the field of satellite communications continued during 1964 at an accelerated pace. Applications relating to financial and technical matters which were submitted by the Corporation were considered and authorizations issued, and procurement procedures were reviewed. The Commission assisted the Securities and Exchange Commission in the review of the Corporation's preliminary prospectus for stock offering in order to determine that full disclosure had been made to the public, and cooperated with the Small Business Administration in enlarging the scope of small business procurement participation. The Commission authorized the Corporation to construct the "EARLY BIRD" satellite. The Commission began deliberations to establish a policy regarding the ownership and operation of U. S. terminal stations; offered testimony in Congressional hearings; heard proposals from industry for extending satellite communications so as to provide global coverage by the multiple-access mode of operations; and cooperated with the Canadian Government in the selection of frequencies for use by their earth station at Mill Village, Nova Scotia.

As air traffic increases so do the communications necessary for the protection of human life and safe operation of the aircraft. In addition to the Commission's regulatory activities in this field studies are under way to determine the feasibility of using satellites for communications related to safety of life and property and thus relieve the congestion on presently overloaded frequencies and provide for orderly expansion of communications needs in the future.

### INTERNATIONAL AGREEMENTS ESTABLISHED

The accelerated pace of developments in satellite communications technology in this country greatly stimulated interest by other nations in participation in the system. A series of international discussions resulted in two international agreements which have established the organizational framework for the global commercial satellite system.

The first, "Agreement Establishing Interim Arrangements for a Global Commercial Communications Satellite System", establishes the principle that a single commercial system should be set up forthwith, that it be expanded to provide world coverage as soon as possible and that it be open to all nations on a non-discriminatory basis.

The second agreement, called the "Special Agreement" includes definitions, operating procedures, financial arrangements, etc. and the recognition of the

Communications Satellite Corporation as manager of the system. Its term runs concurrently with the Agreement Establishing Interim Arrangements.

### REGULATORY ACTIVITIES

In authorizing the EARLY BIRD program in April 1964, the Commission approved the application of the Communications Satellite Corporation for two satellites, each with a capacity of 240 2-way voice channels. At least one of the satellites is to be positioned in nearly equatorial orbit over the Atlantic Ocean and will be capable of providing voice, record, and TV communications between the United States and Canada and Western Europe.

In July 1964 Commission authorized the Corporation to lease the AT&T earth station at Andover, Maine, and to make the necessary modifications to adapt the station for use in the EARLY BIRD program. Also, in July, the Corporation was authorized to modify the existing antenna of the Naval Missile Center, Point Mugu, California, so that the Olympic Games in Tokyo could be relayed by television via SYNCOM III positioned over the Pacific Ocean. Olympic programming was made available for distribution to TV networks in this country and in Canada. European broadcasters made arrangements to have the programs recorded on tape and the tapes transported by jet aircraft across the Atlantic.

The Communications Satellite Corporation, in August 1964, filed a petition which requests the Commission to institute a rule-making proceeding looking toward the adoption of a rule which would limit the ownership and operation of the initial U. S. terminal stations to the Corporation. The Commission asked for comments in support of or in opposition to the petition and received replies from eight parties, seven in opposition. The Corporation replied to these comments on October 26 and now has the matter under consideration.

### Corporate Financing and Issuance of Stock

The Commission is required to approve all borrowing and all issuance of stock by the Corporation except the initial issue. It was necessary that the Corporation borrow money for operating and development expenses, which loans were repaid from the initial stock issue.

The Communications Satellite Act provides that no more than 50% of the stock in the Corporation may be owned by communications common carriers who are authorized by the Commission to hold such stock. The Commission established rules relating to such authorization and to date has received and granted over 200 such applications. Prior to the issuance of stock by the Corporation, representatives of the Commission and the Corporation agreed on an allocation formula to be used in the event of an oversubscription by the carriers. The formula provided that all subscriptions of 5000 shares or less would be filled and that in the event of an oversubscription, only the larger subscriptions would be reduced. A total of 163 subscriptions were received ranging from 5 to 4,250,000 shares. The latter subscription made by the American Telephone and Telegraph Company was reduced under the allocation formula to 2,895,750 shares. In order to encourage the widest possible distribution of the remaining 50% of the stock to the American public, the underwriters and the stock brokers distributing shares of the initial issue were required to agree that they would not sell in allotments of more than 50 shares to each customer. Public

demand for the stock was very high. The Commission has followed the trading of shares closely and has monitored U. S. and foreign ownership.

### Procurement Policies and Actions

The Communications Satellite Act requires the Commission to insure effective competition and equitable opportunity in the procurement by the Corporation and communications common carriers for apparatus, equipment, and services required for the communications satellite system and satellite terminal stations. The Commission adopted rules and regulations on January 8, 1964, to establish procedures to carry out its statutory responsibilities. Since that date, the Commission has reviewed procurement procedures involved in seven prime contracts and five major subcontracts with an aggregate value of approximately \$15 million and \$1.3 million, respectively. Approximately 80% of the dollars awarded were through competitive negotiations and bidding. Some different firms including small business in every major area of the country were solicited before the awards were made. These contracts and subcontracts involved the EARLY BIRD system; Basic Design Study Contracts looking towards the establishment of a basic communications satellite system in 1967-68; the lease and modification of satellite terminal stations at Andover, Maine and Point Mugu, California - for EARLY BIRD and the 1964 Japanese Olympics, respectively.

### ALLOCATION OF FREQUENCIES FOR SPACE COMMUNICATION AND RADIO ASTRONOMY

During the latter part of 1963, the International Telecommunications Union (ITU) held a frequency allocation conference, Extraordinary Administrative Radio Conference (EARC), to consider frequency allocations for space radio communication purposes and radio astronomy. The Conference designated approximately 2800 Mc/s of spectrum space in the 1,000-10,000 Mc/s band to the Communication-Satellite service, 2000 Mc/s of which is immediately useful to the United States; however, all except 100 Mc/s of the 2800 Mc/s of spectrum space must be shared with terrestrial radio services, principally line-of-sight radio relay networks. The Commission has been participating in the interagency activity necessary to implement the space frequency allocations domestically. Necessary changes in the Commission's Rules are expected to be completed before the treaty comes into force in January 1965.

Considerable work remains before the spectrum space designated for the purpose can be used most effectively. Agreement is necessary on how the allocated bands will be subdivided for use by particular space systems or sub-systems. Also, technical criteria for sharing of frequencies between the communication satellite service and terrestrial radio services are only provisional. Preparatory work is going forward in this area in connection with international meetings scheduled to be held in calendar years 1965 and 1966 by the International Radio Consultative Committee (CCIR) of the ITU.

### SOME TECHNICAL ASPECTS OF SATELLITE COMMUNICATIONS

Experiments with TELSTAR II have continued during the past year and operations in all phases of the program have proved to be entirely satisfactory. During the latter part of the year detailed planning for the EARLY BIRD project was completed.

Frequencies in the 6 Gc/s band will be used for transmission from the earth to the satellite and frequencies in the 4 Gc/s band will be used for transmission from the satellite to earth. These are the same frequency bands that are used for TELSTAR and are consistent with all the allocation of frequency bands for space radio-communications as adopted at the Extraordinary Administrative Radio Conference (EARC) in Geneva, 1963. The actual operating frequencies were selected during an international conference attended by all EARLY BIRD (HS-303) participants.

As it often happens during the development of a new technique or system, there are inherent difficulties which must be overcome or reduced to tolerant levels. Telephone communication via satellite is no exception.

Under auspices of FCC, a series of tests has been conducted in order to determine to what extent time-delay and echo effects will prove objectionable and what techniques may be employed to minimize these effects. The tests have not been completed as yet but have led to the design of an improved echo suppressor. Additional tests will be conducted during the experimental phase of the EARLY BIRD program.

### CONGRESSIONAL HEARINGS

On April 14, the Chief of the Common Carrier Bureau and other members of the Commission's staff, appeared before the Military Operations Subcommittee of the Committee on Government Operations, House of Representatives, and testified regarding the then current discussions between Secretary of Defense, acting as executive agent for the National Communication System, and the Communications Satellite Corporation. The hearings were held primarily for the purpose of reviewing government operations in the field of satellite communications, but considerable testimony was received in an attempt to determine whether the Corporation could, as part of its projected commercial system, meet the special needs of the NCS.

### AERONAUTICAL DEVELOPMENTS

The Commission prescribes the manner and conditions under which frequencies may be assigned for aeronautical telecommunications purposes such as flight test communications and telemetry functions used in the development and production of aircraft, missiles, rockets, and satellites; and also assigns frequencies to aircraft radio stations, aeronautical enroute, radio navigation, flight test, aeronautical advisory and to other stations which all together compromise the aeronautical radio services.

Domestic use of high frequency air-ground communications in the 48 contiguous United States was being discontinued rapidly during 1964 as more VHF facilities were provided. It is planned that domestic operations on the aeronautical high frequencies will not be permitted in these states on a regular basis after January 1, 1965. Both HF and VHF are expected to be required in Alaska, Hawaii and the U. S. island possessions, however, for at least the next several years. In the meantime, use of satellites is now under consideration as one of the possible methods of relieving some of the communications channel loading on existing facilities, particularly on long over-water air routes.

The first of a two part Aeronautical Extraordinary Administrative Radio Conference (EARC) of the International Telecommunication Union (ITU) met in Geneva during January and February of 1964 to consider revision of the Frequency Allotment Plan for the Aeronautical Mobile Service and related provisions of the Radio Regulations. Actual revision of the frequency plan is scheduled to be completed at the Second Session in 1966.

The Commission's type acceptance program for transmitters used by stations in the Aviation Services reached its climax at the end of 1964.

UNITED STATES  
INFORMATION AGENCY



## CHAPTER XIII

### INTRODUCTION

USIA, which supports U.S. foreign policy objectives by influencing public attitudes abroad, had more than enough to work with in carrying the U.S. space story to world audiences.

In 1964, two U.S. spacecraft produced what may be the most remarkable pictures ever taken by man -- the first close-ups of the moon's surface, and the first cloud-cover pictures of the dark side of the earth.

Also, the United States moved closer to its goal of a manned lunar landing, launched new and more advanced scientific satellites, extended communication by satellite to Japan, moved to form an international communications satellite organization, and enlarged international cooperation in tracking networks, space applications, and space programs.

From Washington and its 228 foreign posts the USIA staff used radio broadcasting, the press, motion pictures, television, libraries, exhibits, personal contacts, wall newspapers, and cartoon strips to make U.S. space accomplishments known to foreign nations.

In the 106 countries where the U.S. Information Service operates, the space events of the year were translated for local newspapers and magazines, transmitted to the scientific, educational, and governmental communities, and placed on local radio, motion pictures, and television.

The Agency acted with special dispatch to document one of the most significant space achievements of the year, the moon pictures of RANGER VII. USIA-produced photo-posters of RANGER results were being placed on walls abroad within a week, while a television special, a pamphlet, and NASA-produced films telling the RANGER story were distributed abroad within a few weeks.

### GUIDELINES

In covering U.S. space events in 1964, USIA employed these guidelines:

- a. the United States is developing a broad space capability to provide leadership in all vital areas of space, and to make the United States the leading spacefaring nation.
- b. the United States stands for peaceful employment of outer space, emphasizing such space adaptations as weather reporting and space communications, which produce common benefits, and technical

assistance to other countries, which advances a common technology.

- c. international cooperation in space is a cornerstone of U.S. policy. During the past year the United States has reached a second memorandum of understanding with the Soviet Union with regard to areas of space cooperation. At the United Nations, a declaration on legal principles with regard to outer space was adopted, and the United States is working for a convention regarding assistance to, and the return of, astronauts and space vehicles, and liability for damage from space objects.

## ASSETS

The Agency accented these key positive factors of the U.S. space program:

### Sources of Leadership

U.S. leadership in space stems from a program that is fast-paced, orderly, and broadly conceived, and which through a variety of programs seeks to accumulate data that will satisfy human needs, benefit science, and be available to all.

### Space Sharing

The United States shares its research in space, and cooperates in building space programs through working partnerships with 69 countries.

### Putting Space to Work

The United States emphasizes putting space to practical use, through such direct applications of space technology as communications, weather, geodesy, and navigation satellites.

### Visible to All

U.S. manned space launchings are conducted in full view of the world community, and data is distributed as soon as it is available. The world knows what the United States has in space capability, and it is visible to all; the same is not true of the Soviet Union.

## PROBLEM AREA

Efforts to project abroad a favorable image of U.S. space activities were hampered by one factor particularly:

### Soviet Manned Flight

The flight of the multi-passenger space ship VOSKHOD demonstrated a continuing Soviet ability to mount manned flights on a scale surpassing that of the U.S. The capacity of the Soviets to launch larger spacecraft in manned flight remained the negative factor affecting foreign opinion of U.S. space activities.

## USIA TREATMENT

### U. S. Manned Flight

Because of the absence of manned flight this year, Agency media treated preparations for upcoming activity. Astronaut training, development of GEMINI and APOLLO hardware and test facilities, SATURN I test firings, and other steps leading towards resumption of manned flight in 1965 were given full coverage.

### Communications Satellite Demonstrations

The use of communications satellites as an instrument of foreign policy was emphasized in Agency treatment. USIA has responsibility for coordinating inauguration broadcasts. USIS Tokyo completed arrangements with Tokyo officials for the first television broadcast from Japan to the United States; a taped message from Premier Ikeda and both live and filmed scenes of Tokyo and Olympic preparations were sent over RELAY II. Similarly the first television exchange between Japan and the United States was carried by RELAY II. The same satellite was used in a sound broadcast to inaugurate the new Spanish ground station at Orinon, with exchanges between Spanish and American officials, Voice of America Spanish news by satellite, and reports from Madrid correspondents of Spanish newspapers in return. The SYNCOM III satellite was inaugurated with a telecast from Japan to the United States showing the Olympic Games, and an exchange of greetings between the Japanese Foreign Minister, President Johnson and Secretary Rusk.

### NIMBUS

The achievements of NIMBUS, though short-lived, were given specially heavy coverage. NIMBUS photographs, including first night-time cloud cover pictures, were widely distributed. The APT, or Automatic Picture Transmission capacity of the satellite, was emphasized in the dozen countries which received NIMBUS-transmitted pictures by this method. The role of TIROS and the U.S. Weather Satellite Center in world weather reporting was covered on a continuing basis.

### RANGER and MARINER

RANGER VII results were given heavy play. Five features were distributed in advance, two more after the flight. The Wireless File carried pamphlet text to all posts, with photos and layouts going by air to the three regional service centers at Manila, Beirut, and Mexico City for pamphlet printings in English, French, Arabic, and Spanish, and other languages. Pictures went by airmail: 29 picture subjects -- each photo subject involving the servicing of 200 prints and 80 negatives for 80 posts. The Government Printing Office rushed through 1,200 photo posters that were air-mailed, with materials for printing following, to the Regional Service Centers for separate language versions.

The flight of MARINER IV to Mars was being given detailed, continuous treatment.

## ASSISTANCE TO NEWS MEDIA

### Press and Publications

For Agency media, the space program and space science are major themes in the news that demonstrate U.S. scientific leadership. Space launches given repeated attention by Press and Publications Branch included RANGER VI and VII, SYNCOM III, SATURN, NIMBUS, ORBITING GEOPHYSICAL OBSERVATORY, RELAY II, ECHO II, and RADIATION TEST SATELLITES, with the Wireless File carrying a space science story of some kind every other day during the year. The Feature Section turned out 46 space science features, each illustrated, as well as 12 "Science Today" columns covering space, 30 space items in the monthly "Science Notes", and 14 space items in the "What's New in Science" column. Photo servicing on space subjects was heavy. Graphics Section produced two panels on astronauts and satellites in the "It's a Fact" cartoon series, used in hundreds of newspapers overseas. The Photo Bulletin, a monthly offset offering photos that can be ordered, carried the major space launches of the year.

### Television

"Beyond the Sky", a half-hour documentary in color showing preparations for GEMINI and APOLLO, was completed by the Television Branch; it will be exhibited next year. A 15-minute documentary feature, "Romance with the Moon", was rushed through in English and four language versions, and distributed to 61 countries. In "Science Report", a fortnightly 15-minute news review of the American science world, distributed in 53 countries in English, Spanish and Portuguese, and a fourth "Music and Effects" version adaptable to any local narrator, space events were treated consistently and in depth.

### Radio

The Voice of America covered all space events of the year, plus developments in space science. Special events received detailed coverage.

### Motion Pictures

Major space developments were brought to foreign film audiences through newsreels distributed by the Film Branch. NASA films on RANGER progress, on manned flight, and other space subjects were also distributed abroad.

### Exhibits

One of the original Mercury capsules, "Sigma 7", continued to draw crowds. Displayed by USIS in five Japanese cities, it was seen by 750,000 people. In addition, the Agency used scale models of MERCURY capsules, the TIROS satellite, and exhibits on GEMINI, SYNCOM, and "U.S. Progress in Space" to carry the story into communities abroad.

The U.S. -U.S.S.R. exchange exhibit, "Communications USA", shown in the Soviet Union in Leningrad, Kiev, and Moscow, included a TELSTAR demonstration, and models of SYNCOM, TIROS, MARINER, ORBITING SOLAR OBSERVATORY, ALOUETTE, RELAY, and EXPLORER. The exhibit averaged a daily attendance of 12,000 persons and was seen by 342,777 persons. USIA worked closely with NASA

in carrying out these and other exhibit activities.

### Library Centers

Original and special space materials, including NASA reports, Congressional documents, and commercially produced books and publications were made available to foreign audiences through the 178 libraries, 66 reading rooms, and 148 binational centers maintained by the Library Center Service.

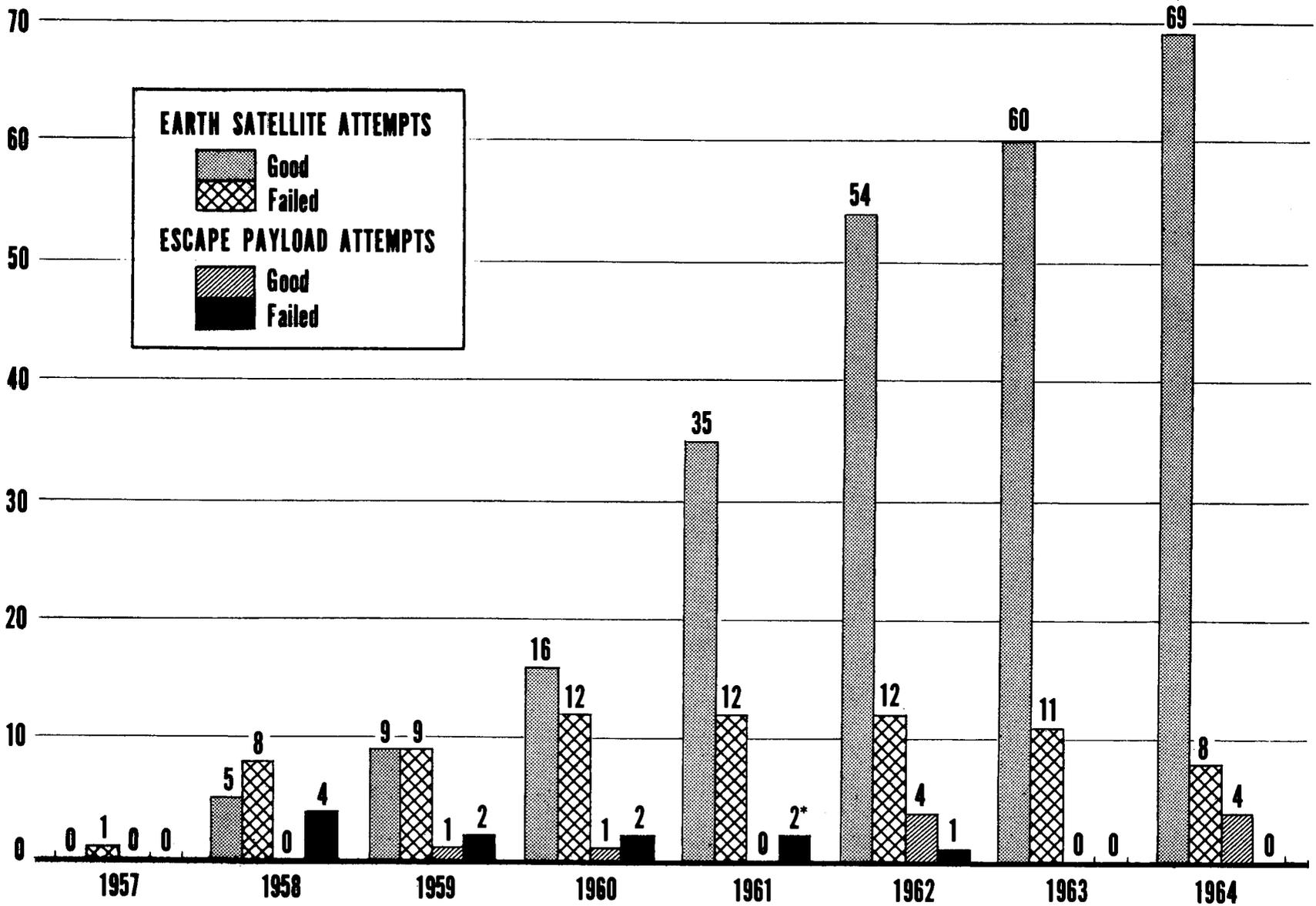
### USIA AND NASA

The relationship between NASA and USIA is one of mutual support and cooperation. Staff officers of both agencies work together to select photographs, set up exhibits, distribute NASA materials, and publicize space events and developments. NASA press materials are distributed abroad through USIA's Science Writers Service, going to 516 newspapermen, scientists, and government officials, on a continuing basis.

To carry the space story to the people -- in hamlets, back areas, and smaller cities -- NASA has supplied Spacemobiles (automobiles carrying spacecraft models and space experiments), attended by NASA-trained lecturers. Three of these are now in Latin America, another has completed its work in India and is en route to New Zealand, while a fifth has been working in Spain. Two NASA-trained USIA officers carrying their own spacecraft models and materials have been working in English-speaking Africa and French-speaking Africa.

# U.S. LAUNCHING RECORD

Number of Payloads



\* Included in Earth Successes

## UNITED STATES LAUNCHING RECORD

Year	Earth Satellite Attempts		Escape Payload Attempts	
	Success	Failure	Success	Failure
1957.....	0	1	0	0
1958.....	5	8	0	4
1959.....	9	9	1	2
1960.....	16	12	1	2
1961.....	35	12	0	2*
1962.....	54	12	4	1
1963.....	60	11	0	0
1964.....	69	8	4	0
Total.....	248	73	10	11

**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 (52 successes and 7 failures), making totals of 196 orbital launch successes, 10 escape launch successes, 61 orbital launch failures, and 11 escape launch failures, for a grand total of 276 launch attempts (2 escape failures were orbital successes).

5. Data quoted include 2 U. S. payloads with British experiments, one Canadian payload launched by the United States. They do not include one Italian earth orbital launch success from U. S. territory, accomplished in 1964.

\*These failed to go to escape as intended, but did attain Earth orbit and are in those totals.

NASC Staff

## SUCCESSFUL U. S. LAUNCHES -- 1964

[ 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. 11 DEFENSE 1A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	581 562 103.5 69.90	Still in orbit.
Jan. 11 DEFENSE 1B Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	587 559 103.5 69.96	Still in orbit.
Jan. 11 DEFENSE 1C Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	581 562 103.5 69.90	Still in orbit.
Jan. 11 DEFENSE 1D Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	581 562 103.5 69.89	Still in orbit.
Jan. 11 DEFENSE 1E Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	590 554 103.5 69.88	Still in orbit.

Jan. 19	Total weight: Not stated.	511	Still in orbit.
DEFENSE	Objective: Development of space	500	
2B	flight techniques and technology.	101.2	
Thor Agena D	Payload: Not stated.	99.4**	
Jan. 19	Total weight: Not stated.	513	Still in orbit.
DEFENSE	Objective: Development of space	500	
2C	flight techniques and technology.	101.2	
Thor Agena D	Payload: Not stated.	99.06**	
Jan. 21	Total weight: 184 lbs.	4,597	RELAY II was very
RELAY II	Objective: Continue flight research in	1,294	similar to RELAY I
3A	active repeater communications satellites,	194.7	(launched Dec. 13,
Thor Delta	radiation damage, and reliability and dura-	46.32	1962) which was still
	tion of performance.		operating, with im-
	Payload: 33" x 29" octagonal prism,		proved components;
	tapered at one end, containing 2 transponders,		no cut-off timer,
	duplicated telemetry and command system,		since part of objective
	attitude control system, tracking beacon;		of RELAY II was to
	temperature sensor; radiation detectors;		determine durability.
	radiation damage experiment; 8,215 n-on-p		Less eccentric orbit
	solar cells; 3 nickel-cadmium batteries;		provided longer on-
	5 external antennas.		station time; excellent
			transmissions ex-
			changed with Europe
			and Japan. Still in
			orbit, still transmit-
			ting.

Jan. 25  
ECHO II  
4A  
Thor Agena B

Total weight: 770 lbs., including accessories; 535 lbs. for balloon alone.  
Objective: Continue communications experiments with passive communications satellite; provide data on orbital environment.  
Payload: 135' sphere of mylar plastic bonded inside and out with aluminum alloy foil; 2 beacon transmitters and antennas; skin temperature and internal pressure sensors; 8 solar cell modules; 16 nickel-cadmium batteries.

816  
642  
108.8  
81.50

Balloon satellite inflated well, seemed to be rigid enough to hold spherical shape well. Most visible of all artificial satellites. Series of international communications experiments between U. S. -U. K. -U. S. S. R. were begun 2/22/64. Still in orbit, still transmitting.

Jan. 29  
SATURN (SA-5)  
5A  
Saturn I

Total weight: 37,700 lbs. (including S-IV stage and 11,500 lbs. of sand ballast), of which 20,000 lbs. was potential payload.  
Objective: Test structure and performance of 2-stage Saturn I; orbit 2nd stage.  
Payload: 84' S-IV stage, with instrument unit, payload adapter, Jupiter nosecone, sand ballast; transmitter; 12 50-lb. batteries; 567 telemetry points for pressure, fuel, and performance monitoring equipment and 7 telemetry systems.

472  
160  
94.8  
31.44

SA-5 was heaviest weight ever launched to that date; 5th straight Saturn success; 1st of the Block II (both stages live) tests; first flight test of the S-IV 2nd stage, which has 6 liquid-hydrogen engines. Confirmed structural integrity of full-scale Saturn I. Still in orbit.

Jan. 30 RANGER VI 7A Atlas Agena B	Total weight: 804 lbs. Objective: Take TV photographs of the Moon from close range. Payload: 15'-wide and 10' 4"-tall (cruise position, with solar panels extended) structure. Hexagonal base contains conical midcourse motor, retrorocket; other elements include command system, radio receiver and 3 transmitters, telemetry system, 4 batteries, 6 TV cameras, 9,792 solar cells, 2 antennas.	Impacted on Moon	Launch was very successful; midcourse correction put spacecraft on impact course to Moon. TV cameras failed to perform when turned on in last 15 min. of flight, probably shorted out by arcing. RANGER VI impacted on Moon February 2, 1964 in Sea of Tranquility, having failed to photograph the Moon.
Feb. 15 DEFENSE 8A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	278 119 90.9 75.06	Decayed March 9, 1964.
Feb. 25 DEFENSE 9A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	107 99 87.8 95.60**	Decayed March 1, 1964.
Feb. 28 DEFENSE 11A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	318 301 94.6 82.05	Still in orbit.
Mar. 11 DEFENSE 12A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	239 89 89.8 95.75**	Decayed March 16, 1964.

Mar. 13 DEFENSE Probe Blue Scout Jr.	Total weight: Not stated. Objective: To measure charged solar particle collisions with magnetic field of Earth. Payload: Particle detectors, telemetry system, batteries.	Orbit not intended.	Intended to climb 23,000 miles from Earth, but fourth stage failed to ignite, and payload fell about 2000 miles away from launch site.
Mar. 24 ASSET II Probe Thor Delta	Total weight: 1200 lbs. Objective: Test of gliding reentry from space. Payload: Delta-winged reentry body; instrumentation and telemetry equipment.	Orbit not intended.	Second stage misfired, and payload fell about 500 miles away from launch site; no recovery.
Mar. 27 ARIEL II 15A Scout	Total weight: 150 lbs. Objective: Measure ionospheric galactic radio noise, vertical distribution of ozone, and number and size of micrometeoroids. Payload: 35" x 23" (dia.) cylinder, plus 2 ferrite rod loop antennas, 130' dipole (65' per side) antenna, and 4 solar paddles containing 5,400 solar cells; 22 nickel-cadmium batteries; telemetry system; transmitter-receiver; tape recorder; 3 scientific experiments measuring galactic noise, ozone, and micrometeoroids.	836 182 101.3 51.63	Second in series of 3 U.K.-U.S. scientific satellites (ARIEL I was launched 4/26/62, contributed much knowledge on upper atmosphere). U.S. built the satellite and launch vehicle, launched, tracked, and acquired the data. U.K. built the scientific experiments and would interpret the data. Still in orbit, still transmitting.

Apr. 8 GEMINI (GT-1) 18A Titan II	<p>Total weight: 11,500 lbs., (including 2nd stage of Titan II) of which 7,000 lbs. was the boiler plate Gemini capsule.</p> <p>Objective: Test in unmanned flight the structural integrity of Gemini spacecraft, including heating characteristics of vehicle on exit from the atmosphere, and its compatibility with Titan II launch vehicle.</p> <p>Payload: 11' x 7-1/2' bell shaped spacecraft, with heat sensors, pressureducers, accelerometers, sound level measuring equipment, telemetry equipment batteries.</p>	204 100 89.3 32.60	<p>First flight of flight-rated Gemini spacecraft was highly successful, only surprise being 14 mph excess speed (17,534 mph instead of 17,520 mph) which made orbit 21 mi. higher than planned. Spacecraft and attached Titan II 2nd stage re-entered April 12, 1964, during 69th orbit.</p>
Apr. 10 RAM Probe 3-stage Scout	<p>Total weight: 250 lbs.</p> <p>Objective: To measure radio attenuation effects on communications during reentry.</p> <p>Payload: Reentry body with instrumentation and transmitters.</p>	Orbit not intended.	<p>Satisfactory performance, with impact 1380 miles away from launch site.</p>
Apr. 14 FIRE I Probe Atlas Altair	<p>Total weight: 200 lbs.</p> <p>Objective: Return data on convective and radiative heating at 25,000 mph reentry speeds--the speed of a vehicle returning from the Moon.</p> <p>Payload: 26" (dia.) x 21" conical re-entry body, equipped with 256 temperature pickups; telemetry system.</p>	Orbit not intended.	<p>Ascended 500 mi., then was boosted to 25,730 mph by Altair; in critical 42 sec. telemetered over 100,000 temperature measurements; reported temperature of gases in front of vehicle reached 20,000°. Vehicle impacted in Atlantic near Ascension Island after 32-min., 5,200-mi. flight.</p>

Apr. 23 DEFENSE 20A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	Elements not stated.	Decayed April 28/29, 1964.
Apr. 27 DEFENSE 22A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	276 109 90.8 79.97	Decayed May 26, 1964.
May 13 APOLLO (BP) System Test Little Joe II	Total weight: 18,080 lbs. (command module 9,000 lbs. and service module 9,080 lbs.). Objective: Test capability of Apollo launch escape system at high dynamic pressure and transonic speed. Payload: 12' 10" (dia. at base) x 11' 2" conical boiler plate Apollo capsule; boiler plate service module 13' 2" long x 12' 10" (dia.); 33'-long launch escape system; telemetry system; motion picture cameras; tape recorder; 5 zinc batteries; 1 drogue parachute, 3 pilot parachutes, and 3 main parachutes.	Orbit not intended.	First flight test of Apollo launch escape system was successful; launch escape motor ignited on schedule, pulled Apollo command module away from booster and service module; command module rose to 24,000 ft., and descended by parachute to landing 47,000 ft. from launch site. Structural integrity of launch escape system was confirmed.
May 19 DEFENSE 24A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	Elements not stated.	Decayed May 22, 1964.

May 28 APOLLO (SA6) 25A Saturn I	Total weight: 37,300 lbs. (including the 14,200 lb. S-IV stage, a 6,100 lb. instrument unit, and 17,000 lb. Apollo boiler plate command module and dummy service module). Objective: Continue qualification of 2-stage Saturn vehicle, orbit first boiler plate Apollo spacecraft. Payload: 80' S-IV stage, with instrument unit and boiler plate Apollo command and service modules; transmitter; 10 telemetry systems; batteries.	104 104 88.1 31.77	Flight was excellent; one of booster engines in 1st stage cut off 23 sec. early but guidance system compensated. Orbiting S-IV stage and Apollo spacecraft re-entered June 1, 1964.
Jun. 4 DEFENSE 26A Blue Scout	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	591 532 103.1 90.49**	Still in orbit.
Jun. 4 DEFENSE 27A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	238 86 89.1 80.10	Decayed June 18, 1964.
Jun. 13 DEFENSE 30A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated, except for STARFLASH geodetic component.	224 218 91.7 114.98**	Still in orbit.
Jun. 18 DEFENSE 31A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	520 515 101.6 99.83**	Still in orbit.
Jun. 18 DEFENSE 31B Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	521 514 101.6 99.83**	Still in orbit.

Jun. 19	Total weight: Not stated.	255	Decayed August 16, 1964.
DEFENSE	Objective: Development of space flight	113	
32A	techniques and technology.	90.6	
Thor Agena D	Payload: Not stated.	85.02	
Jul. 2	Total weight: Not stated.	329	Still in orbit.
DEFENSE	Objective: Development of space flight	309	
35A	techniques and technology.	94.9	
Thor Agena D	Payload: Not stated.	82.08	
Jul. 6	Total weight: Not stated.	Elements	Decayed July 8, 1964.
DEFENSE	Objective: Development of space flight	not	
36A	techniques and technology.	stated.	
Atlas Agena D	Payload: Not stated.		
Jul. 6	Total weight: Not stated.	244	Still in orbit.
DEFENSE	Objective: Development of space flight	184	
36B	techniques and technology.	91.4	
Atlas Agena D	Payload: Not stated.	92.99**	
Jul. 10	Total weight: Not stated.	281	Decayed August 6, 1964.
DEFENSE	Objective: Development of space flight	111	
37A	techniques and technology.	90.9	
Thor Agena D	Payload: Not stated.	84.99	
Jul. 17	Total weight: 292 lbs.	64,814	Still in orbit.
DEFENSE	Objective: Development of space flight	63,247	
40A	techniques and technology.	2,022.7	
Atlas Agena D	Payload: Nuclear radiation detection sensors, telemetry, solar cells.	39.59	
Jul. 17	Total weight: 292 lbs.	69,302	Still in orbit.
DEFENSE	Objective: Development of space flight	58,523	
40B	techniques and technology.	6,007.0	
Atlas Agena D	Payload: Nuclear radiation detection sensors, telemetry, solar cells.	40.88	

<p>Jul. 17            TRS II            40C            Atlas Agena D</p>	<p>Total weight: 4.5 lbs.            Objective: Measure charged particle intensity in Van Allen belts.            Payload: Tetrahedron 9 inches on a side, solar cells, proton and electron detectors, telemetry system.</p>	<p>64,892            135            2,366.2            36.73</p>	<p>Still in orbit.</p>
<p>Jul. 20            SERT I            Probe            Scout</p>	<p>Total weight: 375 lbs.            Objective: Verify that ion engines can produce thrust in space; specifically, that the positive ion beam from the engine can be neutralized.            Payload: Flat circular baseplate on a cylindrical pedestal, with the two ion engines extending out on hinged arms; 4"-dia. 1/2 kw cesium contact thruster engine weighed 13.15 lbs.; 7.5"-dia. 1-1/2 kw mercury electron bombardment thruster engine weighed 11.6 lbs.; battery pack, converters; 3 thrust-detection systems; transmitter.</p>	<p>Orbit            not            intended.</p>	<p>Mercury-propelled ion engine performed in space for 16 min., generated .0055 lbs. of thrust, making backup flight unnecessary. Cesium engine did not operate because of breakdown in electric power supply. First known performance of ion engine in space. The rocket climbed 2500 miles, fell 2000 miles away from the launch site, after a 48 minute flight.</p>
<p>Jul. 22            ASSET III            Probe            Thor Delta</p>	<p>Total weight: 1150 lbs.            Objective: Test of gliding reentry from space.            Payload: Delta-winged reentry body, instrumentation and telemetry equipment.</p>	<p>Orbit            not            intended.</p>	<p>Climbed 44 miles, reentered 1550 miles away at a speed of 12,000 miles per hour, and with a peak skin temperature of 4,000°F. The glider was successfully recovered by frogmen.</p>

Jul. 28  
RANGER VII  
41A  
Atlas Agena B

Total weight: 806 lbs.  
Objective: Take TV photographs of the Moon from close range, enabling identification of items 10 times smaller than identifiable from Earth.

Payload: 15'-wide and 10' 4"-tall (cruise position, with solar panels extended) structure. Hexagonal base contains conical midcourse motor, retrorocket; other elements include command system 1 radio receiver and 3 transmitters, telemetry system, 4 batteries, 6 TV cameras, 9,792 solar cells, 2 antennas.

Impacted  
on  
Moon.

RANGER VII transmitted to Earth 4,316 high-quality photos of the Moon's Sea of Clouds area prior to impacting on Moon July 31, 1964, about 8 to 10 miles from the aimpoint, after excellent flight. Photo time was last 17 min. of flight from about 1,300 mi. from Moon down to 1,600 ft., and improved resolution over telescopic photos from Earth by factor of 2,000. Preliminary analysis of photos argues that surface of Moon is smoother than expected, covered with no more than thin porous layer (1 ft.) over solid material, all this being suitable for manned landing and exploration.

Aug. 5  
DEFENSE  
43A  
Thor Agena D

Total weight: Not stated.  
Objective: Development of space flight techniques and technology.  
Payload: Not stated.

261  
112  
90.5  
79.97

Decayed August 31/  
September 1, 1964.

Aug. 14	Total weight: Not stated.	193	Decayed September 23,
DEFENSE	Objective: Development of space flight	96	1964.
45A	techniques and technology.	88.9	
Atlas Agena D	Payload: Not stated.	95.50**	
Aug. 14	Total weight: Not stated.	233	Still in orbit.
DEFENSE	Objective: Development of space flight	163	
45B	techniques and technology.	127.4	
Atlas Agena D	Payload: Not stated.	95.60**	
Aug. 18	Total weight: 370 lbs.; at start of reentry,	Orbit	The 11-min. flight
REENTRY	182 lbs.	not	was successful, climb-
Probe	Objective: Test heat-shield material in	intended.	ing to 130 miles, then
Scout	heats generated by high-speed reentry.		reentry speed was
	Payload: 4'-long cone 11-1/2" at nose		19,500 mph, impact
	cap to 20-1/4" at widest point; test materials;		was 1,265 mi. down-
	telemetry; 17" spherical rocket motor to in-		range from Wallops
	crease reentry velocity.		Island, Va., launch
			site. Low-density
			charring ablator
			materials were being
			considered for use on
			Apollo heat shield on
			missions returning
			from the Moon.

Aug. 19 SYNCOM III 47A Thrust Augmented Thor Delta	<p>Total weight: 145 lbs. before firing of apogee-kick motor; after, 86 lbs.</p> <p>Objective: Place satellite in synchronous equatorial orbit and conduct communications experiments.</p> <p>Payload: 28" (dia.) x 15-1/2" cylinder, plus apogee-kick motor and antennas; 3,840 n-on-p solar cells, 2 transmitter-receivers, telemetry, hydrogen-peroxide tanks and jets for control.</p>	22,491 21,195 1,407.7 0.07	<p>First satellite to achieve true synchronous orbit; first satellite launch by the uprated Delta booster. After launch came weeks of minor maneuvers until by September 23, 1964 SYNCOM III was in almost perfect stationary position above equator and International Date Line, apogee 22,311 miles, perigee 22,164 miles and period 1,436 minutes. Communications were very successful, including 15 days of transpacific transmission of Olympic Games from Tokyo, beginning October 7, 1964. Still in orbit; still transmitting.</p>
Aug. 21 DEFENSE 48A Thor Agena D	<p>Total weight: Not stated.</p> <p>Objective: Development of space flight techniques and technology.</p> <p>Payload: Not stated, except for STARFLASH geodetic component.</p>	218 206 91.4 114.98**	Still in orbit.

Aug. 25  
IONOSPHERE  
EXPLORER XX  
51A  
Scout

Total weight: 97 lbs.  
Objective: Map irregularities in topside of Earth's atmosphere, measure cosmic noise and ion population.  
Payload: 46-1/2"-long x 26"-dia. cylinder with conical ends plus 4"-dia. ball-shaped ion mass-spectrometer on a 10" boom on one end and 1 set of 122' antennas and 2 sets of 62' antennas; 6 radar sets; transmitter-receiver; tracking beacon; 2,400 solar cells; nickel-cadmium batteries.

632  
539  
103.9  
79.89

Is providing better understanding of F-2 layer of ionosphere and its effect on long-range radio communication by measuring the height of the ionosphere above the Earth and its ion composition. Still in orbit, still transmitting.

Aug. 28  
NIMBUS I  
52A  
Thor Agena B

Total weight: 830 lbs.  
Objective: Demonstrate placement and stabilization of meteorological satellite in a precise, continuous, Earth-pointing orbit: evaluate new camera system and radiometer; and provide improved cloud photos.

Payload: 10' - high structure with hexagonal control section on top, connected by a truss structure to wheel-like sensory ring and flanked by 2 8' x 2' 9" solar paddles containing 10,500 solar cells; 161 nickel-cadmium batteries; active 3-axis control system; 3 vidicon cameras, tape recorder, APT camera system; radiometer; transmitter.

583  
264  
98.4  
98.66\*\*

Orbit more elliptical than intended because Agena 2nd stage had short 2nd burn; photos were best cloud cover shots ever received from space; infrared information on nighttime cloud cover was much more detailed than any previous experiment. On September 23, 1964, NIMBUS I ceased transmitting when solar paddles locked, this after 27,000 excellent photos had been transmitted. Resumed transmissions December 8, 1964, but satellite tumbling makes photos unusable. Still in orbit.

Aug. 28  
DEFENSE  
Probe  
Blue Scout Jr.

Total weight: Not stated.  
Objective: Development of space flight techniques and technology.  
Payload: Not stated.

Orbit  
not  
intended.

Sept. 5 OGO I 54A Atlas Agena B	<p>Total weight: 1,073 lbs.</p> <p>Objective: In highly eccentric orbit, make scientific measurements and observations in the Earth's atmosphere, magnetosphere, and in interplanetary space beyond the Earth's magnetic field.</p> <p>Payload: 59' x 50' (cruise position, with antennas and solar panels extended) structure, central portion a rectangular box from which 7 booms extend; 20 scientific experiments, 3 transmitters, 2 receivers; 2 tape recorders; 3 beacons; 32,250 p-on-n solar cells; 2 nickel-cadmium batteries.</p>	92,618 175 3,838.8 31.16	Orbit of geophysical observatory was very close to plan, but 2 booms failed to deploy, interfering with control system's attempt to lock on Earth. All 20 experiments functioned at least partially; on September 10, 1964 a maneuver succeeded in reorienting solar panels toward Sun, providing good power level, but 6 experiments were crippled by non-deployed booms. Still in orbit, still transmitting.
Sept. 14 DEFENSE 56A Thor Agena D	<p>Total weight: Not stated.</p> <p>Objective: Development of space flight techniques and technology.</p> <p>Payload: Not stated.</p>	285 118 90.8 84.95	Decayed October 6, 1964.
Sept. 18 APOLLO (SA7) 57A Saturn I	<p>Total weight: 36,700 lbs. (including the 14,100 lb. S-IV stage, a 5,400 lb. instrument unit, and 17,200 lb. Apollo boilerplate command and service modules.)</p> <p>Objective: Continue qualification of 2-stage Saturn vehicle and of boilerplate Apollo spacecraft.</p> <p>Payload: 80' S-IV stage, with instrument unit and boilerplate Apollo command and service modules; transmitter; 10 telemetry systems; batteries.</p>	145 112 88.6 31.70	Flight was excellent, resulted in Saturn I being considered operational after 7 flights instead of the planned 10. Re-entered September 22, 1964.

Sept. 23 DEFENSE 58A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	Elements not stated.	Decayed September 28, 1964.
Oct. 4 IMP EXPLORER XXI 60A Thor Delta	Total weight: 136 lbs. Objective: In very eccentric orbit, study charged particles from the Sun and from sources outside the solar system; study magnetosphere. Payload: 28" (dia.) x 8" octagonal structure, plus 6' boom with rubidium-vapor magnetometer on end, flux-gate magnetometers deployed on 7' booms; 4 solar panels; 11,520 solar cells; 13 silver-cadmium batteries; transmitter.	59,266 118 2,097.0 33.53	Partial failure of X-248 3rd stage of Delta caused insufficient apogee, less than half of intended 126,500 mi. ; would provide very little data on intended area beyond the Earth's atmosphere (40,000 mi. +). Classed as an interplanetary monitoring platform. Still in orbit, still transmitting.
Oct. 5 DEFENSE 61A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	242 109 90.4 79.97	Decayed October 26, 1964.
Oct. 6 DEFENSE 63B Thor Able Star	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	671 655 106.6 89.93	Still in orbit.
Oct. 6 DEFENSE 63C Thor Able Star	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	673 653 106.6 89.93	Still in orbit.

Oct. 6	Total weight: Not stated.	671	Still in orbit.
DEFENSE	Objective: Development of space	856	
63E	flight techniques and technology.	106.6	
Thor Able Star	Payload: Not stated.	89.98	
Oct. 9	Total weight: Not stated.	Orbit	Climbed to 800 miles,
RFD-2	Objective: To acquire data on nuclear	not	then reentered 1,000
Probe	generator disassembly and fuel capsule	intended.	miles from the launch
Scout	burnup for use in advanced generator		site. Telemetry was
	designs.		returned and a beacon
	Payload: A nonradioactive mockup of		radio still functioned
	an isotope thermoelectric generator.		after the water impact.
Oct. 10	Total weight: 116 lbs.	671	Satellite was transmit-
BEACON	Objective: Study electron behavior and	550	ting continuous radio
EXPLORER XXII	population in the ionosphere, relate iono-	104.8	signals down through
64A	spheric behavior to solar radiation which	79.69	ionosphere to network
Scout	causes ionization affecting long-range com-		of 80 ground stations
	munications, study geometry and irregulari-		being operated by 50
	ties of the ionosphere, and perform experi-		scientific groups in 32
	ments in geodesy.		countries, largest
	Payload: 18" x 12" octagonal satellite, with		international effort to
	4 solar panels, carrying 12,776 solar cells,		date on a space project.
	and extending like windmill blades; 4 Doppler		On October 11, 1964
	and ionosphere experiment radio transmitters,		laser beam aimed at
	4 antennas; magnetometer; 26 nickel-cadmium		EXPLORER XXII re-
	batteries; 360 1-in. glass-prism reflectors;		ceived answering light
	2 bar magnets.		reflection in geodetic
			experiment to enable
			very precise measure-
			ment of the satellite's
			orbit. Still in orbit,
			still transmitting.
Oct. 17	Total weight: Not stated.	192	Decayed November 4,
DEFENSE	Objective: Development of space flight	109	1964.
67A	techniques and technology.	89.9	
Thor Agena D	Payload: Not stated.	74.99	

Oct. 21 ASTROBEE 1500-II Probe Aerojet Jr-Recruits- Alcor	Total weight: 156 lbs. Objective: To flight test a new vehicle. Payload: Sensors of acceleration, vibration, temperature, and pressure; telemetry equipment, and batteries.	Orbit not intended.	Climbed to 1,212 miles, then impacted 1,326 miles away from launch site. Returned 27 minutes of telemetry in a successful test.
Oct. 23 DEFENSE 68A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	Elements not stated.	Decayed October 28, 1964.
Oct. 23 DEFENSE 68B Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	213 193 91.1 95.50**	Still in orbit.
Oct. 23 DEFENSE 68D Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	Elements not stated.	Decayed October 29, 1964.
Oct. 27 ASSET IV Probe Thor	Total weight: 1,100 lbs. Objective: Test of gliding reentry from space. Payload: Delta-winged reentry body, instrumentation and telemetry equipment.	Orbit not intended.	Climbed 31 miles, re- entered 900 miles away. No physical recovery of payload, but telemetry signals received.
Nov. 2 DEFENSE 71A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	262 114 90.7 79.6	Decayed November 28, 1964.
Nov. 4 DEFENSE 72A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	326 317 95.0 82.04	Still in orbit.

Nov. 5 MARINER III 73A Atlas Agena D	Total weight: 575 lbs. Objective: Investigate interplanetary space between orbits of Earth and Mars; perform experiments in vicinity of Mars. Payload: 9' 6"-high by 22' 7 1/2" (cruise position, with solar panels and pressure vanes deployed)-structure; basically a 50" octagon with 4 6' x 3' solar panels extended horizontally and 4 solar pressure vanes extending beyond the panel.	1.33 au* 1.00 au 448.7 days .254	Satellite was placed in interplanetary orbit successfully--even though Agena D was 4 sec. short on its second burn--but communications failed permanently when fairing did not jettison, prevented solar panel deployment. First NASA use of Agena D 2nd stage. Still in orbit.
Nov. 6 EXPLORER XXIII 74A Scout	Total weight: 295 lbs. Objective: Investigate meteoroid penetration, solar cell degradation. Payload: 24" (dia.) x 92" cylinder, containing 4 types of meteoroid-penetration detectors (pressurized cells, cadmium sulfide cells, impact detectors, and capacitor detectors); 2 test groups of solar cells, 1 group protected, 1 not; 2 transmitters; beacon; 2 nickel-cadmium batteries.	608 287 99.2 51.94	A follow-on to EXPLORER XVI, launched December 16, 1962. Information expected to be of use in Apollo design. Still in orbit, still transmitting.
Nov. 18 DEFENSE 75A Thor Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	193 111 89.4 70.2	Decayed December 6, 1964.
Nov. 21 AIR DENSITY EXPLORER XXIV 76A Scout	Total weight: 19 lbs. (portion of 135 lbs. in dual launch). Objective: Orbit 2 satellites with single launch vehicel to gather data from same portion of space on (1) air density, (2) radiation, and (3) relationship between the two. Payload: 12' polkadotted sphere, consisting of mylar balloon, with beacon, 280 solar cells, and 10 nickel-cadmium batteries.	1,549 329 116.3 81.36	Data would also be used with those from EXPLORER XIX to provide global air density profile. Still in orbit, still transmitting.

<p>Nov. 21 INJUN EXPLORER XXV 76B Scout</p>	<p>Total weight: 90 lbs. (portion of 135 lbs. in a dual launch). Objective: Orbit 2 satellites with single launch vehicle to gather data from same portion of space on (1) air density, (2) radiation, and (3) relationship between the two. Payload: 2' (dia.) spherical polyhedron, with 3 booms; 5 omnidirectional radiation sensors; 11 directional radiation sensors; magnetometer to control alignments; transmitter; telemetry; tape recorder; 2,640 solar cells; 19 nickel-cadmium batteries.</p>	<p>1,547 330 116.3 81.36</p>	<p>Still in orbit; still transmitting.</p>
<p>Nov. 28 MARINER IV 77A Atlas Agena D</p>	<p>Total weight: 575 lbs. Objective: Investigate interplanetary space between orbits of Earth and Mars; perform experiments in vicinity of Mars. Payload: 9' 6" -high by 22' 7 1/2" (cruise position, with solar panels and pressure vanes deployed)-structure; basically a 50" octagon with 4 6' x 3' solar panels extended horizontally and 4 solar pressure vanes extending beyond the panel tips; 28,224 solar cells; 33-lb. silver-zinc battery; 6 experiments to measure interplanetary phenomena (solar plasma probe, ionization chamber, trapped radiation detector, helium vector magnetometer, cosmic ray telescope, cosmic dust detector); TV camera; transmitters; control system; 2 antennas extend vertically from octagon.</p>	<p>1.573 au* .984 au 529.3 days .1286</p>	<p>Placed in excellent interplanetary orbit, with all systems functioning well; trajectory would have caused MARINER IV to pass 151,000 mi. ahead of Mars on July 17, 1965; on December 5, 1964, a mid-course correction maneuver successfully altered course so spacecraft would pass 5,600 mi. behind Mars on July 14, 1965 after 325,000,000-mi. flight; on December 7, 1964, the solar plasma probe failed but other 5 interplanetary sensors continued to return data. In vicinity of Mars an attempt would be made to take</p>

Dec. 4 DEFENSE 79A Atlas Agena D	Total weight: Not stated. Objective: Development of space flight techniques and technology. Payload: Not stated.	Elements not stated.	22 TV photos of Mars and use radio waves in occultation experiment to determine composition of Mars atmosphere. Still in orbit; still transmitting.  Decayed December 5, 1964.
Dec. 8 APOLLO (BP) System Test Little Joe II	Total weight: 27,692 lbs. (including command module 10,000 lbs.; service module 9,600 lbs.; launch escape motor 4,800 lbs.; tower jettison motor 550 lbs.) Objective: Test Apollo launch escape system under catastrophic launch conditions occurring at point of maximum aerodynamic pressure. Payload: 13' 2"-high x 12' 10"-dia. cylindrical boilerplate service module; 11' 3"-high x 12' 10"-(dia. at base) conical boilerplate command module; 33'-long launch escape system; telemetry system; motion picture cameras; tape recorder; 5 zinc batteries; 2 drogue parachutes, 3 pilot parachutes, 3 main parachutes.	Orbit not intended.	Third Apollo test was successful; escape motor ignited on schedule, pulled Apollo modules away from booster, and tower separated; Apollo spacecraft rose to peak of 50,360 ft., and parachuted to landing 32,800 ft. from launch point; demonstrated safe escape under worst launch contingencies.
Dec. 8 ASSET V Probe Thor	Total weight: 1,100 lbs. Objective: Test of gliding reentry from space. Payload: Delta-winged reentry body, instrumentation and telemetry equipment.	Orbit not intended.	Climbed 33 miles up, reentered 840 miles from the launch site, returning telemetry. No recovery of the reentry body was attempted.

Dec. 10	Total weight: 9,000 lbs. (including	120	Midway through the first orbit, the transtage was commanded to turn end over end 360°, and then after one orbit it was separated from the dummy payload. Decayed December 13, 1964.
DEFENSE	3,750 lbs. of inert ballast and 5,250 lbs.	111	
81A	of transtage.)	100	
Titan IIIA	Objective: To test the operation and interaction of assembled systems for a new launch vehicle. Payload: Diagnostic sensors, telemetry, and communications systems.	Not stated.	
Dec. 11	Total weight: 6,500 lbs., including 2,100-lb.	106	Fourth test of liquid-hydrogen Centaur achieved all six primary objectives, orbited Centaur stage and its dummy payload. In orbit, Centaur stage began tumbling, preventing fuel from reaching engines for restart test. Centaur stage reentered after 15 hrs. December 12, 1964.
CENTAUR (AC-4)	dummy model of Surveyor spacecraft.	101	
82A	Objective: Primary objectives, to test	87.8	
Atlas Centaur	structural integrity of total system and test guidance system; secondary objectives, to attempt various maneuvers, including restart of Centaur engines. Payload: 46' x 10' Centaur stage, including dummy Surveyor spacecraft; all-inertial guidance system; telemetry; beacon signal transponder; batteries.	30.67	
Dec. 13	Total weight: Not stated.	673	Still in orbit.
DEFENSE	Objective: Development of space flight	638	
83C	techniques and technology.	106.3	
Thor Able Star	Payload: Not stated.	89.99	
Dec. 13	Total weight: Not stated.	674	Still in orbit.
DEFENSE	Objective: Development of space flight	637	
83D	techniques and technology.	106.3	
Thor Able Star	Payload: Not stated.	89.97	

Dec. 19	Total weight: Not stated.	236	Still in orbit.
DEFENSE	Objective: Development of space flight	114	
85A	techniques and technology.	90.3	
Thor Agena D	Payload: Not stated.	74.99	
Dec. 21	Total weight: 101 lbs.	16,291	Fourth NASA energetic
ENERGETIC	Objective: Provide data on how high-	193	particles satellite
PARTICLES	energy particles are injected, trapped, and	457.1	(others were
EXPLORER XXVI	eventually lost in the Earth's radiation belts.	20.15	EXPLORERS XII, XIV,
86A	Payload: 17" x 27" octagonal satellite, plus		and XV). Information
Thor Delta	external extensions of 4 solar panels, 4 anten-		gained would be im-
	nas, and 34" tube mounting flux-gate magne-		portant to Project
	tometer; electron-proton angular distribution		Apollo in design of
	and energy detectors, directional directors;		spacecraft shielding
	ion-electron detector; solar-cell-damage		and planning trajec-
	experiment; telemetry; 13 silver-cadmium		tories to the Moon.
	batteries.		Still in orbit, still
			transmitting.
Dec. 21	Total weight: Not stated.	155	Still in orbit.
DEFENSE	Objective: Development of space flight	143	
87A	techniques and technology.	89.4	
Thor Agena D	Payload: Not stated.	70.09	
Dec. 21	Total weight: Not stated.	Orbit	
DEFENSE	Objective: Development of space flight	not	
Probe	techniques and technology.	intended.	
Blue Scout Jr.	Payload: Not stated.		
Date not stated	Total weight: Not stated.	Elements	A payload which failed
DEFENSE	Objective: Development of space flight	not	to separate from
Not stated	techniques and technology.	stated.	another payload as
Thor Able Star			intended, already
			reported.

In addition to the foregoing United States launchings, the following Italian launching occurred at a U.S. launch site:

Dec. 15	Total weight: 254 lbs.	498	First satellite built
SAN MARCO I	Objective: Train Italian crew in prepara-	125	and instrumented in
84A	tion for later sea-platform launches;	94.8	Western Europe; first
Scout	qualify satellite; measure ionospheric air	37.77	satellite launching
	density and study ionospheric interference		from U.S. by non-U.S.
	with long-range radio transmissions.		crew. Still in orbit,
	Payload: 26" spherical satellite consisting		still transmitting.
	of a heavy sphere contained in a much		
	lighter one as a means of measuring air		
	density; instruments for radio-interference		
	experiments; telemetry; batteries.		

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 astronomical 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.

NASC Staff

SNAP RADIOISOTOPE ELECTRICAL POWER UNITS FOR SPACE

SNAP NO.	Power electrical (watts)	Life (years)	Application	Fuel	Status
3	2.7	5	Navigation Satellite (Navy)	Plutonium-238	Two units launched; in June and November 1961
9A	25	5	Navigation Satellite (Navy)	Plutonium-238	Two units launched in 1963. One unit aborted April 1964
11	25	1/3	SURVEYOR Spacecraft (NASA)	Curium-242	Scheduled delivery 1966
13	12.5	1/3	Thermionic Demonstration Unit	Curium-242	Delivered to fueling site December 1964
17	25	3-5	Communications Satellites	Strontium-90	Phase I development completed August 1964
19	30	5	NIMBUS-B (NASA)	Plutonium-238	Prototype generator under development

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 (IIA)	Solid	86	3.3	72	240	--	1963 (60)*
	2. Castor (I-E5)	Solid	64					
	3. Antares (X-259)	Solid	23					
	4. Altair (X-258)	Solid	3					
Thor Delta	1. Thor (DM-21)	LOX/RP	170	8	90	800	105	1963 (60)
	2. AJ-10-118	IRFNA/UDMH	7.7					
	3. Altair (X-258)	Solid	3.0					
Thrust augmented Thor Delta	1. Thor (DM-21) plus 3 XM-33	LOX/RP Solid	170 plus 54 each	11	90	1000	150	1964 (60)
	2. AJ-10-118	IRFNA/UDMH	7.7					
	3. Altair (X-258)	Solid	3					
Thor Able Star	1. Thor (DM-21)	LOX/RP	170	8	79	825	--	1962 (60)
	2. AJ-10-104	IRFNA/UDMH	7.9					
Thor Agena D	1. Thor (DM-21)	LOX/RP	170	8	76	1600	--	1962 (59)
	2. Agena D	IRFNA/UDMH	16					
Thrust augmented Thor Agena D	1. Thor (DM-21) plus 3 TX 33-52	LOX/RP Solid	170 54 each	11	76	2200		1963 (60)
	2. Agena D	IRFNA/UDMH	16					
Atlas Agena D	1. Atlas booster and sustainer	LOX/RP	390	10	91	5900	950	1963 (60)
	2. Agena D	IRFNA/UDMH	16					
Titan IIIA	1. Two LR-87	N <sub>2</sub> O <sub>4</sub> /UDMH	430	10	110	5000	--	1964
	2. LR-91	N <sub>2</sub> O <sub>4</sub> /UDMH	100					
	3. Transtage	N <sub>2</sub> O <sub>4</sub> /UDMH	16					

Titan III C	1. Two 5-segment 120" dia. Solid		2000 +	10 x 30	110	23,000	5000	1964/65
	2. Two LR-87	N <sub>2</sub> O <sub>4</sub> /UDMH	430					
	3. LR-91	N <sub>2</sub> O <sub>4</sub> /UDMH	100					
	4. Transtage	N <sub>2</sub> O <sub>4</sub> /UDMH	16					
Atlas Centaur	1. Atlas booster and sustainer	LOX/RP	390	10	105	8500	2300	5/8/62
	2. Centaur (Two RL-10)	LOX/LH	30					
Saturn I	1. S-I (8 H-1)	LOX/RP	1500	21.6	120	15,000	--	1st stage 10/27/61
	2. S-IV (6 RL-10)	LOX/LH	90					2nd stage Block II 1/29/64
Saturn I-B	1. S-IB (8 H-1)	LOX/RP	1600	21.6	142	32,000		1966
	2. SIVB (1 J-2)	LOX/LH	200					
Saturn V	1. S-IC (5 F-1)	LOX/RP	7500	33	281	250,000	95,000	1967
	2. S-II (5 J-2)	LOX/LH	1000					
	3. S-IVB (1 J-2)	LOX/LH	200					

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 Dimethylhydrazine -- IRFNA/UDMH; Nitrogen Tetroxide and Aerozene 50 -- Storable liquid; Liquid Oxygen and Liquid Hydrogen -- LOX/LH.

Values marked -- are either zero or not pertinent for the vehicle.

MAJOR COMMUNICATIONS SATELLITE GROUND TERMINALS

<u>Country</u>	<u>Location</u>	<u>Owner-Operator</u>	<u>Size</u>
United States	Andover, Me.	AT&T	60' Horn
	Nutley, N. J.	ITT	40' (n)
	Barstow, Calif.	NASA	40'
	Camp Roberts, Calif.	DOD	60'
	Fort Dix, N. J.	DOD	60'
	USNS Kingsport	DOD	30' (n) (s)
	Oahu, Hawaii	DOD	30' (n) (t)
	Point Mugu, Calif. (Temporary Conversion)	DOD	85' (r)
	Overseas	DOD	30' (n) (t)
	Overseas	DOD	30' (n) (t)
	Overseas	DOD	15' (n) (t)
Brazil	Rio de Janeiro	Companhia Radio Internacional do Brasil	30' (n)
Japan	Takahagi	Kokusai Denshin Denwa Co.	65'
	Kashima-Machi	Radio Research Laboratories (Gov't)	98'
Great Britain	Goonhilly Downs	British Post Office	85'
France	Pleumeur-Bodou	Centre National d'Etudes des Telecommunications	60' Horn
Italy	Fucino	Telespazio, S. p. A.	30'
Spain	Griega	Companhia Telefonica Nacional de Espana	30' (n)

West Germany	Raisting	Deutsche Bundespost	82'
	Raisting	Deutsche Bundespost	30' (n)
Sweden	Rao	(SC)	84' (r)
Canada	Mill Village Nova Scotia	Canadian Dept of Transport	85'
India	Ahmedabad (tentative)	Indian Dept of Atomic Energy	(not completed)

#### Notes

(n) Narrow band only - not suitable for TV

(r) Receive only

(s) Shipboard Terminal

(t) Transportable Terminal

(SC) Scandanavian Committee for Satellite Telecommunications jointly with Chalmers Univ. of Technology  
Gothenburg, Sweden

SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT

Historical Summary and 1966 Budget Recommendations January 25, 1965

NEW OBLIGATIONAL AUTHORITY

(In millions of dollars)

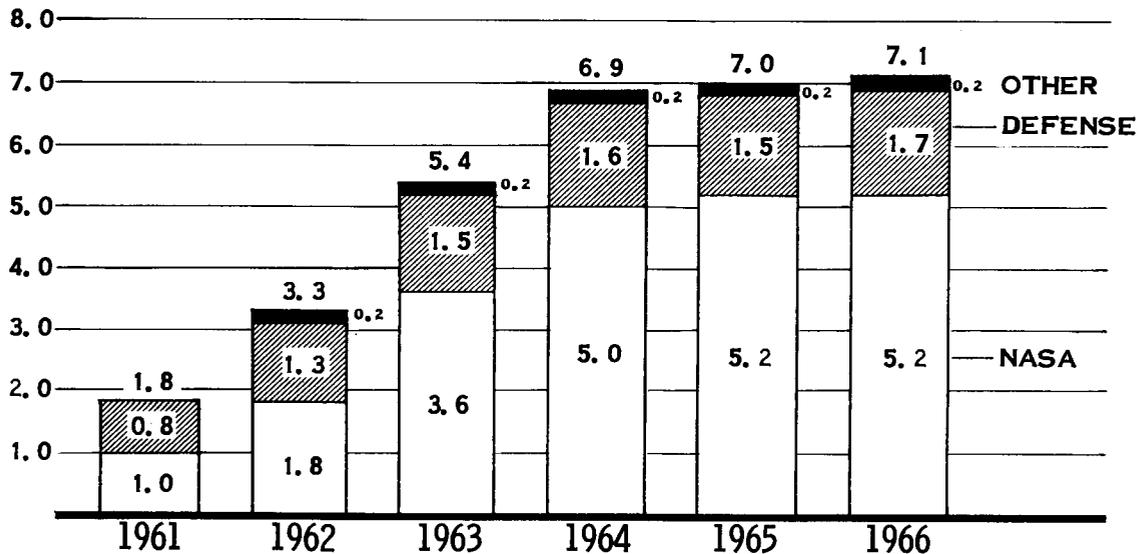
<u>Historical</u>	<u>NASA</u>		<u>Dept. of Defense</u>	<u>AEC</u>	<u>Weather Bureau</u>	<u>NSF</u>	<u>Total Space</u>
	<u>Total</u>	<u>Space 1/</u>					
1955	56.9	56.9	3.0	-	-	-	59.9
1956	72.7	72.7	30.3	7.0	-	7.3	117.3
1957	78.2	78.2	71.0	21.3	-	8.4	178.9
1958	117.3	117.3	205.6	21.3	-	3.3	347.9
1959	338.9	268.9	489.5	34.3	-	-	792.7
1960	523.6	461.5	560.9	43.3	-	.1	1065.8
1961	966.7	928.7	813.9	67.7	-	.6	1810.9
1962	1824.9	1796.8	1298.2	147.8	50.7	1.3	3294.8
1963	3673.0	3626.0	1548.1	213.9	43.2	1.5	5432.7
1964	5100.0	5046.6	1604.1	210.0	2.8	3.0	6866.5
<u>1966 Budget</u>							
1965	5250.0	5179.8	1546.7	236.0	15.4	3.1	6984.0
1966	5260.0	5181.6	1670.2	225.2	33.1	3.8	7113.9

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**

BILLIONS OF DOLLARS



REQUEST  
JAN. 25, 1965

NASC STAFF

# SPACE ACTIVITIES OF THE UNITED STATES GOVERNMENT

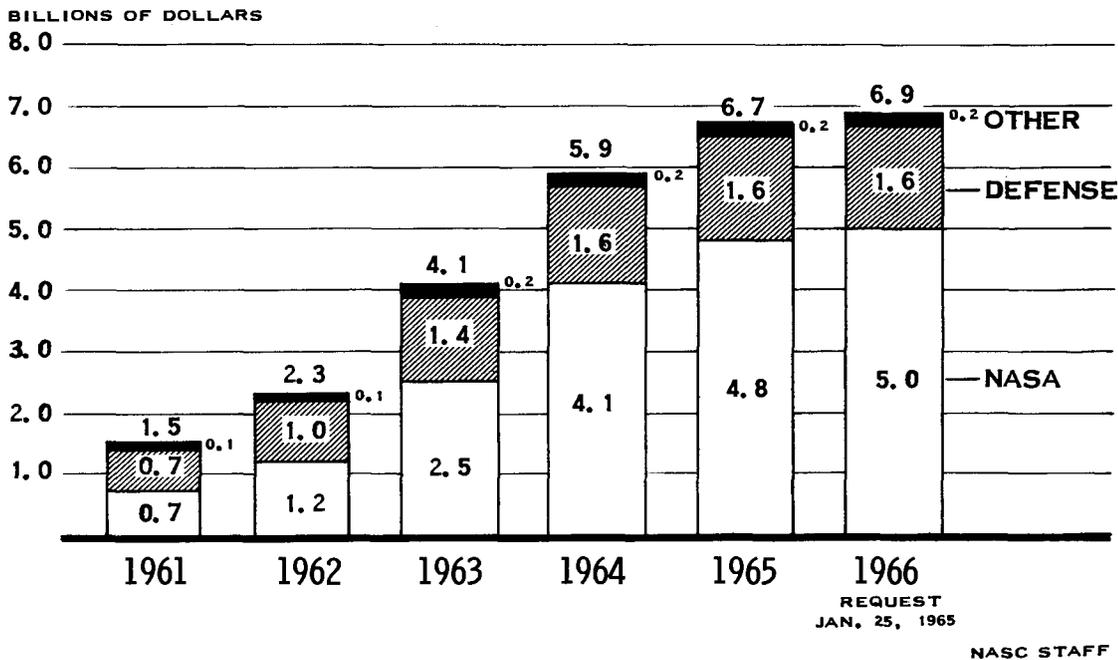
## Historical Summary and 1966 Budget Recommendations January 25, 1965

### EXPENDITURES (In millions of dollars)

	NASA		Dept. of Defense	AEC	Weather Bureau	NSF	Total Space
	Total	Space 1/					
<b>Historical</b>							
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	-	-	1,467.9
1962	1,257.0	1,225.9	1,028.8	130.0	1.0	.9	2,386.6
1963	2,552.3	2,516.8	1,367.5	181.0	12.2	1.1	4,078.6
1964	4,171.0	4,131.3	1,563.5	220.1	12.3	2.6	5,929.8
<b>1966 Budget</b>							
1965	4,900.0	4,837.3	1,570.0	231.2	15.0	3.0	6,656.5
1966	5,100.0	5,031.5	1,610.0	227.9	16.6	3.6	6,889.6

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



SPACE ACTIVITIES BUDGET

1966 Budget Document

(January 25, 1965

(In millions of dollars)

	New Obligational Authority			Expenditures		
	1964 (Actual)	1965 (Estimated)	1966	1964 (Actual)	1965 (Estimated)	1966
<u>Federal Space Program</u>						
NASA* .....	5046.6	5179.8	5181.6	4131.3	4837.3	5031.5
Department of Defense.....	1604.1	1546.7	1670.2	1563.5	1570.0	1610.0
Atomic Energy Commission..	210.0	236.0	225.2	220.1	231.2	227.9
Department of Commerce:						
Weather Bureau.....	2.8	15.4	33.1	12.3	15.0	16.6
National Science Foundation...	3.0	3.1	3.8	2.6	3.0	3.6
<b>TOTAL</b>	<b>6866.5</b>	<b>6981.0</b>	<b>7113.9</b>	<b>5929.8</b>	<b>6656.5</b>	<b>6889.6</b>
<u>NASA</u>						
Manned space flight.....	3456.7	3476.5	3587.5	2767.7	3084.5	3386.3
Scientific investigations...	686.3	701.8	730.3	641.2	692.8	702.7
Space applications.....	118.1	93.2	114.1	112.4	110.3	106.6
Space technology.....	486.6	451.2	399.7	431.9	509.8	444.4
Aircraft technology.....	53.4	70.2	78.4	39.7	62.7	68.5
Supporting activities.....	401.0	384.3	350.0	178.1	439.9	391.5
Adjusted to appropriation.	-102.0	+ 72.8	-			
<b>Total</b>	<b>5100.0</b>	<b>5250.0</b>	<b>5260.0</b>	<b>4171.0</b>	<b>4900.0</b>	<b>5100.0</b>

\*Excludes amounts for aircraft technology.

Source: Bureau of the Budget

# INDEX

- Advanced Manned Strategic  
Aircraft (AMSA) 50  
AEROBEE 78  
Aeronautics 31, 41, 50, 51, 60,  
92  
Aerospace Medical Div.  
Brooks AFB 15  
AGENA 10, 11, 24, 34, 41, 56, 66  
ALOUETTE 36  
Ames Research Center 9  
Anti-Satellite System 3, 45  
APOLLO 3, 4, 5, 9, 10, 11-18, 42,  
48, 73, 83, 85, 91, 92, 94, 95, 122  
ARIEL II 1, 4, 19, 36  
ASSET 4, 54, 55  
Astronauts 10, 94  
ATLAS 2, 11, 21, 24, 25, 33  
Atomic Energy Commission 15,  
24, 28, 29, 63-67  
Automatic Picture Transmission  
(APT) 22, 36, 81, 82, 121  
  
Baker-Nunn cameras 72, 80, 99,  
100, 101, 102  
BEACON 37, 46, 57, 91  
Bioastronautics 9, 21, 26, 97  
Biosatellites 21  
British Committee on Space  
Research 36  
  
C-141 A 53, 111  
Canadian Defence Telecommuni-  
cations Establishment 36  
CELOSCOPE, Project 101  
CENTAUR 3, 21, 24, 25, 99  
Central Radio Propagation  
Laboratory 90  
Cerro Tololo Inter American  
Observatory 78  
Civil Aeronautics Board (CAB) 92  
Coast and Geodetic Survey 79, 86-87  
Commerce, Dept. of 57, 81-93, 110  
Concorde 92  
Counterinsurgency Aircraft (COIN) 53  
Communications, Defense Satellite  
Program 3, 43, 44, 60  
  
Communications Satellites (See  
TIROS, SYNCOM, RELAY, ECHO)  
Communications Satellite Corp. 5, 72,  
114  
Cryogenics 89  
CX-HLS 9  
  
Defense, Dept. of 3, 10, 11, 14, 24,  
41-62, 91, 92, 93, 95, 103  
DELTA (See THOR)  
  
EARLYBIRD 4, 113, 114, 115, 116  
ECHO 4, 24, 25, 71, 122  
Electronics 27  
Ellington AFB 9  
European Space Research Org.  
(ESRO) 36, 38  
Exobiology 22, 97  
EXPLORER 4, 18, 19, 33, 36, 59, 99, 122  
Extraordinary Administrative Radio  
Conference on Space Communications  
71  
  
F-1 Engine 3, 10  
F-5 9  
F-111A 4, 41, 50, 51  
Federal Aviation Agency 32, 103-111  
Federal Communications Commission  
113-116  
FIRE, Project 4  
French National Center for Space  
Studies 36  
  
GEMINI 5, 9, 10-12, 34, 41, 42, 61, 72,  
83, 85, 95, 121, 122  
Geodetic Satellite Program 5, 18, 45,  
46, 59  
Global Commercial Communications  
Satellite System 69-71, 113  
Goddard Space Flight Center 37, 64, 79  
Gravity Gradient Stabilization 57, 58  
60  
  
Helicopters 51, 52, 111  
Hurlburt, E. O. Center for Space  
Research 78

IMP 4, 19  
 International Cooperation 2, 3, 18,  
 35-37, 69-75, 97, 119  
 International Committee on Space  
 Research (COSPAR) 90, 95, 97, 100  
 International Year of the Quiet Sun  
 (IQSY) 79, 80, 90  
 Ionospheric Research Program (ISIS)  
 36  
 Italian Satellite (See SAN MARCO)  
  
 Jet Propulsion Laboratory (JPL) 9  
 Jodrell Bank 37, 71  
 JUPITER 18, 78, 79  
  
 Kennedy, Cape 10, 16, 83, 87, 92  
 Kingsport, USNS 31  
 Kitt Peak National Observatory 77, 78,  
 80  
 KIWI 29, 66  
  
 Langley Research Center 40, 100, 110  
 Lewis Research Center 9  
 Life Sciences (See Bioastronautics)  
 LITTLE JOE 48  
 Lunar Excursion Model (LEM) 11-18  
 Lunar Orbiter 21  
  
 Madagascar 72  
 Manned Orbiting Laboratory (MOL)  
 41, 42, 61  
 Manned Spacecraft Center (MSC)  
 9, 62, 85  
 MARINER 2, 20, 21, 24, 25, 35, 121  
 MARS 2, 18, 20, 21, 22, 97, 102, 121  
 Marshall Space Flight Center 9  
 Materials 25, 57  
 Medicine, Space 9, 21, 26, 97  
 MERCURY 10, 72, 122  
 Merritt Island Launch Area 10  
 Meteorological Satellite Laboratory  
 (MSL) 84  
 Michoud Plant, La. 14  
 Mississippi Test Facility 9, 85  
 Moonwatch 99  
  
 National Academy of Sciences 16, 22,  
 93-97, 110  
 National Aeronautics and Space  
 Administration 3, 9-40, 72, 73, 85, 89,  
 91, 93, 97, 99, 110, 122, 123  
 National Aeronautics and Space  
 Council 5-7  
  
 National Airspace System 103-106  
 National Bureau of Standards 33, 87-92  
 National Meteorological Center 82, 86  
 National Operational Meteorological  
 Satellite System (NOMSS) 64  
 National Radio Astronomy Observatory  
 77  
 National Range Division 47  
 National Science Foundation 77-80, 90  
 National Standard Reference Data  
 System 88  
 National Weather Satellite Center 81  
 Naval Research Laboratory 57, 58, 79  
 Navigational Satellites 3, 41, 46, 60  
 NERVA 29, 67  
 NIMBUS 3, 5, 22, 23, 36, 64, 66, 81, 82, 83  
 Nuclear Test Ban Treaty 1  
 Nuclear Detection Satellites (VELA)  
 3, 41, 45  
  
 Olympics, 1964 5, 74, 75, 114, 121  
 Operational Meteorological Satellites  
 (OMS) 81-86  
 Orbiting Astronautical Observatory  
 (OAO) 101  
 Orbiting Geophysical Observatory  
 (OGO) 2, 19, 24, 36, 91, 122  
 Orbiting Solar Observatory (OSO) 102  
  
 Pacific Missile Range (PMR) 48  
 PEGASUS 13  
 PHOEBUS 66  
 PIONEER 21  
 PLUTO 63  
 Pt. Mugu, Calif. 74  
 Propulsion, chemical 1, 27  
 Propulsion, electrical 1, 30, 55  
 Propulsion, nuclear 2, 3, 5, 28  
 Propulsion, solid 1, 4, 28, 46, 47, 54  
  
 Radar, Over the Horizon 3, 54  
 RANGER 1, 2, 5, 9, 20, 24, 35, 83, 97,  
 119, 122  
 RELAY 3, 4, 23, 44, 75, 121, 122  
 ROVER 63, 66  
  
 S-66 91  
 SAN MARCO 1, 4, 19, 20, 35, 36  
 SATURN I 1, 3, 5, 10, 11, 14, 33, 83, 91,  
 92, 94  
 SATURN IB 10, 11, 14, 17, 21

SATURN V 10, 11, 14, 16, 17, 21  
 SCANNER, Project 48  
 SCAT 31  
 SCOUT 19, 24, 35  
 Seal Beach, Calif. 10  
 Short Airfield Tactical Support  
 (SATS) 54  
 Smithsonian Institution 99-103  
 Smithsonian Institution Astrophysical  
 Observatory 34, 73, 99-103  
 SNAP 54, 63-65  
 Soviet Union (USSR) 2, 5, 69, 70, 119  
 Soviet Academy of Sciences 24, 37, 69,  
 71  
 Sounding Rockets 37, 38  
 Space Power Equipment 30  
 Space Detection and Tracking  
 System (SPADATS) 49  
 Space Science Board 93-97  
 SPACETRACK 49  
 SPASUR 49  
 START 54  
 State, Dept. of 69-75  
 STRATOSCOPE II 78, 79  
 SURVEYOR 21, 60, 64  
 Supersonic Transport (SST)  
 31, 92, 109, 110  
 SYNCOM 1, 2, 3, 5, 9, 23, 24, 37, 44, 75,  
 99, 114, 122  
  
 TRADEPOST 44  
 TELSTAR 23, 44, 115  
 THOR 21, 24, 25, 55, 61  
 TITAN II 41  
 TITAN IIIA 3, 21, 41-44, 60, 87  
 TORY IIC 63  
 TIROS 3, 9, 22, 23, 64, 81-83, 121  
 Tiros Operational Satellite System  
 (TOS) 23, 83  
 Tracking and Data Acquisition 34, 37  
  
 United Nations 5, 69-71, 119  
 United States Information Agency  
 119-123  
 USSR 2, 5, 69, 70, 119  
  
 VELA 3, 4, 41, 45, 67  
 Venus 18, 20, 102  
 VOYAGER 22  
 V/STOL 30, 51, 52  
  
 Wallops Island 5, 35, 36, 65  
 Weather Bureau 34, 64, 71, 79, 81-86, 103

WEST FORD 44, 45, 97  
 Wheeling, USNS 48  
 White Sands Missile Range (WSMR)  
 11, 48  
 World Meteorological Organization  
 (WMO) 69, 85, 86  
  
 X-15 4, 5, 32, 51  
 X-21A 53  
 XB-70 4, 41, 50, 60  
 XF-12A 4, 41, 50, 51  
  
 Zanzibar 72